Liberalizing Research in Science and Technology: Studies in Science Policy

Edited by
Nadia Asheulova, Binay Kumar Pattnaik,
Eduard Kolchinsky, Gregory Sandstrom

Centre for Sociology of Science
and Science Studies,
Institute for the History
of Science and Technology,
St Petersburg Branch, Russian
Academy of Sciences
http://ihst.nw.ru/

Department of Humanities and
Social Sciences Indian Institute
of Technology, Kanpur

http://www.iitk.ac.in/hss/

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The present book is based on papers contributed at the international conference held at IIT Kanpur February 4th–6th, 2009. It was co-organized by Dr. Binay K. Pattnaik (Convener, Department of Humanities and Social Sciences Indian Institute of Technology, Kanpur) and Dr. Nadia Asheulova (Centre for Sociology of Science and Science Studies, Institute for the History of Science and Technology, St Petersburg Branch, Russian Academy of Sciences). Fifty two papers were presented over three days by scholars from six countries: India, Russia, Mexico, China, USA and Canada.

The book is published under the scientific guidance of Dr. Jaime Jiménez, President of the Research Committee 23: Sociology of Science and Technology of the International Sociological Association.

Authors representing different viewpoints and approaches share a common interest in examining the various important aspects of science, research, technology and liberalizing S&T research. In the course of the event, the term 'liberalization' also acquired a broader meaning, as breaking the national boundaries S&T researchers need to reach out to international scientific communities through collaborations and also to be part of international networks/collegial bodies, both formal and informal.

This book is most relevant for those concerned with sociological research in general, and particularly for those in the area of sociology of science and technology.

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Theme: Science Communication and Culture


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Department of Humanities and Social Sciences
Indian Institute of Technology Kanpur
Kanpur, India
Institute for History of Science and Technology
The Russian Academy of Sciences
St. Petersburg, Russia

Nadia Asheulova
Centre for Sociology of Science and Science Studies, Institute for the History of Science and Technology, St Petersburg Branch, Russian Academy of Sciences
e-mail: simar@bk.ru

Binay Kumar Pattnaik
Department of Humanities and Social Sciences, Indian Institute of Technology Kanpur, India
e-mail: binay@iitk.ac.in

Introduction by the Editors:

Russian-Indian Scientific Cooperation: New Opportunities

Russian-Indian scientific contacts became more regular after signing in 1987 the Treaty on scientific cooperation (Integrated Long Term Programme — ILTR). Intergovernmental agreements led to a number of particular programs, for example, The Memorandum on developing bilateral relationship in science and technology between the Russian and Indian governments (1993).

The program stipulates cooperation in basic and applied research in various areas, first of all: medicine, chemistry, computing, and so on.

Over two decades of cooperation between our countries there were periods of fast advancement, stagnation, but the scientific contacts have never broken. Now great attention is paid to creation of a pragmatic, non-politicized model of interaction between Russia and India based on principles of equality and mutual interest. Under the new political-economic conditions, scientific and technological cooperation between Russia and India becomes more active, with various institutional forms, and growing number of participants from both the sides. Thus, in order to strengthen and develop ties between Russian and Indian scientists, India's Ministry for science and technology and the Russian Foundation For Basic Research signed the Memorandum on mutual understanding in scientific and technological cooperation. Since 2008, in accordance with it, there have been competitions for joint research projects and seminars in mathematics, information science, physics, chemistry, biology, Earth science, IT, and so on. Humanities and social sciences have not been included in this program so far. Nevertheless, scholars in these disciplines seek opportunities for cooperation.

Professor Binay K Pattnaik of the Indian Institute of Technology Kanpur, India took part in the XXIII session of the International school of sociology of science and technology in St Petersburg, Russia in October, 2007. He got interested in Russian researches and suggested holding a joint conference on the sociology of science in India under the title “Liberalizing Research in Science & Technology — Studies in Science Policy”. The Russian organizer of this conference was the Centre for Sociology of Science and Science Studies, Institute for the History of Science and Technology, St Petersburg Branch, Russian Academy of Sciences directed by Nadia Asheulova (PhD, sociology). The Indian partner was Department of Humanities and Social Sciences, IIT Kanpur with Professor Binay K Pattnaik (Convener).

The conference “Liberalizing Research in Science & Technology – Studies in Science Policy” was held on February 4–6, 2009 in IIT Kanpur. Founded in 1959 under the Kanpur-Indo-American Programme (KIAP) with technical assistance flowing from nine leading technological Institutes/ Universities from the USA, the Indian Institute of Technology Kanpur today is India’s premier institute of technology with an international standing.

The conference had the following goals: to identify results of liberalizing science policy (cases of developing and ex-socialist countries); to emphasize the significance of liberalization for scientific research; to discuss the prospects of reforms in science and technology drawing from the experiences of partner-countries. Apart from Russia and India, the issues under consideration attracted attention of scholars from China, Mexico, Canada and the USA.

Thus the objectives of the conference were:

(1) To assess the effect of liberalization (and restructuring) in S&T research policies so far (in the erstwhile socialistic countries and other developing countries) and its contribution to the excellence of S&T research,

(2) To emphasize the need for further liberalization and reforms in S&T research policies in those countries (as excellence in research necessitates more freedom and hence liberalization) through shared knowledge of attempts, strategies and experiences by international partners and;

(3) To propose further possible areas and models of liberalization and coordination among the triple-helix components.

The Russian delegation headed by Professor Eduard Kolchinsky came from the Institute for the History of Science and Technology (IHST), St Petersburg Branch, the Russian Academy of Sciences (RAS); the Sociological Institute, RAS, St Petersburg; the IHST Moscow; the Institute of Psychology, RAS, Moscow; the Institute of Economics, RAS, Moscow and the Ufa Law Institute of the Ministry of Internal Affairs of Russia.

The Indian side included specialists from the leading scientific institutions like: The Indian Institutes of Technology Mumbai and Guwahati, National Institute of Science, Technology and Development Studies (NISTADS), New Delhi, NSIT Dwaraka, New Delhi; University of Hyderabad, the Jawaharlal Nehru University, New Delhi, Ravenshaw University, Cuttack; Bangalore University, Bangalore; Punjabi University, Patiala; Indian Science News Association, Calcutta; the Bengal Engineering and Science University Shibpur; The Indian Council of Social Science Research (ICSSR), etc. Specialists drawn from the Council of Scientific and Industrial Research (CSIR), New Delhi; Department of Science & Technology (DST) and the Department of Scientific and Industrial Research (DSIR), National Council for Science & Technology Communication (NCSTC) all under the Government of India, were actively involved in the conference.

The conference started with the traditional ceremony of lighting a burner as a symbol of moving upward, towards gaining knowledge and higher wisdom. Professor S.G. Dhande, Director IIT Kanpur, Professor Eduard Kolchinsky, Professor Binay K Pattnaik took part in this ceremony.

The Conference was inaugurated by Professor S.G. Dhande, who underlined the need for liberalizing research in S&T. To him, research liberalization in S&T means much more than removing or shrinking bureaucratic procedures for decision making, executing policies and allocating funds. Liberalization in this context means liberalizing the mindsets of people in S&T, shedding disciplinary boundaries and engaging in truly interdisciplinary research. The scope of interdisciplinary research, he noted, is in fact very wide, because it is not confined only to synergetic efforts among certain sister disciplines in sciences to address a phenomenon; even technological disciplines should be inducted (this in sociology of sciences is called model Mode II). Dhande transgressed interdisciplinary research boundaries further, saying that if S&T is to fight basic human and social problems such as hunger and nutrition, poverty, diseases, crime and other developmental issues like infrastructure and capacity building, then it has to work with social scientists and historians as well. True liberalization would build upon a synergy of efforts among researchers from S&T and social sciences, while pursuing problem-oriented research.

Then followed key note addresses by invited speakers. Dr P. Anandan, Managing Director of Microsoft Research India, spoke eloquently on industrial R&D in India. He pointed out the changing global perception of India as an intellectual power because of huge technical potential from Indian scientific and technological manpower. India is now increasingly shaping and participating in high technology endeavours worldwide. Other than selected examples, however, industrial R&D in India is not comparable with that of the west. Anandan emphasized the extraordinary role R&D plays in innovation and development in industry. Drawing heavily on the 2008 EU Industrial R&D Investment Report, Anandan tried to show how Europe is emerging as the major R&D hub, and how India is benefiting from globalizing R&D and its subsequent out-sourcing policy. He particularly pointed out the movement toward knowledge-based economies, where academia has a great role to play in innovative research and collaboration with the corporate sector. Further, he pointed out the emergence of entrepreneurial universities, where research is market oriented, and universities earn huge revenues from patenting and industrial research consultancies. Academics are becoming knowledge-based entrepreneurs themselves. Anandan argued strongly for enhancing research capacities by building adequate and quality infrastructure and by producing a large poll of competent scientific and technological manpower.

In the second key note address, Professor O. N. Mohanty, Vice Chancellor, Biju Patnaik University of Technology, discussed how to leverage the knowledge economy under globalization to enhance the high potential of India, particularly in the knowledge-based technology sector. He impressed the strong technological tradition in India with the example of the 'Damascus sword'. Further, while articulating the critical role of ICTs (particularly software) in India's technological future, Mohanty harped on developing a customized, mass production system to face fierce competition and co-operating to build technological capabilities through a technical manpower base. He further dwelled upon the importance of creating a knowledge base that includes indigenous locals through strong IPR cultural practices and of developing capabilities and mechanisms to translate this knowledge base to the market. Finally, Mohanty stressed India's need for research-oriented higher education in science and technology that is concerned with 'quality'. In this context, he referred to the recent internationalization of higher education in India, which itself is not good enough to meet the quality concerns, when the wave of commercialization of S&T education is too strong. Lastly, he emphasized building a strong tradition of research in India, which ought to be autonomous (free from bureaucratic mindsets and procedures), cultivates innovation and IPR, promotes industry-academia interaction and a quality manpower base through a strong accreditation system.

In the other keynote address, Jaime Jiménez from the UNAM, Mexico, spoke about the S&T policy in Latin America and the emerging of new global paradigms. He pointed out that science was cultivated in Latin America since pre-historic times, but was mostly practiced in isolation. After the arrival of 'modern western science' through colonial regimes, science became international, whereby knowledge production was of a type called Mode I as anywhere in the world. International science is now dominant in developing countries, as funds and policies are controlled by a few top scientists and technologists, who pursue research in certain established dominant areas in collaboration with colleagues in developed countries. This international science often does not show concern for local, regional and national problems in Latin America. But Jiménez emphasized that with the advent of ICT's and their extensive use by scientific communities in Latin America, local scientists have become more global, and also it has given rise to news ways of doing scientific research in Latin America. Jaime Jiménez used the ‘new invisible college’ model of C.S. Wagner (2008) to portray the recent changes in Latin American global science to become more interconnected, collaborative and network-based. He further pointed out the best examples of network-based ways of practicing science in Latin America: (1) the Regional Scientific Communities of Mexico and (2) Venezuela’s Research Agendas. Unlike ‘international science,’ these new forms of practicing science are organized locally, on a smaller scale and with the help of indigenous/local knowledge and participation. This appeared to be highly illuminating to the audience as most still practice international science not small, regional sciences.

In summary, both Anandan and Mohanty were prescriptive and accepted that decision making in mainstream science is made top-down. Jaime Jiménez, on the other hand, described some S&T experiences that are essentially small and regional geared to development, that follows a bottom-up approach.

All the papers presented were thematically organized into various sessions.

“International cooperation and competitiveness in S&T”

Eduard Kolchinsky illustrated a radical transformation of academic networks caused by the removal of party/state control over the administration of science in Russia since the fall of the Soviet Union. He showed major shifts in the forms of international co-operation, the changing intensity of contacts, the migration of scholars and adaptation to new academic environments by Russian scientists.

Tatiana Yusupova analyzed the changing institutional bases and underlying value structure of scientific collaborations between these two national scientific communities, specifically Mongolia and the USSR-Russia.

T.C.A. Anant and Arun Bali gave the sole paper on international collaboration among social sciences in India. It was based on the experiences of the Indian Council of Social Science Research (ICSSR) and was articulated from the perspective of a developing country. Limited success has been achieved due to foreign domination, as the funds come from the overseas collaborative agencies.

J. Khanna addressed scientific collaborations between India and Russia. But she was more specific about the emerging Siberian knowledge based economy, where science and technology are undergoing reforms, and Siberia is emerging as a hub of S&T (Novosibirsk Science Centre).

The paper by B K. Jain, concerning '*international Cooperation in Science and Technology by the government of India* 'gave a broad panorama of India's S&T policy on international cooperation and collaborations with several countries including that of Brazil, Russia, China and South Africa (BRICS countries). Bilateral and multilateral agreements by the Govt. of India have been carried out by the Department of Science and Technology.

T Jamal and Y Suman brought out particularly corporate R&D collaborations at international level and those of Indian firms with foreign firms. The authors further discussed both bilateral and multilateral S&T collaborations, revealing the frequency of collaborations in different areas of S&T and changing pattern of nature of collaborations under the globalized regime of R&D. To the authors owing to globalization as international trade barriers are constantly decreasing, the business organizations are being pushed to look for new products in faster pace and not different are the research organizations. This constant search for innovations, new products, and knowledge about various potential sources of collaborations accompanied by the use of developed communication technologies has changed the types, nature and magnitude of R&D collaborations. In support the authors cited several cases of collaboration from the international affairs division of CSIR India.

Agarwal's paper with co-authors was not about international collaboration, but about international competitiveness through technology. They revealed an emerging link between growing R&D expenditures and growing export of technology based products.

At the end of the session it was agreed by the participants that for cross fertilization of ideas international collaborations are essential in S&T research and governments must remove bureaucratic bottlenecks and liberalize procedures for internationalizing S&T.

"Innovation systems and the impact of IT under globalization"

P Banerjee in his paper notes that the institutions in lieu of business entities contest for enhanced access to resources and for enhanced valuation of the resources/ assets that they hold or generate. In this contest for revaluation of assets innovation plays the key role. Under globalization, through innovation a contesting institution attempts to undermine the value of assets under the control of other institutions while engendering and increasing the resources and assets-values under own control. This theoretical explanation has been offered in the paper by Banerjee in terms of developments and innovations in the field of biomedicals. Further Banerjee makes a detailed examination of Indian institutions along with a historical sketch, provided for the first time, of an Indian association of science professionals offer details of Indian capabilities in biomedicals. Finally such a description offers insight into potential Indian strategy for innovation in the area of biomedicals.

M.U. Khan discussed the impact of Indian technology policy on the development of the Indian IT industry. To Khan, when Indian markets opened in 1991, competing developing countries like China, South Korea, Brazil, Argentina had already surged ahead. Comparative advantage in the growth of the Indian software industry, the author believes, is fully R&D based.

From a sociological perspective, R. K. Mohanty put ICTs (Information and communication technologies) as the driving force behind globalization processes in the last two decades. He noted that E-governance is a process of efficient and effective use of ICTs for goal-oriented governmental works and that healthy results have been achieved with Educational Information Management Systems (EIMS) based on web-based services in Indian school education.

Sujit Bhattacharya presented an empirical study of Indian software firms (with certification), which were of course mid-sized firms engaged in R&D. The main objective of the study was to find out if the firms were involved in research and innovation activities and had research partnerships to influence production outputs in any way. The results of the study were mixed, noting that firms take various paths to develop their enterprises.

S. K. Mathur tried to find out technical efficiency in the ICT sector in 52 countries based on global data from the early years of the

2000's. Mathur reported that productivity growth in the ICT sector in developing and newly industrialized countries is slightly larger than growth in developed and transitional countries, which suggests developing countries and newly industrialized countries are catching up fast. Further he reported that technological readiness as a measure of agility, with which an economy can adopt existing technologies, has a positive impact on total factor productivity growth.

Lakhwinder Singh and Baldev Singh analysed secondary data to investigate global trends in terms of R&D input and output measures. They found that a liberalization era, starting with the WTO, has affected innovation systems and economic structures of developing economies. The authors discussed the role of innovation policies and institutional arrangements in certain countries where it has caused success.

"Socio-political Implications of Intellectual Property Rights (IPR)"

Jyoti Yadav discussed the Open Source Drug Discovery Project (OSDD) and emphasized its relevance in the wake of unavailable and unaffordable drugs pertaining to diseases prevailing in the developing world, including drugs tackling tuberculosis. The OSDD combines the power of the Internet with access to expert biologists, chemists, software professionals, clinicians, private enterprises and even students. The paper showed that OSDD contributors can utilize information on this platform only if they share relevant information from their side. Yadav, however, was unsure how IPR processes may affect the open source contribution to new drug discovery.

The paper by C R Reddy is an empirically based exercise on 'globalization and consequent commercialization of traditional knowledge system' that has usually been community based (i.e. plant tissue culture). Reddy points out how a community based knowledge system is used for development of a protocol (legal) and then rendered private and esoteric. He points out that the IPR system is alienating and dehumanizing the masses.

Deepthi Shankar in a closer theme drove home the point that under a global IPR regime traditional knowledge systems are subsumed. She suggested that documentation of traditional knowledge is a requirement for de-privileging IPR rights to non-natives and facilitating the process of making 'knowledge claims' by natives (indigenes). She also highlighted the role of social scientists in comprehending and managing technical issues like IPR that are directly related to human and market resources.

P. M. Prasad proposed a study of village knowledge centres (VKC) in the context of the IPR regime in India. Prasad assumes that the VKCs retain a mechanism for information generation among farmers/gardeners and sharing the same with the scientists (agricultural/horticultural, food processing etc.), which may lead to the formation of a process/product after systematization and can be patented/converted into any other form of intellectual property. This is bound to result in the creation of wealth at the village level (among farmers) by promoting the relevance of IPR particularly for the knowledge base that has been traditionally part of their experiences (ethno scientific/ethno methodological).

Ejnavarzala Haribabu in his paper on open source routes to innovation in agricultural bio-technology pointed out a loophole in the IPR system; even if nobody invents crop plant genomes, the propriety of technology based on genomic knowledge restricts access by others. Hence he proposed the feasibility of the open source model of innovation in biology (based on genomic knowledge available in the public domain) by illustrating Market Assigned Selection (MAS) technology. To him, this is likely to facilitate the development of pro-poor/farmer technologies in agricultural biotechnology, particularly for crops in rain-fed areas.

Sambit Mallik's empirical paper pertains to the changing protocols of IPRs and scientific practices in India under globalization. In his study among plant molecular biologists he mapped out inter institutional collaborative networks among the government departments, universities and private R&D institutions to make the results more deliverable. Of course this networking and collaboration was based on a shared perspective of interests, meaning and values. Mallik points out further that after the emergence of customer-funding agencies- policy maker nexus (a post-globalization phenomenon) scientists are forced to negotiate scientific boundaries and try to bring science close enough to politics and policy making of course with social accountability and legitimacy.

The concluding discussions pointed out that the global IPR regime puts the native population in developing countries on the receiving end. Developing countries have neither upgraded their IPR related laws (not being protective about their own exclusive intellectual resources and not being aggressively inclusive about others' intellectual resources) nor successfully protected their indigenous intellectual resources or ethnic practices, particularly those in the public domain.

"Science and technology in state and policy"

Elena Ivanova and Eduard Tropp portrayed aspects of change that Russian S&T has undergone in the recent past. Based on a targeted survey, the authors discovered the shortage of highly trained manpower in St. Petersburg and learned about the subsequent efforts to negotiate it. In that context, Ivanova and Tropp pointed out the changing pattern of interaction among the researchers in institutions of the Russian Academy of Sciences and at Russian universities.

Tatiana Petrova and Valentina Lomovitskaya articulated the relevance of the scientific elite in post-soviet Russia. They traced the strong roots of scientific elites in Soviet society and pointed out that post-Soviet Russia has turned its back on the Soviet model of science under the pretext of lack of funds. This has led to the disintegration of great science and an exodus of Russian scientists. The scientific elite, however, have pushed back by redefining their role: (I) destroying the earlier status-quo and re-linking themselves to state institutions, (II) managing S&T development and lobbying for the scientific community, etc.; (III) acquiring other functions; apart from their cognitive role, i. e, influencing the citadel of power and public opinion directly in favour of its own relevance to societal and scientific progress.

Galina Smagina and Marina Loskutova traced the genesis of the Russian Academy of Sciences to the regime of the Russian Emperor Peter the Great and pointed out the historic closeness of science and state in Russia. The authors referred to 18th century legislations and several other types of state influence that have shaped scientific organisations and practices in Russia. The authors pointed out the important role of politicians and public figures in the development of scientific life in Russia.

From a Chinese perspective, Wang Yuping spoke on the institutional development of S&T in China, pointing out the existence of a co-operative research system, where co-operation exists between state supported and NGO-supported S&T enterprises. If mega-bodies like the Chinese Academy of Sciences, the Chinese Academy of Engineers, the National Natural Science Foundation of China, etc. are state organs, then large professional scientific bodies like the Chinese Association of S&T (consisting of All China Federation of Natural Science Societies and All China Association for Science Popularisation) are non-state organs/NGOs. The example of state sponsored S&T in China in relation to its socialistic regime was a welcome contribution.

The paper by Canadian sociologist Gregory Sandstrom was a philosophical exercise with nuance, as he proposed M. McLuhan's 'Laws of Media' to comprehend technological growth and development. Within this practical framework, Sandstrom presented a collaborative and integrative approach to S&T, in which, thinking about S&T, acquires a social scientific and humanitarian dimension and also adds the blooming field of history and philosophy of science (HPS). This trio of perspectives will help to liberalize S&T policy, as it disallows a reductionist S&T view of the universe.

Munmun Jha examined the role of S&T in the context of human rights. Are contemporary developmental scientific projects to be associated with human rights violations, displacing communities from lands and depriving people of forests and life supporting resources, etc.? S&T is also used by state powers to meet the basic needs of the population, to provide adequate food, clean water and thereby to protect human rights.

S. K. Saha made an in-depth review of the complex governance of S&T by parliaments. The author discussed how the parliaments deal with S&T legislation in auditing and scrutinizing their structures and processes. Borrowing from UNESCO's initiatives on inter parliamentary Fora of S&T, Shah suggests S&T policy makers, scientists, technologists, industry, parliaments, media, parliaments and civil society elements must engage in an active and effective dialogue for better governance of S&T.

The session witnessed an interesting debate on the role of the scientific elite in shaping S&T. More interestingly measures were suggested for public accountability and public regulation of S&T not only through legislation, but also through other institutional mechanisms, e.g. debates in civil society (e.g. peoples' science movements) and other kinds of regulations through scientific professional bodies and associations.

"Migration Mobility and Innovation"

Mexican scholar Judith G. Zubieta presented on the importance of building 'diaspora networks' in order to deal more effectively with 'brain drain' problems. Having estimated a high number of doctoral graduates from Mexico staying abroad, she explained the difficulties experienced by a developing nation in strengthening its S&T manpower base with large out-migrations. Her proposed '3R' orientation in terms of policy making is essentially a three-pronged approach: (I) restrict migration, (II) recruit/replace manpower and (III) repair losses of S&T manpower.

American scholar Rubin Patterson credited the African diaspora of scientists and their national governments in sub Saharan Africa for gaining benefits from knowledge/skills and academic-corporate connections acquired by scientists and technologists, particularly in the USA. Rubin Patterson explored the feasibility of successfully transferring green technologies (electrical and ICT) to sub Saharan countries through scientific links to the USA, with a migration-development model. Rubin Patterson suggested the Indian diaspora as a suitable model for Africa, since Indian scientists and technologists have organized themselves and made their presence conspicuous in the USA to woo FDI and knowledge transfers to India.

Nadia Asheulova's paper stressed the active participation and involvement of many countries in 'global science.' She proposed developing some common indices for measuring each country's contribution. These indices include measures for assessing numbers of joint publications, participation in international conferences, quantum and frequency of receiving international grants, teaching at foreign universities and participation in joint projects. She described the advantages of international mobility to harness global scientific capabilities and further stressed that world-wide research activities have grown with the association of different specialists from across the globe. She referred to three mobility patterns among scientists that have taken place in Russia, i.e. (I) Pendulum type, (II) Irreversible type and (III) Migration with feedback type. To her, the pendulum type is the most optimum and beneficial one, as it provides for active communication, interflow and sharing of information and activities. She advocated this as the preferred mode of mobility, which must be encouraged and facilitated.

Alexander Allakhverdyan expressed serious concern about the drastic fall in the strength of S&T personnel in Russia since 1991. The 1.9 million S&T personnel employed in Russia in 1990 has dwindled to as low as 807 thousand in 2007. The major reasons for outflow have been economic and social. Allakhverdyan pointed out that in a single year, 1994, as many as 160,000 researchers left the country. Further the average age of the S&T migrants was 49 years. Many of these personnel undertook contractual employment abroad and others changed their forms of employment within Russia.

Y. Madhavi in her paper referred to major changes in the Indian vaccine industry (post 1991) that permeated the entry of the private sector into vaccine manufacturing. As a result, the public sector involved in manufacturing vaccines felt competition to bring in technological advances. The overall impact of this was felt in the access and availability of vaccines in managing public health programmes in India.

This was followed by a highly appropriate presentation by Irina I. Eliseeva on economics. She traced the history of S&T in Russia to the early times of orthodox Marxism, involving total monopolies, fixed prices and controlled distribution of goods and resources. Russia moved on through the Perestroika stage (1985–1991) and the post-Perestroika stage (1992–1997), which were both marked by various developments in its economy. In recent years, much thought has been given to two main means of efficiency — privatization and restructuring — with a view to linking Russia's economy with the rest of the world. Some aspects receiving serious attention in the area of S&T are developing measures/indices and useful statistics to bench-mark Russia's intellectual capabilities, as well as developing appropriate ranking parameters for comparing S&T outputs with other countries. Thus, to Eliseeva, Russia is currently debating how to choose its own relevant economic paradigm.

Lively discussions followed the presentations. One point of emphasis was that, in spite of a great exodus of scientists from Russia, the quality of research work undertaken there is still extremely high. As patenting in Russia today is relatively low, one may mistakenly construe that the quantum of S&T work is also low. But despite low funding (because of the earlier strong system and mechanisms in place) and relatively low monetary returns, highly significant research works are still being carried out in Russia. In India, on the other hand, policies have been changing over the years in tune with changing demands. The Indian economy has been responding accordingly in line with other global developments.

"Science communication and culture"

Yury I. Alexandrov debated the universality of the cognitive process. Having opened with the creativity of Chekhov and Dostoevsky, he said that cognitive processes are no longer considered to be value neutral and that reasoning is intertwined with cultural models; knowledge is culture-specific. As an example, Asian thinking is influenced by 'fields' and 'forces-over-distance' (that are socially and ethically not neutral), whereas western thinkers are influenced by Cartesian reductionism and are concerned with factors internal to objects. Alexandrov noted that some constructs of western social psychology are not valid in an intercultural, globalized world. He suggested that culturally-specific features of sciences may be effectively communicated through free intellectual exchange and cooperation. International science flourishing under globalization is the best platform for this purpose.

Manoj Patairiya spoke on the importance of synchronizing the head and hands to achieve excellence. Although India has invested heavily in science communication to develop a scientific temperament and attitude among the masses, equal efforts are needed in the context of hi-tech advances. Patairiya analyzed attitudinal attributes of children in understanding the factors affecting proper attitudes to excel, those like; upbringing, environment, parenting, schooling, socio-economic cultural milieu, etc. She suggested ways and means to overcome these deficiencies via technological awareness through hands-on science.

B. K. Tyagi talked about the conceptual framework of science communication in India. Science communication in India has its roots in the scientific renaissance of the late nineteenth century in west Bengal and Punjab. In the last 10 years, there has been a sea-change in the methods of science communication for popularizing science. Tyagi discussed recent achievements made by NCSTC, *Vi-*

gyan Prasar, and other voluntary organizations, which introduced a new conceptual framework of science communication based *on the socio-cultural milieu of the people*. This new framework has helped to attract an increasing number of academic institutions, science communicators, science clubs and interested people, resulting in a reduction of the divide between the urban and rural. Tyagi emphasized the need for more suitable approaches, strategies and methodologies, based on the concept of 'minimum science for all.'

Whereas the Russian papers brought out the cultural element in scientific communication, the Indian papers pointed to developing a scientific culture among the masses. Discussions that followed pointed out to the fact that the bulk of the scientific world is non-English speaking and, hence, culture-specific features in the cognitive process and *crosstalk* in scientific communication are legitimate. In a globalized world of scientific research, both English and non-English speaking scientific professionals must engage each other for mutual interests.

"Institutional Liberalization"

This was thematically the most central and dominant session of the conference. Svetlana Kirdina began addressing the limits and prospects of institutional liberalization in Russia, providing a deep insight with her Institutional Matrix Theory (IMT). Two types of institutional matrices were discussed that aggregate various national systems: X-matrix (communitarian ideology) and Y-matrix (individualist ideology). It was shown that all economic systems combine both X- and Y-matrices, but that one of the matrices is dominant over the other. To her, X-matrix institutions predominate in Russia. The 'institutional character' in Russia fixes limits on liberalization and actively implements a liberal market-oriented institutional policy only within the framework of a modern redistributive state economic system. S&T policy in Russia demonstrates this reality. Kirdina's suggestion that India's national character also gravitates towards X-matrix institutions raised eyebrows among the Indian audience.

Eduard Ishkakov expressed a need for liberalizing bureaucratic barriers and spoke of the secluded plight of scientific activities and scientists in Law Enforcement Organizations (LEOs). He stated an urgent need to liberalize scientific activities and related processes in

LEOs on par with other academic institutions. The author suggested various measures of reforms to enhance the S&T performance of LEOs in Russia. This practical approach involving cooperation on security topics was appreciated by the audience.

S. K. Jain and Rao Naik focussed on managing excellence in R&D, based on a study of scientists (247) at premier technology institutions in India. Having studied research facilities, human resources support, receptivity and adaptability of administration toward facility requirements, research funding, library support, etc., the authors found that for most factors, the gaps between the importance of the stated research facility and their availability exceeds 1.0. The authors recommend that premier Indian institutes of technology promote excellence in research, build flexible non-bureaucratic organisations with administrators' roles as facilitators, develop innovation performance measures for scientists, enable collaborative and cross-functional research and introduce unparalleled rewards for innovation to motivate scientists.

S. C. Roy pointed out changes in policy thrust and their impact on scientific research. To him, national boundaries are disappearing in research and scientists are gaining access to the latest information and state of the art equipment. To bring about world class innovations, processes and products, developing countries like India have to create a strong human resource base in S&T. Further, Roy suggested the need to build a value-based culture in S&T research, as well as high reward systems to promote the generation of innovative ideas. Government should clearly spell out its expectations from the scientific community.

Cao Nanyan articulated that before the recent reforms S&T in China was shrouded with problems like, lack of awareness about academic exchange with international scientific communities, disjunction between scientific research and economic development, egalitarianism and absence of motivation for researchers, and the like. After decades of reforms S&T system in China developed some new features, such as, encouraging applied research and cooperative research with industry, competitive research funding, proliferation of the values of various academic intercommunion for innovation, etc. However as consequence of reforms there emerged newer vices of the S&T system like, over-anxiousness to get quick results, instant benefits/ rewards, perceiving S&T research as an instrument rather than an embodiment of a value system, dissention of intellectual property rights, plagiarism, sacrificing objectivity and similar other misconduct in the profession of scientific research. For a healthy growth of S&T and restoration of public trust in S&T Nanyan suggested the develop institutional mechanisms by further reforms, to arrest the rising vices.

Madhav Govind proposed to study the socialization process of science students along four variables: organization culture, socio-economic background, disciplinary culture and sources of funding. In view of the liberalization and globalization of S&T, Govind perceives the emergence of a changing value system and professional practices in S&T research, tending toward market-orientation. This has serious implications for research students that result in their half-hearted socialization, inability to make independent projects, their escapist theories and theoretical problems, etc. To him, time bound performances, based on funding models, have also changed supervisory practices.

Duru Arun Kumar provided the definitions and significance of big and little science (Derek J. de Solla Price). Both types of science projects, she said, are done in India without affecting each other. To her, little science projects are career oriented, whereas big science projects are extensions of the political prioritization of specific fields and, hence, provide public visibility and media coverage.

In speaking about undergraduate science colleges, B. Chakrabarti, a science teacher himself, expressed that college science education in India is pushed to the brink in terms of quality and quantity by its drive for a market orientation. Hence, he suggested giving research exposure to undergraduate science students and sending expert teachers on a transferable basis to science colleges. Further, and most importantly, some undergraduate science colleges should be converted into research institutions with programmes that produce committed and qualified science teaching faculty.

Discussions in this session revolved around the changes that Russian S&T is currently undergoing, i.e. coming out from behind the ‘iron-curtain’ and its ‘nationalist’ brand, and how Russia is slowly internationalizing itself. The systemic changes it envisages for itself could be similar to those of the institutional and ideologically conditioned minds of the Soviet regime. Similar questions were raised about S&T in China, with respect to how S&T is gradually trying under a totalitarian regime to internationalize itself. But India's changes are slow and even not expected to be caught by surprise, although they are subsequently adapted to the national Indian system.

"S&T Policy and Industrial Interaction"

Karuna Jain and R. R. Hirwani studied the effects of liberalization on R&D in the Indian chemical industry. They developed a globalization index to capture R&D effects by taking into account twelve different variables pertaining to technology. They gave equal weight to variables defining the globalization index and collected data from 348 companies. Major findings of the study were: (a) companies, whether Indian or Indian affiliates of MNCs, are all reallocating their resources to R&D with a greater focus on honing human capital skills instead of products, processes and markets, and (b) there are substantial spill-over effects on domestic R&D from global investments in R&D.

R. Sharan spoke of interaction between industry and academia in India, based on a case study of the Samtel centre at IIT Kanpur. The paper interestingly elucidated the importance of creating an efficient 'enabler' — a link between industry and academia. To the author, industrialists, technologists and academics need to fully respect each other's viewpoints and to understand each other's perspectives so that technology does not remain compartmentalized or underdeveloped and is freely transferred for commercialization. Critical issues to be dealt with include regulations for publication of ideas in journals, owning of inventions (patents) and remuneration, given by different stake holders in the industry-academia project.

Nimesh Chandra focussed on knowledge transfer strategies at the Indian Institutes of Technology. The presentation identified three distinct approaches to knowledge transfer and commercialization at I.I.Ts: (I) sponsoring research and industrial consultancy assignments that promotes industry interaction, (II) protecting inventions of institutes and formalizing technology transfers mainly through licensing, and (III) building an entrepreneurial culture for faculty and channelling ideas through incubation units, which facilitate and encourage start-up firms. The paper suggested the need to make separate legal entities of academia research centres and incubation centres to formalize technology transfers. A good model to emulate is the M.I.T. in the US.

Vinish Kathuria's paper pointed out that the absence of industry-academia linkage is not exclusive to India. Rather, it is common in most developing countries. He identifies a number of reasons for the absence of this much needed linkage: (I) theory and concept-oriented, but not problem-oriented syllabi in S&T education, (II) the faculty's dismal industrial experience, (III) research topics of PhD theses are mostly on the interests of the supervisors, (IV) publication-oriented research of academics to fetch quick promotions, (V) obsolete labs and equipment, (VI) the secretive nature of industrial research, and (VII) absence of a research funding culture in industry. He further pointed out that factors hindering the synergies between industry and university based research are more fundamental as there is a mismatch with regard to their: (I) nature of organization (non-profit/profit-orientation), (II) type of research (open, valuation through publication; closed, valuation through patents or product designs), (III) aim of research (expansion of knowledge/ exploitation of knowledge for money), (IV) time frame of research (long term/short term and time bound), and (V) goal of research (communitarian/entrepreneurial). Lastly Kathuria said that the gap between academic and industry-based research can be bridged by creating proper interface between the two.

Enthusiastic discussions pointed out that industry in developing countries does not have an R&D culture as their annual investment rates in R&D have been very low (far below 1 % of turnovers). Technological dependence remains on foreign affiliates. In such a situation, industry-academia interaction becomes a difficult proposition. However, with globalization, developing countries like India and China are slowly moving toward the notion of an entrepreneurial university, may be each with their own variant.

In general, most Indian papers delivered at the conference, looked at different aspects of functioning of high-tech and science-intensive branches of India's economy, and at interaction between science, business and government. A special attention was paid to exploring new forms of partnership between national and trans-national companies and universities, institutes of technology and research centres within India's Ministry of science and technology. The papers highlighted the absolute necessity of finding solutions to urgent problems the Indian society faces now: the birth rate control, filling the huge gap between particular regions and social groups in the level of their economic and cultural development, raising the quality of education, advancement of agriculture and infrastructure. The Indian scientists concentrated on studying the high-tech transfer, as well as on interaction between these technologies and local communities with their traditional lifestyles, that is, problems of interaction between the global and local in the fast changing world.

The Russian side paid attention mainly to more general questions: relationship between science and authorities, science and society, historical analysis of social and political features of international scientific cooperation, philosophical problems of the globalization in science, international mobility as a factor in the emergence of the joint scientific space, internationalization of science and scientific activities, and so on.

Though it was seen from the reports that Russian and Indian approaches to many issues differed greatly, the conference confirmed once again that there was an enormous cooperation potential between Russia and India in the time of the global challenges. Despite big cultural and geopolitical differences our countries can combine our unique identities and the experience accumulated by other nations.

Both Russia and India have various institutions that encourage the innovation climate. So exploring the experience of the two countries is of paramount importance. State corporations and national projects are examples of this kind in Russia, Indians can point to the National innovation foundation, a number of Indian institutes of technology, and so on. Discussions at the conference showed that one of the main tasks of the Russian and Indian internal policies is to find an effective relationship between the governmental management of science and liberalization of scientific and technological activities.

The conference attracted attention of the Indian mass media. Reports on the conference were published in a number of periodicals both in India and Russia. The derivations of the international conference are the following:

Derivations:

The conference underlined that the need of the time is liberalization of S&T research and in the course of the event the term liberalization also acquired a broader meaning, as follows: :

(1) Breaking the national boundaries S&T researchers need to reach out to the international scientific communities through collaborations/ MOUs and also to be part of the international networks/collegial bodies both formal and informal. It would internationalize the bases and mechanisms of evaluation in S&T,

(2) Breaking away bureaucratic practices and cutting short its procedures to acquire more autonomy, of course through self regulation of conduct, is also construed to be central to liberalization,

(3) Breaking away organizational role patterns and their conventional interactional patterns in the domain of S&T (e.g. Triple helix type of interaction among, university/academia, industry/ laboratories and government to facilitate innovations and making of entrepreneurial universities),

(4) Breaking the boundaries of ideologies and ideological blocks of S&T (e.g. nationalist S&T) ,

(5) Breaking the boundaries of disciplines and make research more interdisciplinary by nature in S&T,

(6) The role of S&T be subject to parliamentary scrutiny and public debate.

Specific policy Recommendations of the conference:

General: —

(1) The top down approach of modern S&T be supplemented by bottom up approach where S&T is organized in a small scale and on a low cost basis to address local problems particularly with people's participation and with inputs from traditional knowledge systems,

(2) If the goal is for internationalization of S&T, it is to be achieved through introduction of institutional changes /liberalizations.

Specific: —

(1) To follow open source IPR policy,

(2) To make use of diaspora links for S&T developments,

(3) To foster university- industry interaction,

(4) To move towards the Entrepreneurial university model.

The conference attracted attention of the Indian mass media. Reports on the conference were published in a number of periodicals.

After the conference in Kanpur was over, the National Institute of Science, Technology and Development Studies (NISTADS) invited the Russian delegation to visit their institute in Delhi that had cooperated with Soviet scientists before. NISTADS was established by the Indian government in 1980. The institute has conducted research on various aspects of interaction between science, society and state. In 1980, under the aegis of UNESCO, NISTADS carried out a big research project where scientists from several countries took part: India, USSR, Mexico, and some others. Professor G M Dobrov (Center for studies of scientific and technological potential and the history of science, Ukranian Academy of sciences) was in charge of this work from the USSR side.

On February 8, 2009 Professor P. Banerjee, NISTADS' director, held a reception for the Russian scientists. On the next day, 9th of February, there was a round table, during which the Russian and Indian scientists introduced to each other the main research areas in the history and sociology of science and exchanged views on how scientific institutions in the both countries functioned. The Indian part wanted to know mainly the problems of intellectual property in science, ethics and policies in IT and biotechnology, the role of innovation in the knowledge society, studies of the public understanding of science, innovation policy and the significance of scientific and technological education of people.

The Russian-Indian dialogue continued on February 23, 2009 in St Petersburg. An Indian delegation headed by Y P Kumar (Head of international cooperation, Department of science and technology, Ministry of science and technology, Government of India), who has been in charge of the Indian-Russian scientific cooperation within the Ministry for nearly 20 years, visited the Institute for the History of Science and Technology, St Petersburg Branch, Russian Academy of Sciences. The discussions focused on areas and forms of cooperation in sociology of science and history of science.

The conference and its subsequent meetings with NISTADS (CSIR) and the DST (International collaboration) explicated that Indian scholars were keen to know more about Russian researches in social sciences, and to cooperate actively in these areas. The authors might be representing different viewpoints and approaches but share a common interest in examining the various important aspects of science, research, technology and liberalizing S&T research. In the course of the event, the term 'liberalization' also acquired a broader meaning, as breaking the national boundaries S&T researchers need to reach out to international scientific communities through collaborations and also to be part of international networks/collegial bodies, both formal and informal.

The book is published under the scientific guidance of Dr. Jaime Jiménez G, President of the Research Committee 23: Sociology of Science and Technology of the International Sociological Association. This book is most relevant for those concerned with sociological research in general, and particularly for those in the area of sociology of science and technology. The information can help work out science and technology policies in India, Russia and other countries. The book will promote Russian-Indian scientific contacts in humanities.

We optimistic that Indo-Russian cooperation will continue in newer areas, the programs will be implemented which can strengthen the partnership between Russian and Indian scientists.

INTERNATIONAL COOPERATION AND COMPETITIVENESS IN S&T

Eduard Kolchinsky

Liberalising international cooperation in the history and sociology of science in Leningrad / St. Petersburg

In order to understand the role of liberalisation process in the development of the history of science in Russia I suggest undertaking a comparative historical analysis of the dynamics of international cooperation. I am going to explore the transformation of the problem field studied within the framework of joint projects, changing forms and frequency of contacts on interstate, institutional and personal levels, publication projects, migration of scholars looking for better social environment, scholars' adaptation to new academic communities. Particular attention will be given to the mechanisms that enable the inclusion of historians of science into global academic networks and to the international division of labour through joint projects and research undertakings. I am going to consider such forms of international cooperation as the election of scholars to foreign academic societies, academies, editorial boards, their presentations at international conferences and workshops, publications in foreign journals and books published abroad, grants awarded by foreign foundations, fellowships and scholarships abroad, lecturing in foreign universities, etc. At the same time I am going to examine correlation between the intensity of academic contacts and the degree of control that the capital of the country exercised over a peripheral academic institution, i.e. to explore the problem of centre and periphery.

In order to compare different patterns of international contacts in the Soviet and post-Soviet periods I identify several major stages in the process of institutional formation of the history of science in Leningrad / St. Petersburg: 1) 1926–1932 — the Commission for the history of knowledge of the Russian Academy of Sciences / the Academy of Science of the Soviet Union. 2) 1932–1938 — the Institute for the history of science and technology, the Academy of Science of the Soviet Union. 3) 1938–1953 — the Commission for the history of the Academy of Sciences. 4) 1953–1989 — the Leningrad section (department) of the Institute for the history of science and technology, the Academy of Science of the Soviet Union — the period of total administrative control. 5) 1989 — up to now — the Leningrad (St. Petersburg) branch of the Institute for the history of science and technology, the Russian Academy of Sciences. Each of these periods was characterised by particular combination of totalitarianism and liberalism, determined by domestic and foreign policy of the state and by the authorities' attitudes towards history of science, which served for them as a means of ideological justification. On the other hand, the academic community itself considered the history of science as a way to justify its existence and to obtain financial support and other material resources. That is why in the early years research institutes for the history of science and technology were headed by prominent politicians and scientists (Sergei I. Oldenburg, Vladimir I. Vernadsky, Nikolai I. Bukharin, Sergei I. Vavilov, Vladimir L. Komarov).

In the early years international academic contacts established by the Commission for the history of knowledge (KIZ) were very much encouraged and supported, as they were in line with the governmental policy that stressed the need to master advanced Western science. (Nauka i krizisy, 2003:440–457). Among its employees the Commission could boast a number of prominent scholars, including all full members of the Academy of Sciences with its President Aleksandr P. Karpinsky.[1] (Komissiya po istorii znanii, 2003) The entry of Soviet scholars into international academic community was considered as way that would enable the Soviet Union to overcome international isolation. Academic contacts were particularly intense with scholars from another outcast country — Germany. (The Russian State Historical Archive for Social-Political History (Hereafter GRASPI), f. 17, op. 85, d. 650, l. 96, d. 658, l: 366–367; Sovetsko-germanskiye nauchnye svyazi Veimarskoi respubliki, 2001:153).

Among the KIZ staff were a number of foreign researchers — all of them were German emigrants (G. Zeis, M.L. Levin). (Komissiya po istorii znanii:153, 369) Initially it was a special Commission for trips abroad that determined if a particular trip to a foreign academic institution was permitted or not. It was chaired by

M.A. Trissler, a representative of the OGPU, the security and political police. The Commission vetoed most trips abroad planned by scholars working for the Academy of Sciences. However in those years senior echelons of the state administration held a view that visiting fellowships and lectureships abroad assisted Soviet scholars in mastering international science and research. Therefore Aleksey I. Rykov (the chairman of the Council of People's Commissars — i.e. the prime minister of the country) initiated the transfer of controlling functions to the Commission for advancement of research at the Academy of Sciences (an agency subordinated to the All-Russian Central Executive Committee chaired by A.S. Enukidze), to the Section for scientific institutions subordinated to the Council of People's Commissars, with E.P. Voronova acting as the head of the section, and to the executive secretary of the Council of People's Commissars, Nikolai P. Gorbunov. (Sovetsko-germanskiye nauchnye svyazi:166–167)

As a result, all the leaders of KIZ (S.F. Oldenburg, V.I. Vernadsky, N.I. Bukharin, M.S. Blokh) undertook several trips abroad establishing contacts with their foreign colleagues, visiting institutions for the history of science, presenting papers on the history of science in Russia. Papers on the history of science in Russia were also given abroad by E.Ya. Kol'man, I.D. Strel'nikov, F. A. Fiel'strup. From 1929 a few Leningrad scholars were elected as corresponding members of the International Academy for the history of science (mathematician A.V. Vasil'ev (1929), historian of chemistry M.A. Blokh (1933), orientalist V.V. Struve (1935), physiologist K.M. Bykov (1939). The Commission for the history of knowledge was also interested in the history of western science, it paid particular attention to the work of Svante Arrenius, Marcellin Berthelot, Johannes Kepler, Gottfried Wilhelm Leibnitz, Leonardo da Vinci, James Clerk Maxwell, Vilhelm Thomsen, Michael Faraday and others. In those years his work and legacy were studied only by Soviet researchers. Scholars working for the Commission for the history of knowledge presented papers at all memorial meeting and jubilees. They took part in the projects launched by the International Committee for history of science (collected data on the history of science and technology of the peoples of the USSR), for the International Association of Academies (compiled bibliography, published Greek manuscripts on astrology for a multi-volume series). As an output of these projects, the Commission was able to publish some works by V.V. Struve and S. Ya. Lur'e in Berlin in German. It established contacts with a number of leading international institutions for the history of science and technology — the Newcomen Society in London (the oldest society in the world for the study of the history of engineering and technology), with the German Museum for the history of technology in Munich, with Institute der Geschichte der Technik in Vienna.

Considerable political importance was ascribed to the fact that Soviet historians of science led by Nikolai I. Bukharin took part in the Second International congress for the history of science and technology in London (1931). (Akademiya nauk v resheniyakh Politbyuro TsK RKP(b) — VKP(b). 1922–1952, 2000:106–109) Foreign participants of this congress were particularly impressed by the paper presented by Boris M. Gessen on social and economic origins of Newton's mechanics. Nowadays this paper is considered to be one of early attempts to analyse the emergence of a scientific theory in social and cultural contexts — and a very fruitful attempt. (Graham, 1993:20-31). The paper stimulated a number of books on social factors in the development of science. (Haldane, 1934; Bernal, 1939; Hogben, 1938). In the same year the papers presented by the Soviet participants of the congress (N.I. Bukharin, N.I. Vavilov, B.N. Gessen, B.M. Zavadovsky, A.F. Ioffe, E.Ya. Kol'man, V.F. Mitkevich, M.O.Rubinshtein) were published in English as a special volume 'Science at crossroads', which was many times reprinted after the Second World War both in the West and in Japan.

In 1929 Nikolai I. Bukharin, one of the main leaders of the October Revolution and the Communist Party, became the head of KIZ. In 1932, upon his initiative, the Institute for the history of science and technology (IIST) of the Academy of Sciences of the USSR was established on the basis of KIZ. Initially scholars of the new institute paid considerable attention to international cooperation. Among its members of staff were listed a few German emigrants who had to leave their country for political reasons, G.E. Garing, U. Schaxsel. The institute was instrumental in translating and publishing books by leading Western historians of science and technology. (Dannemann, Vol. 1, 1932; Vol. 2, 1936; Vol. 3 1938; Olschki, Vol. 1, 1933; Vol. 2, 1934; Rosenberg, 3 vols, 1933–1936; Tanneri, 1934; Diels, 1934). Books by F. Dannemann, H. Diels, L. Olschki, F. Rosenberg, P. Tanneri in Russian translation made Western literature of the period more accessible and better known for a broader audience in the USSR. Thanks to these editions Soviet historians of science were in a position to maintain high standards of research and even to set 'an example for the whole world' in this field, according to a leading British historian of science George Sarton. (Vernadsky, 1988).The institute initiated and hosted a number of sessions commemorating the jubilees of major Russian and foreign scholars (Karl von Baer, Charles Darwin, Kaspar Friedrich Wolf, Nikolai E. Zhukovsky, Issac Newton, Vasili V. Petrov, Leonhard Euler and others).

By mid-1930s important changes had taken place in the Communist party policy on science and research. After the failure of the 'Cultural revolution' (1929–1932) and the attempts to create a 'proletarian science', we observe a shift from the policy of proletarian internationalism to the ideology of the 'Soviet state patriotism'. (Kolchinsky, 1999: 203–204). The authorities encouraged the notion of 'Soviet science', based on national traditions as developed by leading pre-revolutionary scholars; new idioms like 'Soviet patriotism' were invading academic discourse. The employees of the Institute for the history of science and technology were forced to provide evidence for the priority of Russian scholars over foreign research. In the development of patriotic discourse a special place was assigned to the jubilees of D.I. Mendeleev (1934) and M.V. Lomonosov. The celebrations were authorised by special resolutions issued by the Politburo of the Communist party. (Akadenya nauk v reshcheniyakh Politbyuro TsK RKP(b) — VKP(b):131, 132, 155, 156). These events were transformed into the praising of 'the great sons of the great Russian people'. (On September 10, 1934). The policy on international contacts had also changed. The governmental Commission for trips abroad was abolished in 1934, and its functions were transferred to a special Commission of the Party Central Committee, led mainly by the heads of control and police institutions. Initially the Commission was chaired by Andrei A. Zhdanov — a leading ideologist of Stalinism, and later by Nikolai I. Ezhov — a future head of the People's Commissariat for Internal

Affairs and the major executive of the Stalinist 'Great Terror' of the 1936–1937. (Esakov, Rubinin, Kapitsa, 2003: 36–37).

International contacts in the field of science were practically abolished. (Dmitriev, 2002:16).The USSR did not take part in the International congresses for history of science in Portugal (1934) and Czechoslovakia (1937). Soviet scholars were also absent at the meetings of the International Academy for the history of science.

The studies written by the staff of the Institute began receiving negative reviews that increasingly resembled political denunciations. The members of the Institute were accused of non-Marxist leanings, old-fashioned elitist academic practices and manners, of failing to establish contact with 'the practice of socialist construction', of immaturity, eclecticism, of choosing trivial problems for research, of venerating Western scholarship, of using alien bourgeois methodology. During the 'Great Terror' unleashed by Stalin in 1935–1938, international cooperation in the field of the history of science became dangerous. Contacts with foreign scholars and membership in international academic institutions were frequently used as a pretext for accusing researchers in espionage activity. Publications abroad were strictly prohibited. N.I. Bukharin and V.V. Osinsky — an economist and sociologist who replaced Bukharin as the head of the Institute — were soon executed. With them at least eight members of the Academic Council of the Institute for the history of science and technology perished in Stalinist prisons and torture-chambers (N.I. Vavilov, B.M. Gessen, S.F. Vasil'ev, M.L. Levin, S.G. Tomsinsky, Ya.M. Uranovsky, Kh.I. Gaber and others). (Krivonosov: 66). The Institute itself was closed on March 5, 1938.

The destruction of the Institute, arrests and executions of its many members hindered the development of research in the field of history of science and technology. However already in the late 1938 the Commission for the history of the Academy of Sciences was established in Leningrad under the umbrella of the Archive of the Academy of Sciences. It was headed by a future President of the Academy of Sciences Sergei I. Vavilov. Originally the Commission was assigned to produce an outline of the history of the Academy of Sciences and a series of monographs on the history of its institutions. However with the outbreak of the World War II the state policy took a new turn and the history of science and technology became even more ideological. It was transformed into a major tool of political and patriotic education. Historians of science were writing about glorious achievements of Russian scholarship. Jubilee sessions commemorating leading scientists and scholars of Great Britain and the United States were staged with explicit purpose of promoting foreign policy objectives. It was expected that these events would prompt a speedy opening of the Second Front in Europe. (For example, the celebration of 300th anniversary of Isaac Newton's birth was staged in 1943 in Moscow). On November 22, 1944 the Council of People's Commissars of the USSR adopted a resolution on the establishment of the Institute for the history of natural sciences of the Academy of Sciences in Moscow. The President of the Academy of Sciences V.L. Komarov was appointed as its head. The institute was entrusted with the task of studying the history of natural sciences in the world and in Russia in particular.

In the Cold War years the history of science in Russia became the priority field of research for the Institute. Jubilees of Russian scholars were celebrated with large-scale events approved by the top party-state leadership. Collected works by scholars who were recognised as 'the classics of natural sciences' were published in massive number of copies. A lot of works appeared on Russian biologists, physicists, mathematicians, geologists, geographers and chemists. Many of these publications were marked by the struggle against 'cosmopolitanism' and 'self-abasement before the West' that was launched in the late 1940s. Not only great names of Russian scholars who made major contribution to science and research but also minor figures who popularised science in the country were rediscovered and reclaimed. Researchers were preoccupied with the search for actual and imaginary evidence confirming the priority of Russian scientists in every field. On January 5, 1949, the M.V. Lomonosov Museum was opened in Leningrad. On the same date a special session devoted to the history of Russian science was convened in the city. In those years Mikhail V. Lomonosov became the major symbolic figure standing for the priority of Russian scholars in all fields of science.

'Materials for the history of the Academy of Sciences of the USSR for the Soviet years (1917–1947)' edited by Sergei I. Vavilov (1950) brilliantly demonstrate the extent to which the policy of isolation was counterproductive for the history of science. The book bears the imprint of the time when it was written: incessant ideological campaigns launched in biology, physics, chemistry and other sciences. The volume failed to mention the names and achievements of prominent scholars who had been persecuted, while it placed on the foreground minor figures who were often utterly irrelevant for the advancement of scholarship. It praised highly the contribution of various pseudo-scientists, like Trofim Lysenko, whom Stalin proclaimed to be 'the luminaries of the world science'. The names of honorary members of the Academy of Sciences Vyacheslav M. Molotov and Iosif V. Stalin were mentioned most often in the book. Nevertheless, the edition failed to match the requirements set by the party leadership. A new front-page was inserted into the volume that had already been printed. It said: 'With the rights of a manuscript. Copy No…'.

Soon after Stalin's death, in September 1953, the Leningrad section of the Institute for the history of science and technology was established where many prominent historians of science (A.I. Andreev, T.A. Gorstein, A.A.Eliseev, A.V. Predtechensky, I.I. Kanaev, B.I. Raikov, M.I. Radovsky, M.G. Yaroshevsky and others) got research positions. Many of them had experienced decades of prison confinement, labour camps, exile, persecution and vile criticisms. The first decade in the history of the Leningrad section coincided with the period of 'Thaw' associated with the name of Nikita Khrushchev as the leader of the Soviet state. International academic contacts were revived, even if they remained under strict control of the Central Committee Commission on trips abroad. Since June 1955 the Commission was chaired by A.S. Paniushkin —the head of the external intelligence section of the Committee for the State Security (KGB). This period in the history of international contacts established by Leningrad historians of science was characterised by tight control exercised not only by the governmental, party and police agencies but also by the Moscow institute for the history of science and technology. In 1954 the delegation of Soviet scholars took part in the International congress on the logic and methodology of science in Switzerland, and two years later Soviet scholars for the first time in 25 years attended the 8th International congress for the history of science in Italy. In the same year the Academy of

Sciences of the USSR became a member of the International Union for the history of philosophy of science. Ever since Russian scholars attended all international congresses for the history of science. However, the Academy of Sciences usually sent only a very limited number of Moscow scholars to attend international congresses abroad. Travel abroad had to be approved by party and police institutions. For most scholars the only available means to establish and maintain contacts with their foreign colleagues were correspondence, exchange of academic publications, and major international congresses that took place in Leningrad celebrating the jubilees of Leonhard Euler (1957, 1982), Mikhail V. Lomonosov (1961, 1986), Johannes Kepler (1971), Dmitri I. Mendeleev (1984). Dozens of foreign scholars were usually invited to take part in these congresses. Probably, it was only the 13th International congress for the history of science (Moscow, 1971) and the 8th International congress for the history, methodology and philosophy of science (1987) that enabled many Leningrad scholars to present their papers to foreign colleagues and to establish direct personal contacts.

Under total control exercised by the party-state authorities and the bureaucracy of the Academy of Sciences free international cooperation was impossible. The majority of Leningrad historians of science were prohibited from travelling abroad, while others had very few opportunities for travel. For the whole history of the Leningrad section its scholars, taken together, went abroad about a few dozens times (on average there were about 1-2 trips abroad per year). Young scholars were deprived of any opportunity to get an internship or a junior fellowship abroad, to work in archives and academic institutions not only in the Western but also in Eastern Europe. Few visits were made by foreign scholars (no more than 2–3 visits per year) who came over to the Leningrad section of the Institute for the history of science and technology in order to work in Leningrad archives. Their visits were possible only if they had been included in formal plans for international cooperation devised by the Academy of Sciences and authorised by the highest party-state authorities upon an approval by the Committee for the State Security.

Very telling is the distribution of academic trips abroad between the Moscow institute and its Leningrad section. For example, in

1986 there were 15 researchers from the Moscow institute travelling abroad and none from Leningrad. In the next three years there was just one employee of the Leningrad section who travelled abroad. The rule applied to visits paid by foreign scholars. In 1986 the Moscow institute hosted 49 foreign scholars, its Leningrad section hosted only 3 (5 in 1987). No employee of the Leningrad section served on an editorial board of an international journal (the only exception was I.I. Kanaev who was elected as a corresponding member of the International Academy for the history of science in 1971, while in Moscow more than 30 members of staff were elected to the International Academy for the history of science).

International projects were also carried out through official channels, mostly with scholars from the countries of Eastern Europe (primarily with GDR, to a lesser extent with Czechoslovakia). In the West academic contacts were maintained only with the Swiss Society for natural sciences and with the Bavarian Academy. With these institutions the Leningrad section carried out joint projects on Leonhard Euler's and Johannes Kepler's legacy in the history of science. In the 1950s–1980s research on Leonhard Euler's contribution to science became one of the major dimensions in the activities of Leningrad historians of science. The Leningrad section of the Institute for the history of science and technology edited and published three volumes of Leonhard Euler's correspondence that characterised the relations between the Berlin Academy and the St. Petersburg Academy of Sciences. It was published in German, the books came out of print in Berlin in 1959–1976. (Die Berliner und die Petersburger Akademie der Wissenschaften im Briefwechsel Leonhard Euler, Bd. 1, 1959; Bd. II, 1961; Bd. III, 1976). The Leningrad section also edited and published the letters exchanged between Leonhard Euler and Christian Goldbach. (Leonhard Euler und Christian Goldbach. Breifwechsel 1729–1764, in Klasse fьr Philosopfie, Geschichte, Staats-, Rechts- und Wirtschaftswissenschaften,1965). M.G. Novlyanskaya took part in a large-scale Soviet-German project, editing and publishing Daniel Gotlieb Messerschmidt's diary on his voyage to Siberia (1720–1727). Four volumes of the diary came out of print in Germany in 1964–1986. Scholars in Germany and the USSR were working of locating and identifying letters exchanged between Alexander Humboldt and Russian scientists. This project was expected to produce a multi-volume edition in two languages, however only the Soviet part of the project was completed. (Perepiska A. Gumbol'dta s uchenymi i gosudarstvennymi deyatelyami Rossii, 1962; Suchova, 1960).

Since the 1960s international projects were also launched in sociology of science within the framework developed by the Council for Economic Mutual Assistance. One of the results of these projects was a book published by Leningrad scholars in Prague in co-authorship with their Czech and German colleagues. (Vedeske kadry v socialistiske spolesnosti, 1979). Samuil A. Kugel participated in a Soviet-American research team, which studied the problem of training scientific, engineer and technical cadres and their application in the two countries (1974). On the whole, between 1953 and 1990 Leningrad historians of science took part in editing and publishing abroad 7 volumes of archival documents, one book on bibliography, one collection of essays and a book by Boris E. Raikov on Karl E. Von Baer (1968). (Raikov, 1968).Almost all these books were published in the GDR. Publications in other countries were very rare, as sending a manuscript abroad required a special expertise, which would establish that it contained no previously unpublished data, and a recommendation by a member of the Presidium of the Academy of Sciences.

Perestroika led to rapid expansion of international cooperation. Already in 1988 the Leningrad section hosted 14 foreign scholars, while other 25 visitors from abroad came over to attend an international conference celebrating Vladimir I. Vernadsky's jubilee (1988). The turning point occurred in 1990. In that year the members of the Leningrad section made 12 trips abroad visiting the US, the Federal Republic of Germany, Sweden, Norway, France. For the first time they travelled abroad not only to take part in academic conferences but also as visiting scholars and fellows of leading world centres for the history and sociology of science. 17 foreign scholars visited the Leningrad branch of the Institute, while 18 scholars from abroad arrived to a conference convened by the Leningrad branch in order to commemorate Theodosius G. Dobzhansky's jubilee (1990). This conference laid a foundation for new nongovernmental forms of international cooperation, it opened the way to the West for dozens of Leningrad scholars and facilitated rapid inclusion of young historians of science into international academic community through their personal contacts and participation in international projects. In 1994 the proceedings of the Dobzhansky conference were published in the US in a book '*The Evolution of Theodosius Dobzhansky*'. Another outcome of the conference was the publication of letters exchanged by Theodosius Dobzhansky and Nikolai I. Vavilov, Vladimir I. Vernadsky, Yuri A. Filipchenko. (U istokov akademicheskoi genetiki v Sankt-Peterburge, 2002).

When the USSR collapsed Russian science experienced a profound crisis. Funds for research were dramatically cut down and remained appallingly low for a long time. In the 1990s financial support provided by foreign scientific and research foundations (The Open Society, The National Science Foundation, The Fulbright Program, Volkswagen Stiftung, Alexander Humboldt Stiftung, The Wellcome Trust, Gerda Henkel Stiftung, Deutsche Allgemeine Forschung Gesellschaft), and later by Russian National Foundations (The Russian Foundation for Humanities (RGNF), the Russian Foundation for Fundamental Research (RFFI), The Integration Program) became the major means of preserving the community of historians and sociologists of science in St. Petersburg. Grants awarded by these foundations were particularly important in 1993–2005. Within the period the sources of funding have become more diverse: apart from state funding an important role has been played by grants awarded by national and international foundations on a competitive basis. In 1991-1997, long-term fellowships and academic trips abroad became major means of preserving the community of historians of science in St. Petersburg. This form of international cooperation was facilitated by elimination of the bureaucratic red tape and considerably simplified governmental regulations on international collaboration in the field of science and research. Historians of science got an opportunity to travel abroad for longer periods: in certain years, including 2008, the employees of St. Petersburg branch went abroad on academic trips 32 times a year. Since 1993 St. Petersburg historians of science have regularly taken part in international, and later in European congresses on the history of science and technology, their number has been constantly increasing, considering the declining number of employees. In these years about 12 per cent of the employees of the St. Petersburg branch remained abroad, another 50 per cent opted for long-term periods of studying or working abroad, while 28 per sent regularly travelled abroad in order to attend various congresses, conferences, symposia. 14 employees of the St. Petersburg branch have become members of 28 foreign academic societies. 3 members of staff serve on editorial boards of 6 international journals on the history of science.

Every year the St. Petersburg branch has been hosting dozens of foreign scholars. Since 1995 St. Petersburg branch has been organising about 3–5 conferences a year. Almost all of them have become international. A series of Russian-American conferences on the history of science that took place in 1994–1999 in Russia and the US, and annual sessions of the International school for sociology of science (1992–2008) helped many young Russian scholars to master macro- and micro-sociological methods in this field. In this period the employees of the St. Petersburg branch established and maintained contacts with a broad range of academic institutions (centres, universities, libraries, museums) world-wide (more than 150 institutions): in Germany (43), the US (37), Great Britain (12), China (9), Norway (9), Sweden (6), Canada (5), Finland (5), France (5), Serbia (4), Italy (4), the Netherlands (3), Denmark (3), Switzerland (3), Hungary (3), Poland (3), India (2), Japan (2), Spain (1), Mongolia (1), Austria (1), Mexico (1), Greece (1), New Zealand (1), Turkey (1). The geography of international cooperation has expanded considerably.

Dozens of large-scale international projects have been successfully implemented by the staff of the St. Petersburg branch in cooperation with German historians of science. Among them were 'In the jungles of power. Educated strata under Hitler and Stalin' (1994–2000), 'Germans in Russia' (1993–2007), 'Science behind the 'Iron Curtain'. Myths and realities of Soviet science' (1996–2002), 'Russian-German academic contacts in biology and medicine' (1998–2002), 'Biology in Germany and Russia' (2007), 'Reforms of science and research in China and Russia' (2007, 2009) and others. The forms of international cooperation have changed considerably: editing and publishing collections of essays have been brought to the foreground. A monumental volume '*Science and Crises*' (2003) was published as a major outcome of a joint project undertaken by scholars from Germany, Russia, China, Japan and the US. St. Petersburg historians of science, together with scholars from the UK, Germany, Canada, Norway, the US, France, Switzerland and Japan, took part in the project ‘Politics and Science in Wartime. Comparative International Perspectives on the Kaiser Wilhelm Institute’ (2005). Together with scholars from virtually every European country they participated in preparing for publication a two-volume edition ‘The Reception of Charles Darwin in Europe’ (2007). On the whole, about 25 books in English, German, Chinese, Japanese and Russian languages have been published by the employees of the St. Petersburg branch as an output of various joint projects. 9 books written by the members of our staff have been published in the US and Germany with funds provided by international foundations.

Altogether in 1953–2008 the St. Petersburg branch (section) of the Institute for the history of science and technology published 511 books: among them were 272 books published in 1953–1990 (5.9 books a year) and 239 books published in 1998–2008 (13.2 books a year). In 1998–2008 an average member of staff published 3.3 books a year. Despite the reduction of staff and declining governmental funding, the number of publications, including books, increased by 3–4 times. The figures for academic trips abroad, participation in joint projects and conferences have increased about 20–30 times.

Thus, we can conclude that prior to the 1990s international cooperation in the field of the history of science was under strict party-state control. Its forms, frequency and the choice of partners were determined by shifting priorities in foreign and domestic policy of the Soviet Union. The state tightly regulated international academic contacts on personal and institutional level. In the 1990s the liberation from governmental tutelage led to increasing productivity of research and scholarship by facilitating integration and mobilisation of intellectual resources. Russian science and research have gone through a process of radical transformation on the principles of liberalism and broad international cooperation on a global scale — a process that led to dramatic changes in the forms of international contacts and their increasing intensity.

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GT.C.A. Anant,
Arun P. Bali

International Collaboration in Social Science Research in India

Abstract:
The paper begins by providing a brief review of the role of international collaboration in Social Science Research, especially from the perspective of a developing country like India. It then examines the nature of collaborative agreements — both bilateral and multilateral — in social science research. The paper will briefly present some of the key experiences of the ICSSR in this area drawing upon the work of the Indo French and Indo Russian joint programmes as well as the Indo-Dutch Programme in Alternatives in Development (IDPAD) in the bilateral domain and the role of ISSC and AASSREC in the multilateral domain. The final section reviews some of the challenges created for this framework by the ongoing processes of globalization and liberalization. In a somewhat speculative way we will discuss some of the policy options available to us. In this context we will also describe the efforts arising out of recent initiatives on the International Data Forum and the meetings with key international funding agencies.

Interest in international collaborative research in the social sciences can be attributed to the following reasons. The first could be traced to the influence of the comparative method in disciplines like Sociology and to some extent, Political Science, International Relations, and Economics. The second reason is the need for undertaking large scale international data collection exercises by international agencies such as International Monetary Fund (IMF), World Bank, and United Nations Development Programme (UNDP) which require cross-country data sets giving rise to comparative studies in Economics, Political Science and other social science disciplines. Some recent examples of such cross-country data collection that readily come to mind are: World Development Indicators, Indices on Governance, and Economic Freedom.

Another important reason for the growing interest in international collaborative research is the advent of globalization. While international collaboration has always been part of the scholarly endeavour, globalization as well as developments in Information and

Communication Technologies (ICTs) are both accelerating its scope and pace and increasing its impact. International research collaboration in social sciences is becoming increasingly important to access the global pool of knowledge, to develop comparative perspectives on key social, cultural and economic issues, to pool knowledge and resources to address complex global issues.

The advancement of natural and life sciences has been attributed to the opportunities to close the open natural system and apply the methodology of the controlled experiment. Collaborative research in the natural and life sciences becomes imperative, at times, as it results in effective cost sharing of finances and consequent economies of scale. For the social sciences, the world itself is a laboratory. Within the social sciences, invariably we face the problem of open-ended contexts without the possibility of being able to freeze objects and contexts of study. Comparison is intrinsic to social sciences because it provides a basis for identifying empirical regularities, evaluating and interpreting particular cases. The problem of "comparison" — of understanding forms of equivalence and difference — within social life has long been central to the human and social sciences, in particular, Sociology. The importance and utility of comparative research are as old as the discipline itself. Durkheim insisted that, 'Comparative sociology is not a particular branch of sociology; it is sociology itself, in so far as it ceases to be purely descriptive and aspires to account for facts' (Durkheim 1938:139).

Comparative research encompasses both quantitative and qualitative comparison of social entities. These entities may be based on many lines, such as geographical or political ones in the form of cross-national or regional comparisons. The aim of comparative research is to seek explanations for similarities as well as differences, to generalize from them in order to gain a greater awareness and a deeper understanding of social reality in different national contexts.

Following Weber's comparative sociology, the search for variance places more emphasis on context and difference in order to understand specificities. Comparisons not only reveal differences between social entities, but also highlight unique aspects of a particular entity that would be virtually impossible to detect otherwise. Comparative research methods have long been used in cross-cultural studies to identify, analyze and explain similarities and differences across societies. Comparative research transcends subject matter, time, space and methodological affiliation.

Comparisons have served as a tool for developing classifications of social phenomena for establishing whether shared phenomena can be explained by the same causes. For many sociologists, comparisons have provided an analytical framework for examining (and explaining) social and cultural differences and specificity. More recently, as greater emphasis has been placed on contextualization, cross-national comparisons have served increasingly as a means of gaining a better understanding of different societies, their structure and institutions.

In addition to the traditional element of comparisons, Social research in the context of globalization faces an additional challenge the social reality has it-self become globalised. Thus we see events in Afghanistan-Pakistan have consequences in New York. Migration has long provided for a means for diffusion of cultures. But the growth in communication and transport technologies have cooled the melting pots and instead leads to diasporas that are culturally segregated. Thus, reflecting on these aspects becomes a necessary ingredient of investigating social reality. These trends create fundamental challenges for research and as for research policies in manners that have not yet been fully understood. Social Research in terms of both research agendas and research infrastructures needs to catch up with these challenges of a globalizing world. For this, there has to occur a significant increase in the collaborative generation of knowledge. Social scientists from different geographical areas need to be involved more actively in joint research efforts. The benefits accruing from such research work also include a deeper understanding of other cultures and their research process to deal with the problems and issues arising from globalization.

We have seen the reasons underlying the increasing interest among researchers in social science in the notion of research collaboration. Collaborative research is defined as “an emergent and systematic inquiry process, embedded in a true partnership between researchers and members of a living system for the purpose generating actionable scientific knowledge”. It is widely assumed that collaboration in research is ‘a good thing’ and that it should be encouraged. Collaboration can take various forms ranging from offering general advice and insights to active participation in a specific piece of research. It has the effect of 'plugging' the researcher into a wider network of contacts in the scientific community. Collaboration can enhance the potential visibility of the work. International collaborations can be tremendously rewarding and productive. They also open researchers' eyes to new methods of conducting research. Among the several benefits of international research collaboration: three stand out prominently: namely, conceptual benefits, pragmatic gains and simple imperatives. International collaborative research helps to unravel one's own hidden cultural preconceptions by showing alternative pathways of action and concepts. Nowadays international collaboration in social science research relies on mutually agreed goals followed by measured debate about the best means of achieving them. International collaborations also have the potential to contribute to continuing development of institutions as contexts within which researchers can achieve a global perspective. However, such collaborations present numerous challenges, both in the process of the research and as a subject of the research.

The diversity of approaches and, in some cases, the small-scale of activity in the social sciences may be reinforced by cultural and linguistic boundaries. Even where projects are considered to be large for the social sciences, they are usually relatively small by comparison with the natural sciences, where research methods require a team of researchers and/or major equipment. However, as with the natural sciences there is an urgent need for greater research funds and infrastructure so as to maximize the output of social scientists and to ensure that the next generation of social scientists is nurtured. . Research in social sciences is critical to the long-term economic and social well being of societies.

In India, international collaboration programme in social science research is overseen by a number of agencies. There is no single nodal agency in the country to channelize efforts in social science collaboration. There are three major agencies, viz., the University Grants Commission (UGC), Indian Council of Cultural Relations (ICCR) and the Indian Council of Social Science Research (ICSSR). It is only the ICSSR whose mandate is the social sciences, whereas in case of the other two agencies, social sciences are one among the many. As a result, social sciences receive mere lip service from them. In addition, Council for Scientific and Industrial Research (CSIR) and Department of Science and Technology (DST) also extend support to research activities involving social science aspects as they impact science and technology.

The ICSSR's primary mandate is social sciences. It fulfils this mandate in a variety of ways: through research projects, fellowships, participation in international conferences and seminars, data collection abroad, provides grants to research institutes, for publication of research, and also enables scholars to collaborate with their peers beyond national boundaries and gain exposure to new forms of knowledge and form new networks, to mention a few. It fosters communication and collaboration across the wide spectrum of social science disciplines and enhances interdisciplinary networking. The ICSSR acknowledges the importance of international research collaboration in social sciences to help sustain excellence in research and position Indian social science research in the world. It recognizes the need to create better opportunities for Indian social scientists to lead and participate in international collaborative research. It also addresses the importance of promoting the distinctive contribution that Indian social science research can make to international research agendas and to better understanding of major global issues. The ICSSR helps researchers develop, participate in, and lead diverse international collaborative research activities.

In this context, the ICSSR developed the international collaboration programme. This Programme has grown gradually, largely in response to the requirements of Indian social scientists seeking to go abroad, or of overseas scholars intending to come to India, for attending conferences and seminars for collection of research materials, and/or otherwise engaging in academic pursuits. This Programme aims to promote academic links among social scientists/ research institutes of India and of other countries of the world. It seeks to stimulate academic interest and activity and to build a community of scholars interested in the nature of global interrelations and interdependence. By and large, the focus of interest was on the Third World countries and their problems, such as the energy crisis, and the North-South divide which called for an intellectual response. Some areas of general and continuing concern which called for attention includ ed: agricultural development, urbanization, education and health care, science and technology, international economic and social stratification systems, various forms of discrimination and exploitation. In all these areas, comparative international research in social science assumed great importance. Many of these areas still continue to engage the attention of social scientists, while adding new areas of concern such as Ageing, Globalization, HIV AIDS, global financial crisis, Gender, Migration, Terrorism, Culture, Identity and Development.

This Programme underscored the special leadership role of Indian social scientists in articulating certain Third World perspectives and in stimulating discussion and debate on, for instance, alternatives in development. It was then felt that if they shied away from performing such a role, then others from the advanced countries (notably area specialists) would grab the opportunity and step in.

Initially, a distinction was made between Area studies/International collaboration programmes and efforts were made to promote and encourage them. This parallel and simultaneous growth of both streams of knowledge proved to be mutually beneficial to the domain of International collaboration in social science research. The expertise of Area Studies specialists dovetailed into the International Collaboration programme was brought to bear this on international collaboration in social science research. Slowly, over the years, the distinction got blurred and the two streams got merged. In recent times, however, interest in reviving the distinction is engaging the attention of social science researchers and social science institutions.

During the mid-1970s, the Council laid emphasis on strengthening its programme of Area Studies. It was felt that the Area Studies should be interdisciplinary and also include comparative studies within and between the regions, also involving India. In seeking to fulfill this objective, the ICSSR identified some major themes of research under this programme. In the light of this ICSSR developed this programme by focusing, in the initial years, on relatively senior scholars, who were expected to and promote not only intellectual understanding but also personal and institutional contacts.

The major activities conceived under this programme are:

1. Participation in Cultural Exchange Programmes (CEPs).

2. Establishing professional contacts with social scientists/ research institutes of countries not covered under CEPs.

3. Financial assistance to Indian scholars for going abroad to participate in conferences and data collection for research.

4. Inviting distinguished social scientists from abroad for delivering lectures and participating in seminars.

5. Participation in the agencies of important professional bodies/agencies such as ISSC, AASSREC, UNESCO and other non-governmental organizations.

6. Financial assistance to Indian social scientists/institutes to organize international conferences/seminars in India.

All these activities, over the years have played a critical role in shaping the international collaboration programme. We will briefly discuss some of these in the following paragraphs.

This section examines the nature of collaborative arrangements in research both bilateral and multilateral. It will highlight some of the key experiences of the ICSSR in these domains drawing upon the experiences of the Indo-French and Indo-Russian joint programmes and the IDPAD in the bilateral domain. While in the multilateral domain it examines the role of International Social Science Council (ISSC) and Asian Association of Social Science Research Councils (AASSREC).

Cultural Exchange Programmes

The Cultural Exchange Programme (CEP) forms a critical element in the International Collaboration programme. Generally, the Government of India enters into a CEP with governments of other countries. The CEP usually has several components inbuilt into it. For their implementation each component is then entrusted to different organizations. The ICSSR has been entrusted with the task of implementing the social science component in the CEPs. The broad contours of collaboration are given, within which the implementing agency or organization operates and implements collaborative arrangements in areas such as: Exchange of scholars; holding of joint seminars, Workshops and Conferences; and joint publications.

Over the last three decades and more, the ICSSR has been actively involved in implementing CEPs with many countries, such as France, Russia, China, Hungary, Mexico, Poland, Egypt, South

Africa, Romania, Czechoslovakia, Vietnam, Korea etc. CEPs with three countries namely, Russia (since 1975), France (since 1976) and China (since 1983) have been durable and successful.

Indo-French Programme in Social Sciences

The Indo-French collaboration in social sciences was initiated under the Indo-French Cultural Exchange Programmes between the Government of India and that of France. Over the past several years the ICSSR on the Indian side and the Maison des Sciences de L'homme (MSH) on the French side have together been able to work out certain concrete plans of action for building up collaboration between the two countries. Accordingly, the major thrusts of the Indo-French collaboration have been: Seminars; exchange of documentation between the two countries in social sciences, and sponsoring exchange of short and long-term visits by social scientists between the two countries for purposes of research and professional contacts.

In 1991–92, a delegation from Maison des Sciences de L'homme (MSH), Paris visited the ICSSR, Indian Council of Historical Research (ICHR) and UGC and established institutional linkages for social science collaboration between India and France in areas of mutual interest within the framework of the India-France CEP. The India-France CEP constituted a Joint Advisory Committee to provide overall guidelines in the implementation of the activities. The members of Joint Advisory Committee are ICSSR, UGC, ICHR from the Indian side and MSH, French Institute, Pondicherry, and Centre for Human Sciences (CSH) of the French Embassy, New Delhi. Later, Indian Council of Philosophical Research (ICPR) was co-opted into this Committee. The Committee meets annually alternately in India and France. The activities identified are exchange of scholars, joint seminars, joint projects, and joint publications. During recent years the following joint seminars were held under this programme: Reforms in Public Administration: French and Indian experience; Privatization of Public Enterprises: Indo-French Perspectives and its Global Relevance; The Politics of Authenticity: The Case of the Visual Arts in Modern and Contemporary India; Indo-French Relations in the Changing World; Culture, Identity and Development (2003); Past and Present: Discourse on South Asia; Development. During 2000–05, 21 French scholars visited India under exchange of scholars' programme; while 44 Indian scholars visited France.

Indo-French Programme is a classic example of CEP. For example, this programme has resulted in some scholars who have been closely associated with it since inception continuing to play a critical role even to this day. Whenever either government intends to start any activity or programme within this framework, these scholars are the first port of call for advice. They are also the ones to be approached to serve on Committees and their expertise much sought after. This programme has helped in nurturing and developing mutual interest and respect for studying each other's society. It has also helped in furthering social science networks and paving the way for a better appreciation of social issues and challenges facing India and France.

Indo-Russian Programme in Social Sciences

The Indo-Russian (formerly Indo-Soviet) Academic Programme in social sciences was started more than three decades ago when the Government of India and the Government of the erstwhile USSR decided to establish an Indo-Soviet (now Indo-Russian) Joint Commission for cooperation in social sciences. The ICSSR is an implementing agency of the India Russia Cultural Exchange Programme for more than 25 years. The Chairperson, ICSSR is the co-Chairperson with its Russian counterpart.

ICSSR is the coordinating/implementing agency of the Joint Commission, while this role is preformed by the Russian Academy of Sciences, Moscow. The Indo-Russian Joint Commission meets once in every two years alternately in New Delhi and Moscow to review its activities and provide guidelines. Exchange of scholars and joint seminars are the major activities implemented under this programme.

During the period 2000–05, 13 Indian scholars visited Russia under the exchange of scholars while five Russian scholars visited India. During the same period the following joint seminars were held: Globalization and International Relations; and Socio-economic Strategies of India and Russia in the 21st Century.

During the years 2006–07, six seminars were held. These seminars focused on the following themes: Gender and Development; Rethinking the Science of Historiography; Institutional Reforms and Development Units in transitional Economy; Popular Culture and Traditional Values; India and Russia: Problems in Ensuring the

Energy Security; Peasants in History of Russia, Central Asia and India. During 2006–08 joint research projects were launched. The themes were: Archaeological Studies in India and Russia(Institute of Oriental Studies, Institute of Archaeology, RAS and ICHR): Social and Economic Problems of Poverty(Institute of Russian economy, Institute of Oriental Studies, IMEMO and ICSSR); and The Problems of Ethnicity and Ethnic Groups(Institute of Oriental Studies, Institute of Ethnology and Anthropology, RAS and ICSSR).

Under the CEP renewed for the period 2007–09, it provides for an annual exchange visits up to 10 scholars for delivering lectures, exchange of experience and research work. Within the framework of the CEP, the ICSSR and the Russian Academy of Sciences have entered into an agreement in 2007. The Agreement provides for supporting cooperation "between scholars and research institutions of both countries in all recognized branches of fundamental research in social sciences with special emphasis on specifically chosen areas without precluding direct forms of scientific cooperation and individual research activities. Priority should be given to the research in urgent social problems of modernity, support of Russian and Indian studies in social changes in economy, politics and societal development." Both organizations will promote scientific cooperation through the following means: (1) The exchange of scientific information, publications and other research materials; (2)The exchange of scientists for research visits; (3) The support of bilateral workshops and symposia and subjects covered by the programme operation; (4) Visits of distinguished scholars for lecturing; (5)Joint research projects; and (6) Other forms of academic cooperation as agreed upon."[2]

Critique of the CEPS

In spite of these examples of successful CEPS, most CEP's remain idiosyncratic and episodic. These activities for a few years were followed by dormancy. CEPs are largely bilateral in focus, whereas concerns of Indian social scientists and the ICSSR are often broader than those envisaged under the bilateral agreements. Take for instance, the Indo-French programme where our interest is in not France *per se* but its importance in the social science arena in Europe. Often it was felt that the parameters for operationalization of the CEPs were found to be restrictive and did not provide any degree of freedom either for accommodating innovative ideas or for making additions/or curtailment of activities. They are also subject to significant variations on account of differences in implementing agencies in partner countries. In some cases where the partner agency was a specialized department or agency they were less enthusiastic of broader concerns outside of their scope. At times, CEPs entered into with some countries were non-starters as these countries were either lacking in social science institutions or social sciences had remained undeveloped.

In this discussion it would be appropriate to take a special look at what was a somewhat unique intergovernmental program. Namely the Indo-Dutch Programme on Alternatives in Development (IDPAD). IDPAD is a collaborative international research programme of the ICSSR and the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), The Hague. It was launched in response to the intense debate on developmental and North-South issues in the 1970s with the goal of charting a new course in policy oriented academic research.

The origins of this programme lay in the concerns that Indian social scientists in general and the ICSSR in particular being aware of the legacy of dependence of Indian social science on Anglo-Saxon concepts, paradigms, perspectives, models and methodologies. In its efforts to build an indigenous and vibrant social science, responsive to the challenges of development, the Council made efforts to diversify its perspectives through greater contacts and collaboration with non-Anglo-Saxon social scientists. In this direction, the Council considered an intellectual opening to the rich traditions of West European social science to be an important component of this effort.

The first serious attempt at giving shape to the idea of collaboration between social scientists in India and west Europe was made in December 1975 at a meeting between Drs. J. Pronk, the then Dutch Minister for Development Cooperation and Shri J.P.Naik (then Member-Secretary, ICSSR) and Professor S. Chakravarty (then Member, Planning Commission) held at New Delhi. The meeting gave concrete expression to this collaboration, through the Indo-Dutch Programme on Alternatives in Development (IDPAD). This experiment at cross-fertilization between social scientists of a leading non-aligned developing country and those of a like-minded developed West European country was a unique event in research collaboration.

Two joint workshops of scholars from the two countries were organized at New Delhi in September 1978 and at Nunspeet in November 1979 to grapple with the operational tasks of defining the contours of the programme and its priorities and also of identifying scholars and projects to be taken up in the First Phase. It was recognized that the research for alternatives should generate a greater awareness among the researchers, policy-makers and the people about the need for development processes and the paths that would lead to enhancing the quality of life of their peoples.

The ICSSR and the Institute for Development Research in Third World Countries (IMWOO) with the support of the Governments of India and the Netherlands signed an MOU in December 1980 signaling launch of the programme. IDPAD formally initiated in mid-1981 was the outcome of gradually intensifying contacts between Indian and Dutch social science researchers and the joint work undertaken by them since early 1970s. The need to explore alternatives in development-related social science research and development, policy-making was being increasingly shared in both countries. Given this, they decided to combine their efforts and devised a Work plan of research and related exchange activities, which constituted IDPAD's First Phase (1981-84). The guiding principle was that both research and policy-making should contribute to meeting basic needs of large masses of people and to strengthening the latter's role as creative agents in the evolving world economy[3].

Initially the Programme concentrated on research projects, conferences and publication of reports. Later, the exchange programme of scholars was made an integral component of the Programme. The Programme has completed five phases, each lasting four to five years.

Research projects formed the most important segment of IDPAD. They have been thematically structured. The thrust areas and themes in the various phases were: Phase I: Small-scale industrialization; export-import industrialization; multinational corporations; women's studies; Information system and the corporate sector in India; Dairy development in India. Phase II focused on:

Comparative Perspectives on Asian Rural Transformation; recent trends in European society; New International Economic Order. Phases III and IV concentrated on: Ecology and development; Rural Transformation in Asia; State and Society; International Economic Order: The overall theme for Phase V was Improving the Quality of Life in a Globalizing World. Within this broad theme, scholars focused attention on the following sub-themes — Employment and Security; The Contested Environment; Population and Health; Education; ICTs and Mega cities.

A total of 121 research projects, for all phases together, were given financial support. Seminars and workshops are another major activities supported under the Programme. 21 international seminars/ conferences were held. The themes for these seminars covered areas such as new international economic order; comparative perspectives on Asian Rural Transformation; Recent Trends in European Society; Economic reforms and Structural adjustment; Comparative research and Water management; Economic liberalization; Refugees and displaced people; Nuclear stability; AIDS; Child labour; Primary education; Labour and capitalist transformation; Information technology; Mega cities; Water security; Biotechnology; Challenges of population and health; and Enculturing Law.

Exchange of scholars also formed an integral part of this Programme. Under this programme, scholars from the two countries exchange visits in order to: undertake short term research; deliver lectures and make presentations on their research work; prepare research proposals; and consult with experts. The aim is to promote Indian studies on Europe, and Dutch studies on India, and comparative work. It helped scholars advance their research work and learn from each other's experiences.

Publication of the reports and findings of the research projects and seminars in the form of books, monographs, and working papers constituted another element of the Programme. In all, 54 books based on IDPAD research were published and another five were in the press. IDPAD has grappled, over the years, with major contemporary issues and promoted research on alternative approaches to development. It has created a community of scholars in the two countries and has influenced the nature of development research and academic discourse. The Government of India's recent decision not to accept any development assistance from other countries also spelled the winding up of the IDPAD programme.

Critique of IDPAD

IDPAD was a special example of a bilateral agreement, which is unlikely to be repeated in future. It was initiative of the two governments, the Dutch Government and Government of India. The Dutch government provided Development Assistance under the Dutch Overseas Assistance. The major criticisms of this programme were: (i) in relation to dependency; (ii) large focus of studies was primarily India-centric; few studies sought to expand India's understanding of the Netherlands and Europe. The pattern of funding this programme was skewed in favour of the Dutch and probably explains who called the 'shots' for setting the research agenda. The Indo-centric character of the research was in part due to it association with WOTRO, that was primarily interested in indological studies. However it must be noted that the vast volume of research generated through the different phases have spurred academic activity across the country.

In response to these criticisms, the ICSSR has negotiated a new bilateral agreement in line with most CEP's with the Netherlands Organization for Scientific Research (NWO), Social Sciences (MaGW) and Science for Global Development.

Further to counter the weaknesses of the CEP programs ICSSR ***suo moto*** began developing as well as expanding collaborative programmes with some existing countries. This provided the impetus for the emergence of Bilateral Agreements outside the CEPs. This led to collaborative agreements and agreements with similar national or apex social science organizations in different countries. A recent example of this is the agreement with Economic and Social Research Council (ESRC), UK to foster and support collaborative social science research and create networks linking individuals and centres within India and UK and outside.

Multilateral collaboration with international organizations

The role played by UNESCO in bringing about multilateral collaboration with international organizations is of prime importance. The International Social Science Council (ISSC) and other agencies, including the Asian Association of Social Science Research Councils (AASSREC) are both UNESCO driven. It played an important role in these organizations and actively participated in their activities and programmes. The underlying rationale was the development of social development research and policy. The ICSSR is an active member of UNESCO, ISSC and AASSREC. It's participation with UNESCO is in the Management of Social Transformation (MOST) programme. The ICSSR is a nodal agency of the MOST programmes. It actively participates in these associations and also facilitates the meetings of international association such as –- International Economic Association, IUAES, and International Sociological Association.

ICSSR-ISSC Collaboration

The ICSSR is a member of the International Social Science Council (ISSC), Paris. The main objectives of the ISSC are: (1) To establish a strong global presence and authority for social sciences; (2) To promote the growth of social sciences in developing and transition economies; (3) To stimulate high-quality, innovative, inter- and trans-disciplinary research, training and knowledge exchange at a global level; and (4) To ensure that social sciences capture and harness the potential of new technological and methodological developments.

The ISSC acts as a catalyst, mobilizer, and coordinator of social sciences across disciplines, domains, and national cultures, encouraging the development and issues of strong conceptual, evidence-based methodologies to facilitate production of high-quality research. To fulfill these objectives, the ISSC and its members take the lead in bringing together social science researchers, scholars, funders and policy makers from all parts of the globe. It seeks to actively engage ISSC members in the Council's work, foster networking between them and strengthen relations with ISSC partners. Further, the ISSC seeks to launch a World Social Science Report (WSSR) Series and a World Social Science Forum (WSSF). The ISSC intends to periodically bring out the WSSR. The WSSF seeks to bring together major stakeholders in international social science cooperation to discuss substantive topics of world relevance and priorities for the future of international social science research. It seeks to stimulate dialogue across the disciplines, connect research and practice, and provide a platform for debate, exchange of experiences, innovative ideas and good practices.

Association of Asian Social Science Research Councils (*AASSREC)*

AASSREC was founded in 1973 as a result of the initiative taken by the UNESCO, ICSSR and the Indian Institute of Advanced Study, Shimla, to encourage development of social sciences in Asia. Thus, the ICSSR is one of the founding members of the AASSREC. It played a key role in establishing AASSREC and played host to the latter's Secretariat in its formative years and even later for several years. It is over 30 years that AASSREC has established itself as a forum for national social science organizations to meet and interact. The members of AASRREC are: Academy of the Social Sciences in Australia(ASSA);SocialScienceResearchCouncil(SSRC),Bangladesh; Chinese Academy of Social Sciences (CASS); Indian Council of Social Science Research (ICSSR); Lembaga Ilmu Pengetauhan Indonesia (Indonesian Institute of Sciences (LIPI); Science Council of Japan (JSC); Korean Association of Social Scientists (KASS), DPRK; Korean Social Science Research Council (KOSSREC), ROK; Foundation for research, Science and Technology, New Zealand; National Institute of Historical & Cultural Research(NIHCR), Pakistan; Philippine Social Science Council(PSSC); Social Sciences Commission of Russia for UNESC; Natural Resources, Energy & Science Authority of Sri Lanka(NARESA); Academy of Sciences of the Republic of Tajikistan; National Research Council(NRC), Thailand; and National Centre for Social Sciences of Vietnam(NCSSV).

The main objectives of AASSREC are: (i) exchange of information among Asian Social Scientists; (ii) exchange of scholars; (iii) promoting research opportunities for young social scientists; and (iv) promoting joint research projects.

AASSREC seeks to realize these objectives through the following activities: (1) publication of reports of its biennial conferences; (2) organization of problem-oriented seminars; and (3) collaborative research programmes on specific problems.

As per its practice, biennial conferences are held in one of the member countries. So far 17 biennial conferences have been held.

AASSREC has also provided the platform for the ICSSR and ASSA to work together closer. Recently they have entered into a MOU to facilitate exchange of scholars between the two countries; hold joint seminars; exchange of documents; joint publications. The aims of this programme include collaboration between Australian and Indian scholars, the opportunity for access to research and research materials not easily accessible outside the countries concerned and the development of networks of scholars with related interests both within and between the two countries. The Academies facilitate visits by scholars to specific research institutes or conferences in both countries.

The objective of this Programme is to develop a better understanding of social sciences in India and in Australia through collaborative research, network of social scientists, and free and open exchange of relevant information. This collaboration aims at establishing sustained and continuing partnership in the social sciences, thereby promoting high standards of research and excellence in social sciences. Both sides will carry on exchanges and cooperation in fields of social sciences and undertake joint research projects.

Critique of UNESCO's Role

UNESCO's own resources for social sciences have drastically reduced over the years. As a consequence, this has severely affected the ISSC and AASSREC. Both these organizations now face financial constraints, which, in turn seriously hamper their activities and programmes. Both are thus facing the challenge to reinvent themselves. This is most visible in the case of ISSC. In response to an internal review ISSC is planning a restructuring of its constitution. It would try to better play the role of a coordinating agency rather than a funding agency as in the days of UNESCO largesse. In this objective it is being primarily supported by major European funding agencies. Towards this end ISSC has taken up the task of generating a biennial World Social Science Report as well as by sponsoring the world social science forum. It is hoped that these efforts would facilitate coordination amongst the different agents in the social science community. A principle challenge in this is to ensure participation of developing countries, where even now the commitment to social science research is weak.

IBSA (India, Brazil and South Africa)

The post-colonial era has seen a number of countries acknowledging the principle of enhancing the standard of living of their people as an objective of state policy. However, economic growth by itself cannot be sustained unless all sections of society derive benefit from such growth and develop a stake in the growth process. Thus, social development is critical fro sustaining the long-term viability of not only economic growth but also of democracy itself. This understanding has underpinned political developments in recent times in the major democracies of India, Brazil and South Africa. Recently, the ICSSRwith support from the Ministry of External Affairs organized a two-day workshop involving participants from India, Brazil and South Africa. These countries exhibit striking similarities, such as sharing a commitment to democratic values, building of an equitable society, and facing common problems of poverty, deprivation, insecurity, and assimilation of these given the heterogeneous cultural diversity of its peoples. Despite these similarities, these countries have different cultures, histories and social compositions. In the light of the discussions, there were some striking features which emerged relating to the character of social development strategies. First, is a critical involvement of the State because it is only the State, which can marshal the necessary resources and coverage to reach to the weakest elements of these societies. There is a clear sense in that we must return to some of the basic principles underlying a welfare state. Second, effective social development policies must be participative in character in which they must involve all elements of the society. Third, it is necessary that a strategy for social development must be integrative in character to take advantage of both complementary and synergy across different policies. Fourth, a comprehensive social protection network could provide the basis for integration of families that are most vulnerable.

To learn lessons from the successful and effective social development strategies adopted in solving common problems such as social protection, public health, employment, poverty alleviation, participants of the IBSA meet felt it necessary: (i) To promote a process of information exchange through seminars and Workshops involving academics, policy makers and representatives of civil society; (ii) To develop expertise in social development strategies in each of these countries, through a process of scholar exchange and initiating comparative studies of common problems and approaches are needed; and (iii) To identify relevant nodal agencies/counterpart organizations in each country to enter into bilateral/trilateral agreements to implement key elements of these strategies. [4]

Historical Perspective

When the International Collaboration programme is viewed in a historical perspective several events and personalities come readily to mind. It also brings into bold relief the role played by the Government to promote international collaboration in the social sciences. It played a crucial role in determining the shape and direction of the Programme. Depending on the socio-political climate prevailing in the country, at any given point in time, the focus was on developing and promoting ties with certain countries and in this the role of the ICSSR was situated in fostering and forging international collaborative research in the social sciences. In the initial years, the IC programme was directed towards building collaborative arrangements with the former Soviet Union. To be followed with interest being evinced in promoting international collaboration with countries like France, UK, and later Japan, and China. Here one witnesses the close nexus between the Government and the ICSSR and the active involvement of diplomatic embassies and ambassadors who often acted as facilitators. Over the years, the degree of such involvement seems to have waned. The decade of the nineties was one of financial stringency in a number of public programmes; social science research was no exception. This led to a number of programs being abandoned or disappearing for lack of resources.

The early years of the twenty-first century saw some easing of the financial crunch and with that a flurry of activity with concerted efforts being made by the ICSSR to renew, revive, strengthen, and consolidate existing arrangements while simultaneously exploring new areas of collaboration.

The recognition of India as a high growth economy has led to a resurgence of interest in India. This has led to a new development the influx of foreign funding agencies setting shop in India. This trend can be partly attributed to European countries having continued interests in their former colonies. But is also in good measure recognition of the importance of controlling the social science research agenda as a instrument of public policy. This trend further underscores the asymmetrical relations between investment resources and collaboration research. It remains to be seen how Indian social science establishment, the governments — State and Central — and the social science community respond to this phenomenon.

Comparative research in social science, drawing expertise from across the country, and beyond will increasingly become important as it responds to the new opportunities offered by the process of globalization. It is obvious that social science research must adjust their approaches towards the collective generation of knowledge to match the internationalization of the social science phenomena. It is important to find out how the social sciences in India try to respond to the process of globalization and how social science research communities adjust their research activities to the needs of an internationalized research approach.

A cursory glance at major international journals would reveal that research on India is more likely to be done by scholars both Indian and foreign based in western universities than India. Further it is well accepted that social research paves the way for future social policy. With globalization forces sweeping the globe, India can ill afford to remain insulated or isolated from the rest of the globalizing world. To avoid this, Indian social science research and social scientists would have to make conscious efforts to keep in touch with the changing social science scenario in the world. This is possible only through a process of active participation. We should think in terms of opening up ours research sites, some of which have remained out of bounds for overseas researchers, data bases, official documents and also making for large allocations of resources — financial and infrastructure — for effective balanced the international collaborative research to take place.

India would also need to adjust its funding arrangements in order to promote an Indian (an international) dimension where collaborative research in social science becomes necessary in addressing socio-economic topics/phenomena that go beyond national boundaries. Further, there arises the need to coordinate the activities of various funding agencies with a view to augment resources and also avoid duplication of research effort. The mapping of the social science landscape in India reveals a large number of small departments and institutes (university and non-university), and hence research expertise tends to be dispersed widely across them. Better research collaboration between universities and research institutes would be called for, through mechanisms such as the UGC and ICSSR that foster cooperation without favouring one institution type over another.

There is also the need to put policies in place with the avowed aim of improving the links between social science research institutes and universities through innovative institutional mechanisms. It would be necessary to ensure timely and flexible rules and procedures to facilitate easy mobility of scholars from and into the country to ensure smooth conduct of collaborative international research. Another important dimension that needs attention is the relation between social science research and social policy. Planners and administrators must be sensitized to the importance of this link and to act pro-actively rather than reacting to international pressures.

World-class twenty-first century social science requires major investments in infrastructure. While it is still possible, in some areas of social science, to undertake leading edge research with relatively little infrastructure, much social science requires the use of large data sets and sophisticated computing power. These data sets are increasingly costly to collect and to maintain.

For India to maximize its potential in social science research it will be essential to ensure access to appropriate data. Given the costs involved, it will be necessary to develop strategic priorities for funding on sustained and long term basis. There is a need to develop a vision for research in the social sciences over the next decade. This vision should address the key core social science challenges being faced by researchers in the social sciences; the major cross-disciplinary questions; and the future capacity needs. Such work could also include some benchmarking of Indian social science against global competitors.

Technologies for building, searching, compiling, integrating, storing, and sharing of data of various types and formats are advancing rapidly. While the possibilities for gaining access to global and international data sets and international communications will undoubtedly facilitate collaboration in research by saving time, travel, and costs, the access to these resources is, unsurprisingly perhaps, unequal. Private companies generally reserve some interesting and useful data sets for proprietary use. Even data collected by social scientists with support by public funding, are not always required to be made publicly available. Even if public agencies and governments would have liked to develop informational infrastructures they obviously have not had the capacity to do so. However, there is an increasing need for large, cross-national datasets and these could be enormous. There may be a case, therefore, for an ICSSR in conjunction with other national agencies supporting large cross-national social scientific infrastructure. New technologies of data storage and manipulation promise to make possible shared access and analysis of growing administrative and research databases worldwide. Deciding strategies for creating new databases through integration of old data sets as well through development of new ones would benefit from international consultations between technologists, researchers, administrators and funders.

The time is ripe for the social sciences to consider new ways to organize internationally collaborative research as part of their efforts to illuminate the nature and implications of such transformations for the rest of society. Comparison of physical and social science research and regional inequalities of capacity and resources highlight issues that ought to be addressed in future international efforts to promote collaborative research.

The impact of intensified globalization is possibly the most cited challenge facing the field of comparative international social science research at this point in time. Global forces, it is argued, are dramatically changing the role of the state in social science research, and demanding increased attention to be paid to factors operating beyond the national levels. The mechanisms and processes driving globalization are thus prioritized for examination, as is the increased significance for multilateral agencies in shaping global policy debates and agendas.

In many respects, the rational for this is related to efforts to help “bridge” the gap between social science research and its potential to improve policy and practice. This is one of the prominent challenges faced by social science research communities worldwide. The widening constituency of policy makers and practitioners who have taken renewed interest in comparative and international research are certainly looking for findings that will be of use to them in their professional activities. The ICSSR is aware of this major problem facing the social sciences. It recognizes that social science research is a key element in policy planning. It also acknowledges the need to develop capacity to anticipate developments for social science research and proactively respond to societal needs.

Growing tensions between the global, the national and the local, thus so fundamentally underpin all aspects of contemporary society and development, that a similarly fundamental reconceptualization of the field of comparative and international social science research is required, if we are to more effectively address such issues.

If funding of research is increasingly linked to commercial interests, for example, the potential for critical theory, or for alterative cultural perspectives to influence the construction of new knowledge, may be increasingly challenged — even in, paradoxically the new “knowledge” economy. So questions of “power” and “whose knowledge counts?” in the process of development arise perhaps more strongly than ever before.

Contemporary writing in the social sciences indicates some fundamental changes in the social production of knowledge. The changes include who is involved in the production of knowledge, the process of knowledge production and types of available knowledge, new levels of international collaboration in research, and new settings and opportunities for knowledge production, dissemination, and use.

One needs to recognize the complex interactions among multiple stakeholders in the research process and a more contested landscape for evaluating the quality and relevance of social processes, outputs, and outcomes.

Responding to New Conditions

The management of dispersed research and development collaboration is now crucial in university-, industry-, and government-based social science research. For most part, these agencies are just beginning to explore how their interests and activities might be made complementary. Globalization engenders both interconnections and fragmentation. “Our education research systems for the training of research professionals and the development of their careers are better suited to the needs of the past decades than to the needs we envision in the future”. [5]

Collaborative research may well bring greater complexities and transaction costs in the research process. Will the benefits outweigh the costs? What additional intellectual, social and political skills are demanded of everyone in these kinds of knowledge production? What are the special challenges imposed on those who coordinate or lead this kind of research, and how do we prepare future generation of scholars to be motivated and skilful in collaborative research? Finally, what kind of knowledge will emanate from collaborative research, and what reception will that knowledge have among scholars, practitioners, and policymakers? The answers to these important questions will, of course, depend on the nature of institutions we create for social research.

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S.P. Agarwal,
Madan Lal,
Ajay Chauhan

An Empirical Study of Technology, FDI and Exports in India and China

Abstract:

R&D, innovation and technology are now being increasingly recognized as important drivers for growth, exports, and competitiveness of businesses in globalizing economies such as India and China. Foreign Direct Investments (FDI) have also been leveraged by several developing countries such as Korea and China to enhance their technolgocial, management and trade capabilities when FDI policies are appropriately integrated with other domestic policies including S&T, trade and industrial policies. Corporates and medium & small firms in India are also restructuring their business strategies, attracting FDI, and investing more on R&D, technology acquisitions and technology related capacities in several sectors since the implementation of new policies from 1991 onward. The government policies and mechanisms have also been supporting the initiatives of enterprises and corporates, resulting in high growth rates of economies and exports. However, there are very very limited studies and documentation available for India in the context of technology and exports.

The national export basket continues to be mainly of low technology and low value added manufactured products in India while the exports have shifted to high technology based products in China during 1996 to 2006. High technology exports from China increased from 20% in 2001 to 30% in 2006. There have been significant shifts in technology policies and institutional mechanisms in China, increasing national R&D expenditures to 1.3% of GDP in 2005 compared to 0.8% in India. Similarly FDI flows in manufacturing in China have been about 67% of total FDI as against 37% in India during 2000–2008.

The paper reports the findings of research studies at IIFT, based on field surveys of 303 technology based exporting firms in India, carried out during 2006–08 and 163 firms for the period 2002–03 to 2007–08. The studies revealed that the firms have been increasing their R&D expenditures for growth and competitiveness and R&D positively impacts the exports though may not be linearly and may vary across the sectors. The technology intensive exports from India have increased to about 25 per cent of total exports in 2006–07 from about 19 per cent in 2002–03 though high technology exports have remained at around 6–7 per cent but medium

technology exports have increased, for the sample of firms studied. FDI inflows do not seem to have significantly impacted directly the technology intensive exports in India. The paper concludes with certain suggestions to improve the export competitiveness in technology based sectors in India.

Introduction

Technology and technological capabilities are recognized as a prime driving factor for growth and competitiveness in trade and industry. Share of technology intensive trade in world trade has been steeply increasing in recent years, generally dominated by developed countries. However, many developing countries such as India and China are now emerging as competitive sources for technology based products, projects, processes, services, and are aiming at enhancing their technological and innovation capabilities for larger export share in world trade.

Over the period, 2005–2007, GDP has grown by over 8 per cent a year in India. Growth has been driven by a jump in export-oriented and skill intensive manufacturing like pharmaceuticals, auto components, and services sector. These sectors have been accompanied by innovative activities.

Corporate and small firms are continuously restructuring their business strategies, organizational and manufacturing capabilities, financing and marketing methodologies, and so on, besides emphasizing on innovation and technology capability building through in-house R&D efforts, networking with external organizations, foreign collaborations and foreign direct investments, and mergers & acquisitions. Newer modes of technology transfers are being adopted, generally going away from importing turnkey projects, etc. New policies are catalyzing these efforts though lot more need to be done for effective implementation. India is assessed to be second top destination for foreign direct investment, after China, in the world.

The Indian Institute of Foreign trade (IIFT) has been engaged for the last ten years, in collection , compilation, and analysis of R&D and exports related data of technology based forms, mainly SMEs, to study their export behaviour and its relationships with R&D and technological capacities in India. The present paper briefly describes the findings. The studies are being carried out with the active support of Department of Scientific and Industrial Research (DSIR).

International Technology Indicators

World merchandise exports in dollar terms rose by 15 per cent to US$13.6 trillion in 2007 from US$11.8 trillion in 2006.[1] India's merchandise exports valued at US$163 billion in 2007–08, marked an increase in world exports to 1.6 per cent in 2007–08 from 0.9 per cent in 2005-06. India's manufactured exports grew by 23.02 per cent and had a share of around 70 per cent in its total merchandise exports.

As per the *Global Competitiveness Report 2007-08*,[2] India is placed at 48th in the list of 131 economies covered under the Global Competitiveness Index, while China is at 34. The quality of the business environment in India has improved tangibly in recent years, with increased efficiency of goods, labour and financial markets and greater innovation and sophistication of firm operations. India is separately ranked as one of the top three destinations for foreign investments.

The technology readiness index ranking of India is 62 in 2007–08 as against 73 for China. While product exports have inherent limitation in the form of infrastructure, natural resources, marketing, technology and skills, etc., technology intensive exports have tremendous potential because of industrial and technological capabilities in several sectors and large S&T manpower, among other factors. Innovative and R&D activities are the primary source of generation of technology intensive products, processes and services, and technological competitiveness.

Worldwide R&D expenditure rose from US$377 billion in 1990 to US$810 billion in 2003. The OECD countries represented about 84 per cent of global R&D expenditure, contributing at 2.26 per cent of GDP.[3]

India's higher spending on R&D may reflect its enhanced status in the technology related capabilities, manufacturing capacities, and competitiveness. Country's domestic R&D spending was US$5.9 billion in 2004, contributing a mere 0.85 per cent of GDP, much lesser than most advanced and some of the developing economies. China's share in 2004 was 1.4 per cent and is expected to reach 2.0 per cent by 2010. The average for developed countries is roughly 2.5 per cent. Several new initiatives have been taken or proposed to be taken to promote and strengthen S&T capabilities and outputs in India. These include technology venture capital funds public-private partnerships, centres of excellence and higher studies, improving quality of education and developing human resources in S&T, forging foreign alliances and partnerships, modernising and expanding Indian Patent office, sectoral R&D and testing facilities in areas such as automotives, food processing, textiles, and pharma etc. Innovation and R&D in industry is also being encouraged and special attention is being given to medium and small enterprises. The protection and utilisation of Public Funded Intellectual Property Bill, 2008 has been passed in Parliament.

World Exports of Technology

World's high technology exports increased from US$207 billion in 1988 to US$1,243 billion in 2005, registering an increase of 500.48 per cent. Its percentage share in manufactured exports also increased from 11.11 per cent to 22 per cent during the same period as shown in Table 1.[4]

TABLE 1
WORLD EXPORT OF HIGH TECHNOLOGY EXPORTS, 1988–2005
(US$ million)

Year	*High technology exports*	*High technology exports (% of manufactured exports)*	*Merchandise exports*	*Exports of goods and services*
1988	207,142	11.11	2,762,231	3,551,335
2002	1,149,146	21	6,454,929	7,966,155
2003	1,043,222	18	7,578,698	9,307,830
2004	1,269,586	20	9,145,027	11,335,604
2005	1,243,114	22	10,433,971	12,893,823

Source: World Bank, *World Development Indicators* 2003, 2004, 2005, 2006 and 2007, Washington, D.C. (USA).

In 2005, world export of high technology products by major countries is shown in Table 2, the USA with US$233 billion was the leading country, followed by China (US$214 billion), Japan (US$123 billion), and Germany (US$137 billion). But three countries, namely Philippines, Singapore and Malaysia had much more percentage share in manufactured exports, i.e. 71, 57 and 55 in comparison to these countries in 2005. Singapore's export of high technology products was valued at US$105 billion, Malaysia's at US$57 billion and the Philippines' at US$26 billion.

India's exports of high technology products increased from US$1,680 million in 2001 to US$2,840 million in 2005, registering an increase of 69 per cent. Its average percentage in manufactured exports remained at 5 except in 2001, when it was 6 per cent. Comparatively, China has emerged as an important country for export of high technology products.

TABLE 2
HIGH TECHNOLOGY EXPORTS BY MAJOR COUNTRIES
According to Percentage Share of Manufactured Exports
(2001 to 2005)

(Value: US$ million)
(%: Manufactured exports)

Country	2001 (US$)	(%)	2002 (US$)	(%)	2003 (US$)	(%)	2004 (US$)	(%)	2005 (US$)	(%)
USA	178,906	32	162,345	32	160,212	31	216,016	32	233,079	32
China	49,427	20	68,182	23	107,543	27	161,603	30	214,246	31
Japan	99,389	26	94,730	24	105,454	24	124,045	24	122,680	22
Germany	85,958	18	86,861	17	102,869	16	131,838	17	137,547	17
Singapore	62,572	60	63,792	60	71,421	59	87,742	59	105,078	57
UK	67,416	31	71,481	31	64,511	26	64,295	24	82,841	28
Korea Rep	40,427	29	46,438	32	57,161	32	75,742	33	83,527	32
France	67,191	23	52,582	21	56,336	19	64,871	19	69,673	20
Netherlands	38,960	32	33,667	28	49,546	31	55,211	29	65,758	30
Malaysia	40,939	57	40,912	58	47,042	58	52,868	55	57,376	55
Mexico	29,759	22	28,939	21	28,734	21	31,832	21	32,262	20
Ireland	35,898	48	31,624	41	27,578	34	30,239	34	-	-
Philippines	21,032	70	11,488	65	23,942	74	-	-	26,077	71
Switzerland	14,271	18	1,077	21	20,472	22	24,121	22	25,544	22
Thailand	15,286	31	15,234	31	18,203	30	18,203	30	22,480	27
Finland	9,254	23	9,139	24	10,485	24	10,625	21	13,835	25
Hungary	6,298	23	7,364	25	9,631	26	14,158	29	13,045	25
Israel	7,456	25	5,414	20	5,322	18	6,861	19	4,937	14
Denmark	6,912	21	8,089	22	8,402	20	9,686	20	11,733	22
India	1,680	6	1,788	5	2,292	5	2,840	5	2,840	5
Brazil	6,110	18	6,007	19	4,505	12	5,929	12	8,007	13
Hongkong, China	3,716	20	2,688	17	1,845	13	80,109	32	94,808	34

Source: World Bank, *World Development Indicators* 2003, 2004, 2005, 2006 and 2007, Washington, D.C. (USA).

Although as per percentage share in manufactured exports, it remained fourth in comparison to select Asian economies. The Philippines (71%), Singapore (57%), Malaysia (55%) were the other Asian economies. These data clearly show that India needs to raise its share of high technology exports in manufactured exports from about 5 per cent towards the world level of 20 per cent though some of the Asian countries have a level of more than 50 per cent. However, the definition of technology exports appears to be arbitrary and is debatable in various countries.

Royalty and Licence Fee

Growth of technology exports is reflected in the receipts and payments of royalty and licence fee in the world trade of technology in cases where know-how are licensed. Receipts and payments of licence fee and royalty are the important components, which show the intensity in the development of technology trade world over. According to the *World Development Indicators*, India's receipts of royalty and licence fee decreased to US$25 million in 2005 from US$29 million in 2003 and US$83 million in 2001, even to as low as US$12 million in 2002.

On the contrary, India's payments for the same increased to US$421 million in 2005 from US$306 million in 2001. Among select countries with regard to royalty and licence fee, the USA was leading, followed by Ireland, Japan, UK, Singapore, Canada, Germany, South Korea, China, the Netherlands and France. In case of China, receipts were only US$107 million and payments were at US$3,548 million in 2003 and increased to US$157 million and US$4,398 million in 2005. In case of South Korea, receipts were US$1,325 million and payments were US$3,597 million in 2003 and further increased to US$1,827 million and US$5,321 million in 2005. Data show that higher the ratio between the receipts and payments, higher the technological competitiveness. At the same time, higher the payment means higher the technology based manufacturing activity or higher the efforts to strengthen technological capabilities. In case of India, neither the technology payments are high nor is the ratio of receipts to payments high, while China seems to have leveraged technology import successfully to enhance its technology intensive exports and manufacturing capabilities. This is a matter of concern and needs attention at policy and industry levels in India.

Technology Intensive Exports

There is no standard definition of technology exports or technology intensive exports. Technology intensive exports are considered here as consisting of capital goods, computer software services, turnkey projects and consultancy services, joint ventures and wholly owned services etc. Obviously, technology intensive exports would be more than technology or high technology exports. Since 2002–03, technology intensive exports increased from Rs. 63,156 crore to Rs 105,989 crore in 2004–05, showing an increase of 67.82 per cent. In 2004–05, technology intensive exports increased to 28.76 per cent over the 2003–04. In growth of exports of technology which amounted to Rs 209,083 crore in 2006–07, major sectors were capital goods (Rs 41,963 crore), computer software services (Rs 146,000 crore), turnkey projects (Rs 9,380 crore), construction (Rs 4,360 crore), consultancy services (Rs 270 crore) and engineering services (Rs.1,302 crore). As a percentage, share of technology intensive exports in merchandise exports plus miscellaneous receipt increased from 19.49 in 2002–03 to 20.89 in 2004–05 and further increased to 25.14 per cent in 2006–07.

India's exports have shown a robust growth in recent years and are moving towards a higher growth trajectory with higher technology intensity. Manufactured exports constitute around 70 per cent in India's total exports. Evidently bringing technology intensive manufacturing to the central stage can help in increasing merchandise exports at rates substantially above the world average, to reach a higher share in world exports, and ride the value chain for long-term sustainability.

In 2006–07, textiles and textile products (Rs 72,931 crore), chemicals and petrochemicals (Rs 61,152 crore), machinery and instrument (Rs 29,434 crore), iron and steel (Rs 23,692 crore), manufactures of metals (Rs 22,745 crore), transport equipment (Rs 22,199 crore) plastic & manufactures thereof (Rs 14,441 crore) and medicinal & pharmaceutical products (Rs 14,380 crore), were among the major products contributed in India's exports of select technology intensive sectors. Consultancy services amounted to Rs 270 crore. Exports in the select sectors have increased from Rs 129,537 crore in 2002–03 to Rs 293,161 crore in 2006–07, showing an increase of 126.31 per cent. The contribution of these technology intensive sectors in India's total merchandise exports increased from 50.77 per cent in 2002–03 to 51.27 per cent in 2006–07.

S&T Indicators, FDI and Trade Patterns, in India and China

FDI flows to India increased from US $ 7.61 b in 2005 to US $ 22.95 in 2009 and is at US $ 30 b in 2008, while FDI inflows to China increased from US $ 72.41 to US $ 83.52 during the same period of 2005-07. On the other hand, FDI outflows have increased from US $ 2.98 b in 2005 to US $ 13.65 b in 2007 as against US $ 12.27 to US $22.47 from China. It is not only the quantity of FDI but also the quality and objectives of FDI. The policies in China encourage FDI flows in manufacturing sector (67%), besides technology transfers and high value technology exports, as against 37% in India without such emphasis. About 1200 foreign R&D centres are reported to have been set up by TNCs in China, as against about 200-300 in India. Again, the quality and level of research and its contribution to domestic research capacity building is important. Another important fact is that export from foreign affiliates in China increased from US $ 240 b in 2003 to US $ 444 in 2005 as against US $ 3 b and US $ 4.9 b only in India.

The S&T policies in China are more focused toward technology based manufacturing and exports, and a preferential treatment is given to such enterprises compared to those in traditional low technology sectors. It aims to be an innovative nation in next 15 years and that S&T should contribute atleast 60% to national development. Other notable features are national IPR strategy, converting public R&D institutions to enterprises, and a national coordination mechanism for S&T. In India, Science Policy resolution of 1958, Technology Policy Statement of 1983, and S&T Policy of 2003, and proposed National Innovation Act of 2008 (draft) primarily aim at encouraging public funded research in new technologies, and creating new mechanisms without reviewing the existing ones, and practically no connectivity, with trade. National coordination mechanisms are weak. Table 3 gives S&T indicators for India and China, which reflect the impact of related policies and measures.

Tables 4 and 5 give the trade composition and shift in exports from China and India during 1996 and 2005. It may be seen that export composition primarily remains dominated by low value, low technology and traditional sectors during ten years period in India.

On the other hand, there is a visible shift from low technology sectors to high technology sectors in China. These two trends might indicate the impact of S&T policies and mechanisms, FDI flows, and trade and other policies on exports as discussed in earlier paras. It is debatable that service sector in India is contributing more to economy as a whole than that in China. It is also believed in many quarters that manufacturing sector catalyses the growth of service sector, and creates much more employment. In the long term, it is the technological competitiveness which sustains exports.

R&D and Exports in India — A Field Study

R&D expenditure is a measure of technology related capabilities and competitiveness. According to a field study, the R&D expenditure of 303 surveyed units carried out by IIFT with the support of DSIR in 2006–08, aggregately increased from Rs. 514.79 crore in 2002–03 to

Rs 6,716.43 crore[5]. While exports increased from Rs. 14453.28 crores to Rs. 1664455.30 crores, though there were some variation in the firms covered during the period. Data for only 2005–06 and 2006–07 was available for the same 303 firms. Time series data for only 163 firms could be obtained for the period 2002–03–06–07, which is given in Table 7. These data tend to indicate that the turnover and exports increased as the R&D expenditure also increased though there may be several other factors for increased performance of enterprises. Further, there appear to be a positive relationship between R&D expenditure, exports and turnover. This relationship is, however, not linear and vary sector to sector as indicated in *Figure 1*.

TABLE 3

SCIENCE AND TECHNOLOGY: INDIA AND CHINA

Country	Researcher R&D (Per million people 2000-05)	Scientific and Technical Journals Articles (2005)	Expenditure for R&D (%of GDP, 2000-05)	Patent Applications field		Trade Applications Field	
				Residents 2005	Non-Resident 2005	Residents 2005	Non-Resident 2005
India	400	14,608	0.61	6,795	10,671	-	-
China	708	41,596	1.34	93,172	80,155	593,382	63,902

TABLE 4
CHANGING STRUCTURE OF INDIA'S TRADE: 10 TOP

Product name	1996 Value	1996 share	Product name	2005 value	2005 share
Diamonds non-industrial nex excluding	4028039	9	Petroleum oils, etc. (excl. crude)	11439920	9
Semi-milled or whooly milled rice	891755	2	Diamonds non-industrial nex excluding	11214411	8
Oil-cake and other solid residues	769332	2	Non-agglomerated iron ores and …	3519748	2
Men's or boy/s shirts of cotton	748712	2	Art. Of jewellery and pts therof	3357736	2
Frozen shrimps and prawns	725340	2	Other organic compounds, nes	1690186	1
Combed single cotton yarn, with>=8	557561	1	Other medicaments of mixed or unmixed	1424499	1
Women's or girls's blouses, shirts,	526754	1	Semi-milled or whooly milled rice	1364245	1
Art. of jewellery and pts thereof	517244	1	T-shirts, singlets and other vests,	1107091	1
Petroleum oils, etc. (excl. crude)	482013	1	Flat rolled prod, i/nas, plated or	1059096	1
Non-agglomerated iron ores and..	428364	1	Women's or girls' blouses, shirts,	1018038	1

Source: ICIER Working Paper No. 21, August 2008

TABLE 5
Changing Structure of China's trade: 10 top

Product name	1996 Value	1996 share	Product name	2006 value	2006 share
Petroleum oils and oils obtained from	2,789,285	1.50	Digital auto data process mach entg	43,383,744	3.40
Input or output units, whether or not	1,984,923	1.10	Transmission apparatus, for radiate	35,753,598	2.80
Footwear with rubber…soles, leather	1,901,782	1.10	Parts and accessories of automatic	32,618,566	2.50
Footwear, nes, not covering the	1,831,672	1.00	Input or output units, whether or not	25,676,922	2.00
Toys nes	1,653,536	0.90	Parts suitable for use solely or	23,969,022	1.90
Parts and accessories of automatic	1,626,778	0.90	Monolithic integrated circuits, dig	18,410,882	1.40
Articles of apparel of leather	1,440,980	0.80	Optical devices, appliances and ins	13,231,578	1.00
Trunks, suit-cases…, etc, with	1,397,615	0.80	Television receivers including vide	12,837,204	1.00
Radio broad race combined with soun	1,301,715	0.70	Storage units, whether or not	11,917,080	0.90
Other articles of plastics, nes	1,254,054	0.70	Video recording or reproducing appa	7,699,542	0.60

Source: ICIER Working Paper No. 21, August 2008

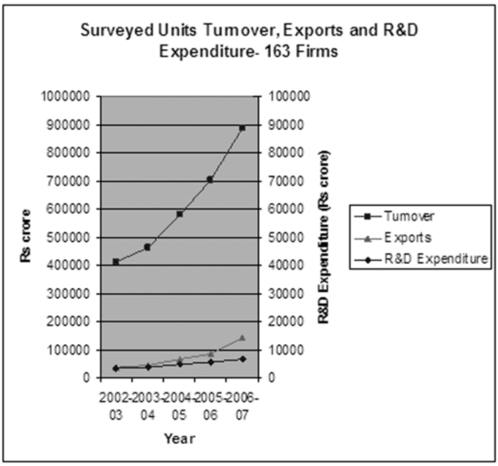
Export Behaviour of Firms

The technology intensity wise classification of 303 companies/ organisations, surveyed and reported in this paper has been done on the basis of *World Investment Report 2002*[6]. As Low Technology, Medium Technology and High Technology companies/organisations included 56 low technology companies, 153 medium technology and 94 high technology enterprises. The technology intensity-wise exports for the years 2002–03 to 2006–07 for 163 firms are given in Table 7.

Exports of low technology products increased from Rs 18,029 crore in 2002–03 to Rs 87,263 crore in 2006–07, showing an increase of 384.01 per cent. Percentagewise an increase of 78.49 was registered over the previous year 2005-06 when exports amounted to Rs 48,891 crore. This low technology product exports increased from 39.38 per cent to 52.42 per cent and dominated in total exports of surveyed companies in 2006–07.

Exports of medium technology increased from Rs 9,474 crore in 2002-03 to Rs 28,672 crore in 2006–07, registering an increase of 202.64 per cent. An increase of 42.92 per cent was registered of its previous year exports of Rs 20,062 crore. It contributed 17.22 per cent to total exports of surveyed companies in 2006–07. Medium technology intensity percentage varied between 17 and 21.

FIGURE 1



However, high technology intensity exports, slided down from 39.92 per cent in 2002–03 to 30.35 per cent in 2006–07 in total exports of surveyed companies, though exports increased from Rs 18,277 crore in 2002–03 to Rs 50,520 crore in 2006–07 in absolute numbers, registering an increase 176.41 per cent. Thus, valuewise export of low technology products increased approximately five times over the period 2002–03 to 2006–07; medium technology products increased more than three times; and so high technology products reached nearly three times during same period. The differences in high technology exports in our studies and those reported by World Bank or UNCTAD may be due to differences in the categorization of high technology exports in conceptual terms. It may be noted that the national high technology exports were only at 5-6% of manufactured exports. Thus, the result, from the sample data are at variance from the national data for the country as a whole since out sample included service exports such as computer software and consulting services also, and hence the two figures are not directly comparable.

Exports of technology and technology intensive products for 303 survey units. amounted to Rs 166,455 crore in 2006–07, compared to Rs 106,057 crore in 2005–06, registering a growth of 56.95 per cent. Technology intensive products emerged as the major sector of exports in 2006–07, having a share of 81.06 per cent in the total exports of technology and technology intensive products. Their exports amounted to Rs 134,936 crore in 2006–07, registering an increase of 62.96 per cent over the previous year.

Sectorwise Exports

Sectorwise analysis of the exports of technology intensive products of responding units for the period, 2002–03 to 2006–07, shows that valuewise export of chemicals and allied products have emerged as the major sector. In 2006–07, their exports registered a growth of 80.12 per cent to Rs 85,960 crore. Other sectors showing a significant growth included, *inter alia*, electrical machinery apparatus and appliances (69.99%), non-electrical machinery, apparatus and appliances including machine tools (63.76%), iron ores and iron & steel (62.93%), plastic materials (48.97%), manufactures of metals (43.59%) and medicinal & pharmaceutical products (38.83%), consultancy services (35.45%) and transport equipment (31.15%). Two sectors, namely machinery and instruments (-18.72%) and professional instruments (-13.93%) had declined. The export and R&D expenditures data for 163 firms for the period 2002-03 are given in Table 6, showing a similar trend as far 303 firms discussed above.

TABLE 6
Surveyed Units Turnover, Exports and R&D Expenditure -163 Firms
(2002–03 to 2006-07) (Rs crore)

Year	R&D Expenditure	Turnover	Exports	R&D as percent-age of Turnover	Exports as percentage of Turnover
2002–03	3147.53	411277.06	34737.27	0.77	8.45
2003–04	3456.69 (9.82)	463294.63 (12.65)	43747.88 (25.94)	0.75	9.44
2004–05	4550.84 (31.65)	576550.03 (24.45)	64009.79 (46.32)	0.67	11.1
2005–06	5470.39 (20.21)	701085.72 (21.60)	84958.10 (32.73)	0.78	12.12
2006–07	6559.79 (19.91)	886942.24 (26.51)	140223.02 (65.05)	0.74	15.81

Note: Figures within brackets indicate percentage change over previous year.
Source: IIFT-DSIR, Compendium on Technology Exports 2007 and 2008, New Delhi

TABLE 7
TECHNOLOGY INTENSITYWISE CLASSIFICATION OF COMPANIES SURVEYED — 163 FIRMS (2002-03 TO 2006-07)

Technology Intensity	***Exports of 163 Companies Surveyed (Rs crore)***					***% change in 2006-07 over 2005–06***
	2002–03	***2003–04***	***2004–05***	***2005–06***	***2006–07***	
Low Technology	16205.78 (46.65)	20009.94 (45.74)	32935.14 (51.45)	42287.00 (49.77)	79780.76 (56.90)	**88.66**
Medium Technology	5281.80 (15.20)	8102.56 (18.52)	11902.15 (18.59)	16686.00 (19.64)	24613.49 (17.55)	**47.51**
High Technology	13249.69 (38.14)	15635.38 (35.74)	19172.50 (29.95)	25985.10 (30.59)	35828.77 (25.55)	**37.88**
TOTAL	**34737.27 (100)**	**43747.88 (100)**	**64009.79 (100)**	**84958.10 (100)**	**140223.02 (100)**	**65.05**

Notes: (i) Figures within brackets indicate percentage shares to the total.
(ii) Technology-wise classification has been made on the basis of World Investment Report 2002.

Source: IIFT-DSIR, Compendium on Technology Exports 2008, New Delhi.

Foreign Collaborations

An analysis of the data of the 163 responding companies/organizations out of the 303 companies engaged in exports and having foreign collaborations reveals that exports of these companies/organizations in 2006–07 registered an increase of 55.18 per cent over the previous year when the same reached a level of Rs. 146,767 crore as against Rs. 94,578 crore in the previous year. This indicates increasing trend in companies' exports having foreign collaborations, though exports are more in low technology products. Seventy seven companies/organizations were engaged in the exports of medium technology products followed by 57 having high technology products and 29 with low technology products. These 29 companies having foreign collaboration increased their low technology exports as contrary to medium technology and high technology exports. Low technology share accounted for 49.36 per cent in total exports of Rs 146,767 crore in 2006–07. In both the years, 2005–06 and 2006–07, exports of medium and high technology experienced a decline.

Exports in 2006–07 amounted to Rs 146,767 crore compared to the exports of Rs 94,578 crore in 2005–06. These studies tend to indicate that foreign collaborations generally do not seem to have any significant impact on the export intensity of organizations though might vary from sector to sector. Foreign collaborations perhaps do not really accelerate medium technology and high technology exports significantly and therefore might not be significantly contributing to the domestic technology capacity building. However, foreign collaborations seem to enhance overall competitiveness and capabilities in the industry. Firms have not reported the nature of foreign collaborations, technical or financial or any other form. Also, these observations are based as a limited data only. There further research is needed before arriving at such conclusions.

Concluding Remarks

We have discussed about the linkages among R&D, FDI and trade (exports) in India and China, based on the policies and performance data over a period of ten years. Both countries have shown a steep growth rates in economy and exports during last 10 to 15 years, and are being considered among top FDI destinations by large transnational corporations, though development trajectories have been somewhat different. The S&T policies in India remain generally uncoordinated at national level, and are more towards public funded research and development of new products and processes in new and emerging technologies, while S&T policies in China are more coordinated with national quantitatives objectives with focus on specific high tech research, and assisting the industry in manufacturing and exporting more high technology products. Various S&T indicators vary widely in two countries, favouring China. FDI in China has been better leveraged towards enhancing national technological capacities and technology based exports, while FDI in India appear to be more in sectors such as services and infrastructure, and only spill over advantages have accrued to the manufacturing sector. FDI in research centres is also much more in China than in India. There is a clear shift in export patterns towards high technology products in China during last ten years while exports from India continue to be dominated by low or medium technology products. Research results from studies for 303 technology based firms at IIFT have indicated a positive relative relationship of R&D expenditure with their exports during 2005–06 and 2006–07, and also data for 165 firms during 2002–03 to 2006–07, though the relationship is non-linear and vary across the sectors. Further, the R&D expenditures and export behaviour of foreign collaboration firms were not significantly different than domestic enterprises though there could be sectoral differences. The exporting firms have increased there R&D expenditures during last few years in absolute amounts but remains same as percentage of sales annually. The surveys have also indicated that there are weak linkages with R&D institutions in the country, the priority being to easier financing, simplification of government rules and implementation mechanisms, support for marketing, and easier access to foreign technologies.

The above studies have also indicated that existing S&T policies and mechanisms need to be reviewed, and more efficient and focused policies need to be evolved for research leadership in select areas and encouraging technology intensive exports from India. Incentives for easier access to foreign technologies inducive for technology intensive manufacturing and exports need to be considered, alongwith coordination with trade policies and mechanisms. FDI policy also needs a review. Human resource is important for competitiveness and growth, and hence industry and academic institutions need to be more sensitized in innovation and technology management related education and skills upgradation.

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Tatiana I. Yusupova

The "Constants" and Factors of Change in the History of Russian-Mongolian Scientific Collaboration

Russian-Mongolian scientific contacts, begun in the middle of 1920s, up till now were one of the most actively developing areas of international collaboration for Russian researchers, first of all in the field of humanities. Their format, content and intensity varied due to the international status of Mongolia, the condition of Russian-Mongolian relations, internal political situation in both countries.

Russian-Mongolian academic connections have a rich history. They developed from the gratuitous aid on the part of Russia (1925–1960s), to the bilateral parity relationship (1960s–1980s), then they went through a period of stagnation (1990s) and proceeded (from 2000) to an active research collaboration on the basis of various agreements and conventions in which both countries took part.

In the report we are going to give a brief outline on the history of establishment of Russian-Mongolian academic contacts through 1920s–1930s, and the activity of the Mongolian Commission of the Russian Academy of Sciences (RAS) in the first place. The work implemented by the Mongolian Commission (1925–1953) is of a great interest for us since it became a foundation for further development of collaboration for two countries. The Mongolian Commission was founded in 1925. It consisted of the most prominent scholars of different specialties, mostly researchers from the institutions of the RAS. At different times outstanding famous Russian scholars such as S.F. Oldenburg (1927–1929), V.L. Komarov (1930–1945), V.A. Obruchev (1946–1953), headed the Mongolian Commission (Yusupova, 2006).

Its establishing was encouraged by three factors. Requests of the Mongolian Scientific Committee to Russian Academy of Sciences to provide help with research works in the country gave rise to it. To tackle this problem the leaders of the Academy who were themselves interested in the research in the area started an extensive discussion of the problem and turned to Soviet Government asking to continue already initiated works[1]. They stressed the necessity to develop previous investigation not only because of scientific, but also economical and political advantages for Mongolia and the Soviet Russia. The arguments provided by academic society turned out to be convincing and the Government ordered to organize a large-scale research of Mongolia. Also political factor played an important part in the decision. N.P. Gorbunov, who supervised this project in the Soviet government, emphasized in his speech that it was necessary to conduct research in Mongolia for cementing our friendly relations with the Mongols and for the penetration of our political influence into Mongolia.

The formation of special Mongolian Commission therefore is a bright example of interaction between the state and the scientists where both sides had an opportunity to benefit: the state achieved its foreign policy goals with the help of the academic society; the academic society obtained funding on one of its research projects.

The foundation of the Mongolian Commission became one part of an adaptation process of academic society to a new socio-political situation, building in a new social networks. This experience proved to be extremely successful, at least, during the next 10 years: the Academy of Sciences received a lavish funding on its research in Mongolia.

It should be noted, for more than 60 years Russian-Mongolian relations were defined as relations between a patron and a satellite. This framework of Russian\Soviet — Mongolian relations was determin*e*d by a complex of historical reasons, such as undefined international status of Mongolia in the first place: the independence of Mongolia, declared in 1921, was officially recognized only by Soviet Russia. Due to this fact Russia provided Mongolia with various aid aimed at establishing the economy of the country, research and development of its natural resources, formation of national state institutions, fortification of defensive capacity. An important

1 Russian scientists began to pay attention to Mongolia already in the XVIII century, that is in the early years if the Russian Academy of Science (RAS) itself, due to academic expeditions. Later this stream in academic activities developed strongly. Asian, Botanic, Zoological, Geological and Mineralogical museums of RAS accumulated impressive collections representing Mongolian nature. These collections stimulated further development of Mongolian studies and deeper specialization of future researchers.

constituent of the Soviet foreign policy was also comprehensive support of the growing research potential of Mongolia.

The tasks that the government set for the Mongolian Commission varied according to the foreign policy goals.

1925 — Academic research of Mongolia that was necessary for «penetration our political influence in Mongolia»;

1926 — "Research of Mongolia is a kind of duty for the Soviet Russia, the closest neighbor of Mongolia that is equipped with necessary means of research";

1930 — "Our [Soviet Russia] duty is to help to develop and rise economic and cultural construction in Mongolia";

1947 — It is necessary "to build a foundation for practical steps of Mongolian Government in the field of improving economic and cultural construction".

It should be noted, the ideological and political motivation of Russian expeditions in Mongolia did not affect methods and academic credibility of research, as it is demonstrated by the reports of the expeditions. The style of the reports, by the way, conforms to established norms of academic literature with its characteristic logic of argumentation.

The period of 1925–1933 became the most prolific one in the activity of the Mongolian Commission. During these years 41 expeditions were organized where more than 30 people participated. As a rule members of the Mongolian Scientific Committee took part in Russian expeditions which was a unique opportunity for them to improve their professional level. The expeditions led archeological, botanical, geological, geochemical, zoological, soil and geographical, ethnographical and linguistic research. Moreover all research results obtained by the expeditions were published in the issues of the Mongolian Commission and handed over to Mongolian Scientific Committee.

The activity of the Mongolian Commission closely followed legal regulations of international interaction and was subject to treaty engagements between the academic societies, but till 1929 they were not official. The first formal treaty between the Academy of Sciences and the Mongolian Scientific Committee was signed in 1929. This agreement was aimed at eliminating all legal misunderstandings if they were to happen in the work of research expeditions in Mongolia.

The preparation of the treaty highlighted various contradictions between the Russian Academy of Sciences and the Mongolian Scientific Committee. For the Russian Academy of Sciences as a rule research work in Mongolia was a basis for further theoretical studies. Mongolian party was more interested in the works of applied character, especially in economic and agricultural fields, which could enable to realize plans of quick sociopolitical reorganization of the country. The reorientation of research programs of the Mongolian Commission towards salvation of economic problems begun from 1930s, as a result of intense state and ideological control of research activity in Soviet Russia. Soil, geological, geochemical, the development of agriculture, and first and the basis of Mongilian's economy, cattle breeding, all this became a priority in the activity of the Mongolian Commission in the next years.

In 1932 a sharp reduction of expedition research happened due to the aggravation of the internal situation both in Mongolia and on the Far East. And so in June 1935 Political Bureau of Bolshevik party made a decision to suspend the expedition activity of the Mongolian Commission.

Since then and up to the Second World War publishing activities became the main focus of the Mongolian Comission. The issues published by it became study guides in nature, history, language, literature, economy of Mongolia.

Further we will give a summary on Russian-Mongolian scientific collaboration in the different next time-periods.

Besides the research work of the Mongolian Commission academic aid consisted of sending specialists to the research institutions of the country, education of Mongolian youth in Russia, assistance in organizing educational institutions and foundation of Mongolian University in the first place (1942).

In 1946 the independence of Mongolia was officially recognized by the international society. Nevertheless the Russian line both in foreign policy and in research activity remained a priority for Mongolia. However, establishing collaboration with China and East-European countries became an important part of the foreign policy that is why the research work of Russian scientists in Mongolia decreased. Strengthening of academic contacts with the new international partners became more vital for Russia.

After signing a new treaty in 1967 between the Academies of Sciences of two countries connections were taken to a new quality level and new forms of collaboration appeared. During this period cardinal motivation changes in collaboration of Russian researchers with Mongolian colleagues happened: from gratuitous aid to parity collaboration. This approach enabled to take the development of the former collaborative forms to the whole new level and to create the new ones. Thus, over 20 years 5 joint research expeditions (geological, biological, paleontological, historical-cultural, geophysical) led a successful work. During this period Mongolian scholars developed international contacts with a wide range of Academies of Sciences of the other, mainly socialistic, countries (Oknianskiy, 1984).

The major social-political changes happened both in Russia and Mongolia at the turn of 1980s bore a negative impact on the academic contacts between them. Nearly all contacts were ceased. Besides, within the framework of critical approach to the common historical past of our countries and value reorientation of academic community there was an attempt to evaluate it negatively. Luckily, this didn't last long and despite the fact that today Russia is not the only international partner of Mongolia, Russian-Mongolian academic cooperation continues its development.

After visit of Russian president, Vladimir Putin, to Mongolia in 2000, which was connected with a new stage of in Russian-Mongolian relations, the change of communicative strategy within the contacts of Russian and Mongolian scientists begun. Nowadays Mongolia is becoming one of the major international partners of Russia in Central Asia for this reason the state actively encourages the development of academic connections (Istoriya Mongolii. XX vek, 2007:290–291, 313–395).

The new forms of collaboration could be divided in several groups:

- The treaty between Russian Academy of Sciences and Mongolian Academy of Sciences of exchange of research workers for training;
- Commission of Russian Academy of Sciences and Mongolian Academy of Sciences in the Field of Humanities;
- Intergovernmental Russian-Mongolian Commission of Collaboration in the Field of Archives;
- Joint grant program of Mongolian Ministry of Education, Culture and Science and Russian Humanities Foundation;

- Joint grant program of Mongolian Ministry of Education, Culture and Science and Russian Foundation for Basic Research, etc.

A new era in the development of Russian-Mongolian research collaboration can be described not only by growing number of collaboration projects, expeditions, conferences, publications but also by growing number of regions, neighboring both countries, included in it.

The geographic neighboring and deep historical connections between Mongolia and Russia define a mutual interest and motivate for collaboration in different areas including close research interaction. As the historical experience shows Russian-Mongolian research collaboration always remained a substantial component of international activities for both countries. However, its intensity depended on the state of Russian-Mongolian relationship.

The analysis of a rich history of scientific collaboration gives us a chance to realize past changes and make an impression of our opportunities and tasks both managerial and creative.

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Andrey V. Yurevich

Globalization Processes in Contemporaray Science and Scholarship in Russia

Presently the world is undergoing intensive globalization, which affects not only 'the totality of social life', to use Max Weber's words, but also its particular subsystems — politics, economics, science and scholarship, education, culture, etc. For the world science, or more precisely, for Western science the globalization process is merely an extension of tendencies that emerged long ago, while for Russian science and scholarship globalization brings a number of new phenomena.

Our basic understanding of globalization in general can be projected onto globalization process in contemporary Russian science and scholarship. Globalization means a growing international involvement of Russian science, its increasing dependency on world science, enhancement of contacts and gradual erosion of interstate borders, progressive integration of Russia into international academic community, etc.

When globalization of Russian science and research is considered, usually it is ***emigration of Russian scholars abroad*** that dominates the discussion. Indeed, since the fall of the 'Iron Curtain' the emigration of scholars has achieved massive proportions. The resettlement of scholars leaving Russia for good and taking a permanent residence in other countries (mainly the US and Germany) has been commonly associated with the so-called 'brain-drain'. In the last few decades this process has been perceived in Russia either as a national tragedy and a threat to national security, or as a potential source of fabulous profit, while its scope has been persistently overestimated. It has been suggested, for example, that about 70–90 thousands scholars have been leaving the country for good annually (if it were the case, today the size of our academic community would be expressed as a negative number). Others claim that Russian academic diaspora is about 300 thousands people strong, that our specialists in nuclear physics have put down roots in Iraq and Iran, etc.

More balanced estimations of the size of Russian academic diaspora suggest that about 30 thousands Russian scholars have left the country for good and got settled abroad. The figure is certainly quite substantial. If we consider only those scholars who have reached leading positions abroad, for example, a permanent position at an American university, their figure would not exceed 300 persons. These estimations are confirmed by the data collected by the Russian Ministry of Interior: in the period between 1992 and 2001 about 43 000 citizens of the Russian Federation who had been employed in science, research and education applied for and obtained a permission to take permanent residence abroad. However, when estimating the overall loss of Russian science and research, we need to take into account those scholars who have left the country in order to take up a fellowship or a temporary position abroad but who have not returned to Russia. According to the OCED data, in 2003/2004 Russian citizens constituted only about 2 per cent (2403 persons) of all foreign researchers working in the US. However their number is rapidly increasing: in 1995–2004 it was growing at 6.6 per cent annually. Russian citizens form the second largest group of European scholars working in the US and the seventh largest group of all foreign scholars working in the US.

Another important dimension of globalization of science and research is an opposite process when ***foreign scholars are immigrating to Russia.***[1] There is no need to remind readers that academic community in Russia was established precisely in this way in the 18th century under Peter I. In the Soviet period, naturally, there were very few foreign scholars visiting the USSR with guest lectures or for some other academic purpose. The only exception were scholars coming over from other socialist countries. However, as science and research in these countries were modelled upon the Soviet Union, this particular type of international contacts had

[1] In the West foreigners constitute a substantial share of scholars employed by business and by academic institutions alike. In 1995, 10 per cent of scholars working for 100 top European research centres were foreigners. In smaller countries, like the Netherlands or Switzerland, they constituted about 30 per cent.

very limited impact on our science and scholarship in terms of their globalization.

In the last few years foreign scholars have been increasingly coming over to Russia, and not only Russian expatriates but also researchers with no previous connection to Russia. Moreover, if previously they usually visited only Moscow and St. Petersburg (Leningrad), nowadays they travel to many regional centres where universities have sufficient means to pay decent fees for their lectures.

We have to admit: the 'brain-drain' from Russia has not yet been counterbalanced by the opposite form of migration — by the immigration of foreign scholars. Such cases are still quite rare. However, Russian expatriates have begun returning to their home country, thus contributing to globalization of contemporary Russian science and research.

Another aspect of globalization process in Russian science has been also linked to the fall of the 'Iron Curtain', however unlike the first one it concerns not the physical mobility of scholars but the phenomenon of ***'outsourcing'***. Recently many Russian research institutes and centres are working for their foreign partners who are particularly interested in developing contacts with Russian military-industrial complex. Many foreign corporations and companies, such as 'Ford Motor Company', 'General Electric', 'United Technologies Corporation', 'Goodrich Corporation', 'AT&Bell Laboratories', 'Sun Diamond Technologies', 'Sun Microsystems', and others, have signed contracts with research institutes in Russia. As a result, about 10 000 researchers who live and work in Russia are actually working for American institutions, while another 20 000 work for institutions of the European Union. The reason is quite obvious. It has been most unequivocally expressed by the head of 'Plankton' enterprise: 'In Russia you can hire a specialist in chemistry and biology for 1/10 of a salary that you have to pay in America'. Many foreign companies have been quick to realise: they can save millions of dollars and years of research just by buying brains in Russia — the country that has become a real 'supermarket' of science and technology.

Some evidence for this process is furnished by a rising share of foreign enterprises holding patents on inventions made in Russia. Among all patent applications considered by the European Patent Office in 2000, which were concerned with inventions made in

Russia, 63.3 per cent were submitted by foreign applicants. Russia occupies one of the top positions in the list of countries with the largest share of applications submitted to the European Patent Office by foreign applicants concerning inventions made their territory: respective figures are higher only in four other Eastern European countries and Luxemburg.

Recent development of the internet has led some experts to talk about ‘electronic brain-drain’ or ‘ideas-drain’: ‘goods’ (i.e. ideas) from the Russian ‘supermarket’ of science and technology have been delivered to their customers abroad by the internet. Many experts consider this problem no less serious than physical emigration of scholars. Regardless of our attitude to this phenomenon, it should be recognised as one of the forms in which Russian science and research enter the global academic community. Moreover, this is a two-way process: Russian academic community is familiarizing itself with the priorities of world science, while at the same time it is attracting funding for its most promising research projects and disciplines.

The third aspect of globalization of Russian science is most akin to those forms of globalization that are characteristic for developed countries: it concerns ***the growing internationalization of the production of new knowledge***, i.e. an increasing number of research projects and inventions published or patented abroad, a growing share of publications produced by international teams of authors, a growing share of patents issued to international teams of inventors, increasing participation of scholars in international projects[2].

The process has manifested itself in *a growing number of publications abroad*. As our survey conducted in 2003 indicates, 76 per cent of Russian scholars have publications abroad, 17 per cent publish abroad quite often. While scholars who specialise in humanities and social sciences typically have a better command of foreign languages, they are less likely to publish abroad (59 per cent), as compared to their peers in natural sciences (85 per cent) who are in high demand in other countries. *Similar trends apply to patents*. The number of patents issued by the United States Patent

[2] It is quite symptomatic that in Europe public opinion considers the impact of globalization upon scientific and technological progress as the most positive aspect of globalization. 83 per cent of respondents in the countries of the European Union consider the impact upon scientific and technological progress as a positive aspect of globalization (Eurobarometer survey 2003).

and Trademark Office for inventions developed by Russian citizens increased in recent years: from 3 patents issued in 1993 to 173 issued in 2004 (more than 200-fold increase per one researcher), the number of patents issued by the European Patent Office rose from 8 in 1996 to 50 in 2004 (15-fold increase per one researcher).

An even more important indicator of a growing integration of Russian scholars into the international academic community is *a substantial number of articles they publish in co-authorship with their foreign colleagues*. While Russia has rather modest figures for publications produced by international teams of authors in comparison with most other European countries, nevertheless the country is ahead of many other nations if we consider the rates of increase. The share of articles published by Russian scholars in co-authorship with their foreign partners in journals listed by the Institute of Scientific Information (ISI) increased in 1994-2004 from 28.8 per cent to 40.5 per cent.

There is also *a substantial increase in the number of patents for inventions made by several authors from different countries*, and Russia in particular has been affected by this process. The share of patents issued by the European Patent Office for inventions developed by Russian citizens in co-authorship with their foreign partners increased from 23 per cent (of all patents issued to Russian citizens) in 1990–1992 to 42 per cent in 2000–2002. Russia is one of the leading countries when this indicator is considered, the country surpasses even smaller European nations that have achieved the highest level of international cooperation in the field of inventions — Belgium, Ireland and Hungary (over 30 per cent), coming second only to Luxemburg (53 per cent). This trend corresponds to a very active use of the internet by Russian researchers that enables them to facilitate their work on joint projects.

Increasing numbers of publications and patents abroad, a growing share of articles and patents produced in co-authorship with foreign partners reflect a rapid geographic expansion and intensification of international academic communication and cooperation — the processes in which an important role has been played by the development of information-communication technologies. While the scope of international cooperation usually depends on the distance separating the participants, the last two decades have been marked by increasing geographical diversity and a growing spatial distance between research institutions that take part in joint projects. The data collected by the US National Science Foundation provide evidence for *expanding geography of international cooperation*. Thus, in 1996 those Russian scholars whose joint publications were listed in the ISI database had co-authors in 82 countries, while in 2003 they had co-authors in 94 countries.

A growing number of Russian scholars participate in international projects. Our survey conducted in 2003 indicates that 39 per cent of Russian scholars take part in international projects. Specialists in natural sciences are more active in this respect (42 per cent) than specialists in humanities and social sciences (31 per cent). These figures are quite high, matching the level reached by the countries of Western Europe where, according to the 2003 survey, 36 per cent of scholars took part in joint projects with foreign partners (the figures vary across disciplines, ranging from 18 per cent in psychology to 83 per cent in astronomy/astrophysics).

Perhaps the most obvious dimension of globalization of Russian science and research is ***increasing use of the internet in the fields of science, technology and experimental design***. It has even led to the emergence of a new term — ‘e-science’. Russia’s entry to the internet was belated but when it took place it was very fast. Russian internet is quickly catching up, developing at a much faster pace than in the countries of Northern Europe where the share of internet users has exceeded 70 or even 80 per cent of the whole population. In the last three years the number of internet users in the Russian Federation has increased three-fold, reaching 17.6 million (or 21 per cent of adult population) in winter 2005–2006 (data provided by ‘Public Opinion’ Foundation).

The data provided by the Russian Federal State Statistics Service (Rosstat) indicate that over 80 per cent of Russian academic institutions are using internet and email, which is a much higher figure than the figure for the country as a whole. Almost 40 per cent of academic institutions have their own web-sites. The largest Russian academic network for science and higher education RBNet/RUNNet[3] is transmitting data ever faster, it is integrated into the

[3] RBNet/RUNNet (R2Net) unites the Russian Backbone Network, or RBNet (http://www.rbnet.ru) and the Russian Universities Network (http://www.runnet.ru).

global internet system through the system of international channels, at the moment their overall capacity is 2.5 Gbit/second.

In Russia, as well as in other countries, scholars are among the most active groups in terms of information exchange (however they do lag behind their Western colleagues, among whom 99.7 per cent use email and 98.9 use the internet). Obviously, globalization of Russian science and scholarship depends on their 'internetization' and it will be increasing as wider strata of Russian researchers are familiarizing themselves with the global web.

Less obvious and more complicated problem is ***globalization of the content*** of contemporary Russian science and research. We should bear in mind that in Russia science and scholarship have always had their national attributes, regardless of all declarations about international character of science. These attributes have been manifest in their particular social organization, in distinctive systems of knowledge developed by Russian scholars. They can be most vividly exemplified by the development of peculiar fields of 'knowledge', such as Marxist-Leninist philosophy, or 'scientific communism', which were not considered as science in the West. The opposite was also true: genetics, cybernetics, sociology were not recognised in Russia/ the Soviet Union at certain moments, while in the West these disciplines have been considered as sound disciplines. Moreover, the Soviet Union cultivated so-called 'Marxist sociology', 'Marxist psychology' and other 'disciplines' that aggressively positioned themselves against ideologically uncommitted fields bearing the same names.

More subtle manifestations of the cognitive specificity of Russian science and scholarship could also be observed. For example, national attributes of Russian philosophy were evident even in those periods when ideological and political pressures were absent, reflecting certain features of Russian mentality. It is generally recognised that philosophical systems developed by Vladimir Solovyov, Nikolai Berdyaev, Ivan Ilin could have emerged only in Russia. The same applies to a number of concepts developed by Russian specialists in social sciences, humanities (for example, Lev Vygotsky in psychology), and to a certain extent even in natural sciences. Russian/Soviet educational system, which in many ways has shaped the specificity of the content of Russian science, has also had its own distinctive features that have manifested themselves in privileging certain disciplines and methods of instruction.

Recently the content of Russian science and scholarship is increasingly converging with science and scholarship in the West. Convergence is most evident in those fields where previously the divisions were most obvious, i.e. in social sciences and humanities. Education provided to Russian specialists in humanities is getting more and more similar to the Western one, and it happens not only because some of these specialists have been educated abroad. Other factors accounting for this process are: the fall of the 'Iron Curtain', the rejection of such academic 'disciplines' as historical materialism, dialectical materialism, the history of the Communist Party of the Soviet Union, scientific communism that provided for 'distinctly original' character of the Soviet educational system; its general ideological disengagement; a substantial number of faculty members who have been widely travelling to foreign countries. At the same time we observe increasing similarity in ethical standards[4], theoretical framework and methods of research, while Russian students often display a better command of foreign theories than of those developed in their own country. Naturally, it does not mean that Russian science and scholarship have totally lost their originality in terms of their content. Probably, Russian scholarship, especially in humanities and social sciences, will always retain its originality. However in the context of globalization national distinctions are gradually diminishing, while academic research acquires international forms that correspond to the logic of scientific inquiry. Moreover, there are reasons to claim that Russian social sciences and humanities are gradually becoming an intermediary for translating Western knowledge to our social practice.

Internationalization of the content of Russian science and scholarship is closely linked to another dimension of their globalization — to ***increasing similarity in the ways, in which Russian academic community and international academic community view the history of science.***

[4] Russian / Soviet scholars have never questioned such norms of scientific inquiry as objectivity, disinterestedness, organised scepticism, etc, that Robert Merton defined as the basic principles of the ethics of scientific inquiry. However the Soviet science declared its allegiance to the 'the principles of the Communist Party', which only the most skilful demagogues could reconcile with objectivity and disinterestedness.

The specificity of the Soviet view on the history of science was conditioned by the dominant ideology, by the tendency to perceive history through the lens of Marxist ideas on 'basis and superstructure', by the myth about 'combining the advantages of socialism with the achievements of scientific and technological progress', etc. Today the situation is changing, however our understanding of the history of science — in Russia, as well as in the world — retains its peculiarities that can be observed, for example, in the remaining tendency to view prominent scientists of the past through the prism of adoration — a well-known psychological phenomenon. In the works written by our historians major figures of Russian science are portrayed as if they had no human weakness and shortcomings, while foreign historians do not shy away from writing about Isaac Newton as a very quarrelsome man or about Albert Einstein mistreating his wife — an approach that enables them to reconstruct the true history of science. In Russia the tendency to present an official history of science in its most ostentatious forms can still be discerned, however we can also observe an opposite trend — recent fascination with exposure.

A very important and interesting aspect of globalization of contemporary Russian science is ***changing socio-psychological (and even physical) outlook of a Russian scholar***, who is acquiring general international characteristics common to our foreign colleagues and who is gradually reaching international standards.

As some polls and surveys indicate, contemporary Russian public opinion has formed a humiliating image of a Russian scholar (an image that has certain foundations in reality) who is perceived as a 'pauper begging alms' — an impoverished intellectual in a shabby dress. This image has been actively promoted by mass-media, driven by their sympathy to the plight of Russian science and research. In this way mass-media apparently hope to arouse compassion among our citizens, however in practice they do a bad service to Russian science, as contemporary Russian society is extremely pragmatic. As the content analysis of Russian publications on science and scholarship reveals, there is a paradoxical discrepancy between 'strong' image of science and 'weak' image of scholars. Science and research are described in the categories of state power and prestige; they are seen as the foundations of efficient economy and prerequisites for technological and societal progress, while Russian scholars are portrayed as poor, destitute, running away abroad in search for a better life. While the discrepancy between these two stereotypes is strategically inadequate, we have to admit that it is grounded in real life, or more precisely, in absurd environment in which Russian researchers have to work and live.

At the same time it should be stressed that Russian academic community has been often diagnosed by 'calculating a mean temperature for a hospital', while it is very far from being homogenous. Like Russian society as a whole, Russian academic community is undergoing rapid divergence. As a result, apart from impoverished intellectuals, we observe the rise of a new stratum, which can be called 'new Russian scholars'. These people have quite decent incomes (no less than 2 000 USD per month); as a rule they have several jobs, a very good command of foreign languages, they regularly travel abroad where they do not differ from their colleagues betrayed by their outlook or poor command of foreign languages. This is an international type of a scholar, a 'citizen of the world' who feels him/herself comfortable in any country and can be distinguished among local intellectuals only by his/her surname.

This stratum of our academic community is still quite slim. However it is growing very fast, it has much greater vitality than other strata and the future undoubtedly belongs to these people. Moreover, as the polls indicate, these people, unlike some other categories of Russian scholars, have no intention of leaving the country for good. It is likely that it is this stratum, which is the main harbinger of globalization in contemporary Russian science and humanities, as these scholars conform to international standards and transfer international trends to Russia.

Therefore we can identify one more dimension of the globalization of contemporary Russian science and scholarship — ***social and psychological globalization***.

Social globalization consists of gradual withering of characteristically Soviet forms in the institutional infrastructure of science and research and the dissemination of Western forms. As in the West, science and research in Russia are establishing links with education — a natural process, if considered against the background of a general westernization of life in the country.

Much less obvious is psychological globalization, since it was scholars' distinctive psychology that defined the originality of Russian science and scholarship. It presupposed very special relationships among Russian scholars, who had never been particularly interested in competing for priority — a trait dominating the history of science in the West since a protracted dispute between Isaac Newton and Gottfried Wilhelm Leibniz. Russian scholars had a very distinctive motivation for their research, a kind of 'collectivist messianism' — as the opposite of 'individualist messianism' typical for Western science; they had a distinctive value system that led to the 'cult of service to society'.

It would be an overstatement to suggest that all these values have entirely disappeared in the pragmatic environment of contemporary Russia. Still Russian courts have been hearing cases where intellectual property rights are disputed, while for many scholars emigration to the West and a good academic position in a Western university have become major career objectives. The cult of service to society has given way to individualistic motives: to earn money, to receive recognition, to get a good job.

Pragmatic considerations are manifest in another aspect of globalization of Russian science — in ***changing relations between science and society***. Previously these relations looked very romantic, academic community shared the 'cult of service to society', while society believed in 'romantic scientism'. Today these relations have become extremely pragmatic. The old ideology has been replaced by a new one, grounded in the belief that society needs science and scholarship first and foremost in order to solve practical problems: to build 'knowledge economy', to develop high-tech industry, to increase GDP. Therefore, priorities have shifted towards applied research serving practical objectives, while 'the pursuit of knowledge out of curiosity' and in order to achieve other non-pragmatic goals has been pushed to the background, which makes fundamental research very vulnerable.

Finally, another aspect of globalization of contemporary Russian science is highly specific to the country and can be defined as ***internal globalization***.

Traditionally science and scholarship in Russia were located in the two capitals of the country, Moscow and St. Petersburg. Their lion's share is still concentrated in these cities. Naturally, any national science has the centre and periphery, but it would be difficult to find another country where the disparity in the development of science at the 'centre' and at the 'periphery' would be so manifest, as they are in Russia.

Gradually resources have been distributed more evenly between the centre and the periphery; still it has not yet led to more even spread of Russian science and research across the country. However centripetal tendencies, so typical for previous periods, are no more observed, and the most mobile researchers leave their native regions not for Moscow but for living and working abroad. Regional research in Russia has developed direct contacts with the world science; it has been directly integrated in it. Partly it is a result of the policy adopted by foreign scientific and research foundations that have given priority support to regional research centres in Russia.[5] Another factor is the emergence of 'oil universities' where faculty's salaries are much higher than in most higher schools in Moscow. Some other new factors might be in play as well.

As a result we observe a tendency towards gradual levelling of science and research in the capitals and in the regions; regional research centres are increasingly losing their 'provincial' stigma. While quantitative disproportions are still substantial, an average professor in Saratov or Kemerovo does not differ that much from his or her colleague in Moscow. Therefore we can claim that the gap between the centre and periphery is decreasing: Russian science has been undergoing a process of internal globalization.

Counter-globalizing tendencies are also present in contemporary Russian science and scholarship. Some of them are born out of persistent traditional features of Russian science; others are produced by new phenomena. Among these phenomena are the cases when a footwear factory has been opened on the premises of the research institute for aircraft design or a building society has been established on the basis of the Institute for microelectronics technology, when research institutes are forced to let out their premises in order to generate funding — something that has no analogues anywhere in the world.

At the same time globalizing tendencies are certainly dominant. It can be legitimately claimed that contemporary Russian science and scholarship are undergoing intensive process of globalization.

[5] For example, Higher Education Support Program for Regional Universities and Higher Schools administered by Soros Foundation, or Program for Developing Interregional Institutes of Social Sciences administered by the Carnegie Foundation.

Nanyan Cao

Characteristics, Problems and Policy Responses in Chinese S&T Research after Reform and Opening

Abstract:

After thirty years of Reform and Opening, China's S&T system has changed radically. The aim of this presentation is to examine the characteristics and problems that the changed S&T system has brought, and to discuss S&T research policies responding to these problems.

Reform of Chinese S&T system found effective solutions to critical problems which had blocked the development of Chinese S&T for a long time. Those problems include lack of understanding of and academic exchanging with international S&T communities, disjunction between scientific research and economic development, egalitarianism and lack of inspiring mechanism for researchers. Due to Reform of S&T system and redressal of S&T policy, Chinese S&T have developed rapidly, and there is no doubt that S&T research has made great contribution to Chinese economic and social development.

Some characteristics of S&T research are changed completely, such as attaching importance to application research and cooperative research with industry, intense competition between researchers and institutes, innovation and prolificacy in virtue of various academic intercommunion, etc.

New problems are brought up along with Reform of S&T system. Researchers are over-anxious to get quick results and instant benefits, and treat science only as instrument rather than scientific values and culture. Dissension of intellectual property, plagiarism and other misconduct in research increase radically. Conflicts of interest in S&T research tamper with objectivity, veracity and justness which scientific research should possess.

All those problems obstruct healthy development of Chinese S&T and damage Chinese public trust in S&T. Therefore, it is necessary to formulate corresponding S&T policies to cope with the current situation, such as deepening reform of S&T system further, stipulating for detailed regulations and rules, setting up corresponding systems and institutes of supervision and restriction, establishing and improving the system of academic management and assessment.

Under the pattern of planned economy before R&O, the development of Chinese S&T and its impact on the society were confined by Chinese S & T policy in many aspects:

1. Theory was separated from practice to a large extent, and scientific research was disjointed from economic constructing. Research institutes and enterprises had no connections with each other, and research achievements were transferred gratis. Therefore, research institutes and researchers had weak understanding of intellectual property rights, and did not, and need not pay attention to the applications and impacts on the society of their research achievements.

2. Equalitarianism. Research institutes lacked competitive mechanism under planned economic system. Research funds of institutes and researchers relied on government financial allocations, which were rarely made according to the actual contributions of researchers, and the promotions of scholars gave priority only to seniority.

3. Close the country to international intercourse. Researchers lacked international academic intercommunion and cooperation, as well as intercommunions and cooperation between disciplines and institutes. These limited researchers' vision and led them to repeat their research at low-level and tail after other countries blindly.

Reform and Open policy, carried from the end of 1970s, changed Chinese society radically. Under the aim of realizing "Four Modernizations", and founding a socialist, modernized, and powerful country with high civilization and democracy, economic construction has been attached unprecedented importance. Chinese Reformation is a course to break up self-blockade, and move towards international. The essence of the Reformation is to establish market economy and democracy polity, and organize social, political, economic, and cultural activities according to rational manner.

In order to improve efficiency and make S&T to serve economy and society better, Chinese S&T system underwent grand innovation. To walk out the tower of ivory, S&T directly looked on economy and other practical applications. To smash "iron rice bowl", the S&T system introduced into competition mechanism. To break away from confine of terrain and institution, researchers could move between different areas or institutes, as well as go abroad to academic communion and cooperate. For a long time under planned economy many researchers conducted depended on officer's will and were accustomed to equalitarian and "eating in the canteen the same as everyone else", and never care how many research achievements they would gain, yet whether their achievements would be applied. However, reformation impacted on the researchers enormously, inspired their research positivity, nevertheless, also brought a series of new problems.

Open and Reform policy impelled S&T to develop rapidly. In order to realize "Four Modernization" earlier and salute the era of knowledge based economy and globalization, China placed skyscraping expectation on S&T. Especially, after China joined WTO in 2001, the function of national economy, trade and enterprises went along WTO framework. As a developing country, to find a foothold and win in international competition, China must use its own predominance, upgrade industry configuration, and step up its productivity level to a new height. Therefore, the whole nation would like to depend on and long for S&T, and investment of S&T increased rapidly. S&T became a positive magical term, and researchers and intellectuals, who were "Notorious Ninth" during the Culture Revolution, became the delegate of the First Productivity and advanced productivity and advanced culture.

In resent years, along with the increase of S&T funds, China becomes a great power of S&T manpower resource. In 1996, GERD/GDP is 0.60%; in 2002, GERD/GDP is 1.23%; and in 2006, GERD/GDP is 1.41%. In 2006, Chinese R&D personnel reached 1.42 millions, which became number two in the world; the total amount of S&T payout is ¥450 billions.[1 2]

"S&T is the First Productivity" and the strategy of "invigorating the country through Science and Education" spurred Chinese S&T to change the limitation of scientific theory separating from practice, and research achievements couldn't be translated into productivity. After reformation, except one third of research institutes funded by government, other institutes need self-financing and initiative search for projects, funds and channels for application to different

[1] Zou Shengwen, A "detailed list" of Chinese S&T strength, Xinhua News, 2007.10.07. http://www.xinhuanet.com, 2007.10.07.

[2] http://www.sts.org.cn/nwdt/gndt/document/070319.htm2007.07

extent. Researchers' efforts are connected with their financial benefits. Application research and cooperation research with industry become popular. Thereupon, S&T innovation contribute to economic development directly, and became the key of national competition and the means that make researchers, enterprisers, and even common people, be rich. However, it also leads to the utilitarization of science more as tool.

S&T system reformation introduced into competition mechanism and smashed equalitarianism "iron rice bowel" in former days. As a result, research institutes and researchers feel stressful for survival. Individual fame and gain no longer gave priority merely to seniority, but to projects, grants, publications and patents. Researchers and institutes compete intensely, and the motivation for R&D boost greatly.

Researchers' moving among institutes, areas and countries became an encouraged and normal behavior. Researchers no long leech on to some unit for life, and have huge room for independent developing. Personnel moving broaden researchers' eyespots, advance disciples to intercross and develop, facilitate academic to cooperate and intercourse.

The reformation of Chinese S&T system and augment of S&T funds make S&T strength and its social influence enhance rapidly. In 2006, the number of Chinese invention patents reached the 4^{th} in the world. Chinese publications account for 7% of the three international searches systems (SCI, EI, ISTP) and reached the 4^{th} in the world. At present, Chinese researchers have set up cooperative relations with 152 countries and areas.[3]

However, problems and crisis came along with the success brought by reformation. When the old S&T system was broken, the suitable system, norms and regulations had not been constituted in time. While S&T were playing more and more vital roles in the development of economy and society, scientific idea, scientific spirit and the cultural function of science were neglected, which led to extreme utilitarianism and instrumentalism. While efficiency and competitive mechanisms were emphasized, few relevant bylaw and supervising system were established, which makes inordinate and nonstandard competition. While opening and introducing into

3 http://www.sts.org.cn/nwdt/gndt/document/070319.htm2007.07

advanced S&T from other countries, reinforcing education and carrying forward excellent tradition in the culture were ignored, with the result of the prevailing of money worship, egomania overrun and demoralizing. To sum up, since the social transformation is a long-term course, problems brought by incomplete new system frequently interweave with the limitations of old system.

The major issues in S&T research activities are as follows:

Due to the systems being restructured halfway, new systems and old systems co-exist, which result in huge room for corruption. For example, a technical expert, , who works as a dean of a research institute and dominate the distribution of resources, could also be a board chairman of a company on market and control the force of nature in the capital market. Those people are able to achieve success in one way or another and gain advantage from both sides of two kinds of system, and translate administration power and economic benefits from one to the other.

Official standard and excessive administrative intervention tamper with research direction, outlay distribution, and reward and punishment system, so that many people intend to gain academic resources by improper means, such as, "trying to establish a relationship with somebody" and "through the back door". As a result, research resource was allotted unfairly and academy lacks freedom and independence.

Chinese scientific research funded by public must be managed and supervised be government. Currently a great deal of research outlay is misappropriated due to the lack of strict management system.

The awareness of intellectual property right is weak among researchers, and the Chinese S&T world is still unable to protect intellectual property right effectively, so there are so many rampant piracy and disputes related to intellectual property right.

Research misconducts occur from time to time, e.g. researchers fake or tamper data and information in order to get their desired results, provide false information about publications, expert appraisals, academic experiences etc. when applying for funds, jobs, promotions or degrees. [4] The notorious cases are Chen Jin's falsification. [5]

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[4] Li Jian, *Chinese youth daily*, 2006.03.31,06:02 http://www.sina.com.cn

[5] http://baike.baidu.com/view/1682963.htm

Scientific research is linked to financial benefits directly, evaluation systems simply measure the quantity instead of quality of research, and researchers care more about quick success and instant benefits. As a result, the publications are fickle and grandiloquent with lots of academic garbage on low-level repetition.

Conflicts of interest are getting serious, especially in various peer reviews, such as proposals assessment, research achievement evaluation. Conclusions are lack of objectivity and justness due to the interference with the interests.

Some researchers are short of social responsibility and desgin products that damage public safety and healthy to gain profits for individuals or company. Moreover, the regulatory agencies couldn't supervise and punish them in time, e.g. the cases of Melamine and Clenbuterol.[6]

Short of team spirit. After encouraging competition, giving priority to efficiency and legitimizing pursuing individual interest, collectivism and dedication began to decline gradually. The disputes of interests increase rapidly among research institutes and enterprises, researcher teams, and mentors and students.

In order to protect self interests, some institutes fraud on behalf of collective. When research misconduct occurs, out of the idea of "don't wash your dirty linen in public", some managers are reluctant to investigate and deal with misconducts taken place in their own units.

All those issues damaged the healthy development of Chinese S&T, and demolished public trust in S&T. In fact, at the beginning of Reform and Open, there were scientists concerning such problems and discussing on the media. For instance, an academician of Chinese Academy of Science, Zou Chenglu, had published articles to criticize boast and fraud in research.[7] However, he declared that research misconduct became worse now than 20 years ago, rather than better. [8]

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[6] See the details in http://www.zaobao.com/special/china/milk/milk.shtml and http://www.gd.xinhuanet.com/zt09/shourj/.

[7] Shi Xisheng, Zou Chenglu and two cases of academic corruption 30 years ago, Nan Fang Zhou Mo, 2008.11.13, D 29th printing plate, http://hi.baidu.com/%BA%A3%D3%E7%BA%B2%C4%AB/blog/item/a409d91704e0771e962b435f.html

[8] Zou Chenglu, Must deal with academic corruption cases seriously, *Democracy and Science*, 2006. vol.5.

Notwithstanding so many people concern and fight against research misconduct, why does the situation become worse and worse? During the course of Reform and Open, old-time behavioral norms and moral values were discarded, whereas it still takes a long time to establish new behavior norms and moral values. There should raise a lot of chaos and conflicts in the meanwhile.

Some of research misconduct is caused by professional moral defects of researchers, but research misconduct is not only an issue of professional ethics, neither can be settled merely by education and self-discipline, which are very important though. The whole society endeavor from different aspects is needed, including deepening reform in politics, economy, law, and education etc. especially S&T policies and regulations.

First, it is necessary to further deepen the reform of S&T system. Recently, Chinese government put forward "the scientific concept of development", which emphasizes on "people-oriented", "social harmony", and "sustainable development". Those are the foundation and starting point for making S&T policies. There are a lot of detailed concepts in "Medium and Long-term National Science and Technology Development Planning" promulgated in 2006.

Second, it is necessary to advance reformation of S&T management system, constitute and promulgate regulations and behavior norms that adapt to current China's national condition, restructure assessment and evaluation system, and perfect indicator system of S&T evaluation.

Third, strengthen supervision at the same time of increasing investment in S&T and set up and perfect relevant regulatory constrains system and institutes, including rules of reporting and dealing with research misconduct. At present, policies and regulations are set up and perfected gradually, however, measures need to be taken to implement and inspect those established policies and regulations. Actually, it is more important to execute policies and regulations with specific measures.

Finally, reinforce universal education of Intellectual Property Right laws and regulations and research integrity. The education should be routinization and diversification, and brought into the formal education system.

Svetlana Kirdina

Prospects of Liberalization for S&T Policies in Russia: Institutional Analysis

Abstract:

The objective of the paper is to define the trajectory of economic institutional reforms in Russia as a framework of S&T policies. The methodology of this research is based upon *the institutional matrices theory* (Кирдина, 2001; Kirdina, 2003). The hypothesis claims that the "institutional nature" of Russia defines its prospects of liberalization and needs the active implementation of liberal market institutions policy only within a framework of modernization of redistributive state economic system. Modern S&T policy in Russia demonstrates the implications of such kind of development. The new institutional form of *State Corporation* that is non-profit organization under government regulation has been widely developed for last 3 years. The main sphere of State Corporations activity is high-tech development. The share of State Corporations in the state budget is more than 20% and it is constantly increasing.

Introduction

The essence and prospects of national S&T policy in modern Russia can be considered in the context of the institutional liberalization process. The institutional liberalization is defined in this paper as the development and implementation of liberal institutions in economic, political and ideological spheres of the society. What kind of institutions are they? We will use the methodology, based upon *the institutional matrices theory*, or *X- and Y-theory* (Kirdina, 2001, 2003 etc)

1. The Institutional Matrices Theory (the IMT), or X- and Y-theory

The main theses of the IMT (or X- and Y-theory) are presented in the paragraph. This theory regards the society as a structured whole with three main spheres — economy, politics and ideology, which are morphologically interconnected. Thus social relations forming the inherent structure include the following:

economic interrelations related to resources used for the reproduction of social entities;

political, i.e. regular and organized social actions to achieve the defined objectives; and ideological interrelations embodying important social ideas and values.

Each sphere is regulated by a corresponding set of basic institutions. These basic institutions are the subject of the analysis. Institutions permanently reproduce the staples of social relations in different civilizations and historical periods. Basic institutions integrate a society into one 'whole' that is developing, sometimes with conflicts and at other times with harmony, sometimes with competition and at other times with cooperation.

Institutions have a dual natural-artificial character. On the one hand, institutions manifest self-organizational principles in a society as a co-extensive natural-social system. On the other hand, institutions are the result of purposeful human reflection with regard to relevant laws and rules; they emerge and are shaped as 'human-made' entities. Aggregations of interrelated basic economic, political and ideological institutions are defined as *institutional matrices*. Historical observations and empirical research as well as mathematical modelling and a broad philosophical approach provide a ground for our hypothesis about two particular types of institutional matrices existing around the world. Namely, we call the two types X-matrices and Y-matrices and compare the unique identities of each one. These matrices differ in a set of basic institutions forming them (see Image 1).

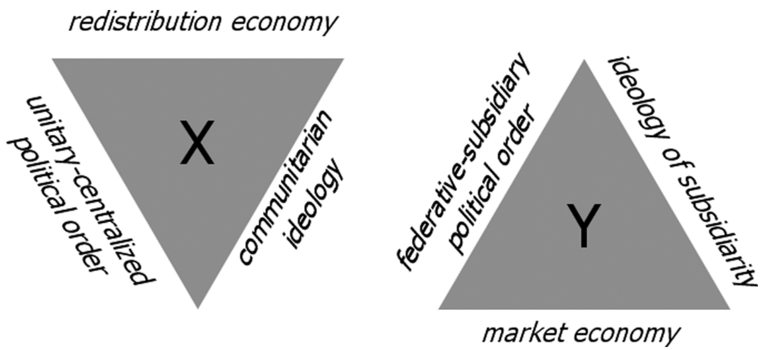

Image 1. Institutions of X- and Y- matrices.

An X-matrix is characterized by the following basic institutions:

• in the economic sphere: *redistributive economy institutions* (term introduced by Karl Polanyi, 1977). Redistributive economies are characterized by the situation when the center regulates the movement of goods and services, as well as the rights for their production and use;

• in the political sphere: *institutions of unitary (unitary-centralized) political order*;

• in the ideological sphere: *institutions of communitarian ideology*, the essence of which is expressed by the idea of dominance of collective, public values over individual ones, the priority of We over I.

The following basic institutions belong to the Y-matrix:

• in the economic sphere: *institutions of market economy*;

• in the political sphere: *institutions of federative (federative-subsidiary) political order*;

• in the ideological sphere: *institutions of the ideology of subsidiarity* which proclaims the dominance of individual values over the values of larger communities, the latter bearing a subsidiary, subordinating character to the personality, i.e. the priority of I over We.

In real-life societies and nations, X- and Y-matrices interact, with one of them permanently prevailing. Nevertheless, the matrices are not entirely exclusive of each other, given that both X- and Y-matrices co-exist concurrently in a given case. The other words, the social structure of any society can be singled out as a dynamic binary-conjugate structure of these two interacting, yet alternative institutional complexes. The domination of one of the matrices over the other is constant in the course of history. The dominant institutions of the prevailing matrix therefore define society and serve as a performance framework for complementary institutions from the other matrix (see Image 2).

We contend that X-matrix institutions are predominant in Russia, China, and India, along with most Asian and Latin American countries. In this case Y-matrix institutions are “a must” but they have the complementary and additional nature. And controversy — Y-matrix institutions are prevailing in the public order of most

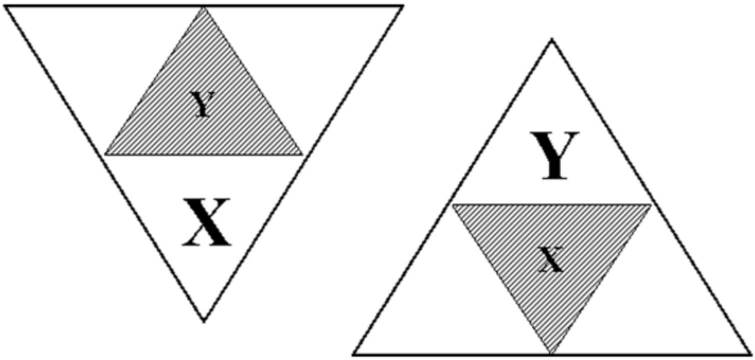

Image 2. Balances of dominant and complementary institutional matrices.

European countries and the USA, whereas X-matrix institutions are additional.

Structures and functions of basic institutions in X- and Y-matrices are presented in Tables 1–3. First of all we consider economic institutions (Table 1).

TABLE 1. ECONOMIC INSTITUTIONS

Functions of institutions	Institutions of redistributive economy in X-matrix	Institutions of market economy in Y-matrix
Fixing of goods (property rights system)	Supreme conditional ownership	Private ownership
Transfer of goods	Redistribution (accumulation-coordination-distribution)	Exchange (buying-selling)
Interactions between economic agents	Cooperation	Competition
Labor system	Employment (unlimited-term) labor	Contract (short- and medium-term) labor
Feed-back (effectiveness indices)	Cost limitation (X-efficiency)	Profit maximization (Y- efficiency)

We can see that the same economic functions are enacted by specific institutions in different matrices. Complexes of redistributive institutions (X-matrix) and market institutions (Y-matrix) are the main subject of our research, which is why they are given special attention.

The property rights system in a nation or community ensures the basis for stable relations between economic agents. The structure of property rights secures the order of resources procured from the nature, and prepares the way for production and the subsequent delivery of goods to people for their subsistence and development.

Supreme conditioned ownership (X-matrix institutions) is specific in that the rules of access for the use of *some* objects in production and consumption are conditioned in the final case by the 'supreme' (which in Russian means 'from above') level of economic hierarchy. These rules change over time and depend on external circumstances. The supreme hierarchical level of governance determines rights of access in accordance with the public role and importance of given resources at each historical moment. The Supreme level of management sets frameworks for forming property rights for ŕsubordinateŕ regional and local levels, which regulate the relations of property in corresponding territories. Due to the existence of supreme conditioned ownership, the property configuration is permanently changing, but the role of the administrative hierarchy with a national center as the principal regulator of ownership or property rights is constantly preserved. If the objects belonging to any economic agent do not assure an essential contribution to total productivity or if they are not used for public benefit, then they can be legally seized and returned to public ownership or transferred to other productive economic agents. The institution of supreme conditional ownership assumes the formation of corresponding hierarchical economic structures of management in the jurisdictional territory of the state.

Private ownership (Y-matrix institutions) means that society sanctions all property rights (including the possession, disposal and use of objects) to individual or collective economic agents.

Transfer of goods within the respective property rights framework is regulated by redistribution or exchange. **Redistribution** (X-matrix institution) describes the transfer process of material goods and services (and also property rights) not between entirely independent agents, but between agents and the center as their mediator. Historically, a redistribution framework is an institution that emerges in nations where the majority of economic agents depend on significant common resources (e.g. water, fertile land, rivers, roads, staple goods, etc). Such resources can be called 'public goods.' In such cases, it is necessary to coordinate transactions not only between two autonomous interactive agents, but also between other dependent economic agents that can be involved explicitly or implicitly. The motivation to minimize transaction costs leads to the creation of one special center responsible for institutional coordination. All necessary information is accumulated in this center, which the agents access. The rules and order for using public goods are defined there. Appropriate resources are also concentrated in this center to support its coordinative functions.

The redistribution model thus involves three transaction participants, namely, a pair of economic agents and the center as their mediator. Redistribution means a permanent process with three basic phases: 1) *accumulation* (collection and storage of resources and goods), 2) *coordination* (concentrated in the center), and 3) *distribution* (resources, goods and property rights).

Exchange (Y-matrix institution) means horizontal interactions between independent economic agents, primarily with the goal of gaining profit in a market economy[1].

Since exchange (market) and redistribution (centralisation) are fundamental peculiarities of different economic systems, economies with predominating X-institutions can be rightfully named 'redistributive economies' (following Karl Polanyi, 1977), or 'centralised economies,' whereas the economies with prevailing Y-institutions can be named 'exchange or market economies.'

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[1] "As far as it goes about market economy, for fundamental theory it makes no difference what kind of market economy it is: a system of primitive exchange between hunters and fishermen or a complex organism that we can see today. The main features, contours are entirely the same, and even the way in which national economic accounts are kept — with or without money — makes no difference. We have already noticed that money circulation in such an economy is no more than an auxiliary technical tool that changes almost nothing. No matter how different is modern economy from primitive, mostly the same occurs in both" (Schumpeter, 1926:74).

Institutions of cooperation and institutions of competition regulate the interactions between economic agents. **Cooperation** (X-matrix institution) establishes itself as a definitive institution if joining economic actors for common tasks involving a nation's or community's resources in the economy is more productive than restricting resources to use by separate, autonomous agents. The most known form of cooperation are rural communities in different countries of the world, that is, agricultural, industrial and trading cooperatives, **(friendly) credit companies**, etc. Accordingly, **Competition** (Y-matrix institution) stimulates the possession of limited resources by individuals when personal benefit is gained from owning (part of the) material resources, the technological environment and other means of production. There are many different models of competition in market economies, for instance "monopolistic competition" (Chamberlin, 1956) or "imperfect competition" (Robinson, 1948) etc.

What institutions regulate the labour relations in X- and Y-economic systems? **Employment (unlimited-term) labour** institution (X-matrix) means the necessity of obligatory employment and forming public guarantees of attracting the able-bodied population to work. The Japanese phenomenon of "lifelong hiring", for example, reflects the actions of this institution. Thus, the sphere of work also realizes the laws of redistribution, assuming the accumulation-coordination-distribution of manpower (human resources) with the corresponding information, as K. Polanyi noted (Polanyi, 1977:36). The essence of the **Contract (short- and medium-term) labour** institution (Y-matrix) is that labour relations are mainly in the sphere of mutual relations between the employer and the worker and have a character of hiring for a certain limited time according to a contract. "Normal" unemployment is a necessary attribute of such a system of labour relations. In the sphere of work, as with X-economies, the institutional laws define their character, in this case, the market character, and, as Karl Marx wrote (Marx), labour-power becomes a commodity that is bought and sold on the market.

Those institutions that function with feedback signals also perform in economic systems. Without competition, the efficiency of the redistributive economy can be achieved only at the centralised control of cost in each segment and in the economy as a whole. H. Leibenstain called this phenomenon X-efficiency (Leibenstain, 1966, 1978). Restraint of costs is carried out by means of normalizing expenses, price controls, tariffs and other measures with the purpose of raising economic efficiency. **X-efficiency (Cost limitation)** institutions (X-matrix) serve as feedback loops to central authorities. **Y-efficiency (Profit maximization)** institutions (Y-matrix) identify the priority of profitability, or growing producer and consumer surpluses (Mankiw, 1998).

All X- and Y-institutions coexist in actual national and local economies in different combinations and are embodied in many institutional forms. Thus, though we are outlining the general features of X- and Y-matrix economic institutions, in real-life situations the extreme cases are never fully demonstrated this way.

The basic political institutions in the X- and Y-matrices are presented in Table 2.

TABLE 2. POLITICAL INSTITUTIONS

Functions of institutions	**Institutions of unitary political order in X-matrix**	**Institutions federative political order in Y- matrix**
Territorial administrative organization of the nation	Administrative division (unitarity)	Federative structure (federation)
Governance system (flow of decision making)	Vertical hierarchical authority with Center on the top	Self-government and subsidiarity
Type of interaction in the order of decision making	General assembly and unanimity	Multi-party system and democratic majority
Filling of governing positions	Appointment	Election
Feed-back	Appeals to higher levels of hierarchical authority	Law suits

We distinguish 5 basic economic and political institutions in each matrix. Also, we consider 3 pairs of ideological institutions in X- and Y-matrices (Table 3).

TABLE 3. IDEOLOGICAL INSTITUTIONS

Functions of institutions	Institutions of communitarian ideology in X-matrix	Institutions of subsidiary ideology in Y-matrix
Driver of social actions	Collectivism	Individualism
Normative understanding of social structure	Egalitarianism	Stratification
Prevailing social values	Order	Freedom

For a fuller description of political and ideological institutions in details see (Кирдина, 2001:123–183). Normal functioning of X- and Y-matrices requires an appropriate institutional set with all morphologically interconnected institutions. For example, **supreme conditioned ownership** cannot act perfectly without X-efficiency (cost limitation) institutions and other institutions from the X-matrix institutional set. For the Y-matrix the same is true.

The material and technological environment in a society is a key historical determinant of whether either an X-matrix or a Y-matrix prevails, along with culture and personality. The environment can be a *communal* indivisible system, wherein removal of some elements can lead to disintegration of the whole system or it can be *non-communal* with possibilities of functional technological dissociation (Bessonova, Kirdina, O'Sullivan, 1996:17–18).

Communality denotes the feature of material and technological environment that assumes it exists as a unified, further indivisible system, parts of which cannot be taken out without threatening its disintegration. A communal environment can function only in the form of public goods and cannot be divided into consumption units and sold (consumed) by parts. Accordingly, joint, coordinated efforts by a considerable part of the population, along with a unified centralized government are needed. Therefore, the institutional content of a nation developing within a communal environment is, eventually, determined by the tasks of coordinating joint efforts towards effective use. Thus, X-matrices are formed under communal conditions.

Non-communality signifies technological dissociation, with the possibility of atomizing core elements of the material infrastructure, as well as independent functioning and private usage. A non-communal environment is divisible into separate, disconnected elements; it is able to disperse and can exist as an aggregate of dissociated, independent technological objects. In this case, an individual or groups of people (e.g. families) can involve parts of the non-communal environment in their economy, maintain their effectiveness, and use the obtained results on their own, without cooperating with other members of the society. If this is the case, the main function of such formed social institutions is to assure an interaction between the atomized economic and social agents. Y-matrix institutions are thus shaped in a non-communal environment.

To be more accurate, in a communal environment X-matrix institutions are dominant and Y-matrix institutions are complementary (e.g. in Russia, China, India and most Asian and Latin American countries). In a non-communal environment (e.g. in the USA and Europe) the institutional situation is *vice versa*.

The ratio of dominant and complementary institutions is defined by the changing conditions of social-economic development. On one extreme, there is a totality of dominant institutions without conscious implementation of complementary institutions. This tends to result in collapse (e.g. USSR's breakdown in the '80s and '90s) or in a social and economic crisis (e.g. the U.S.'s recent '07–'09 recession). The opposite extreme implies the attempt to replace historically dominant institutions with complementary ones. This move leads to revolutions through reconstructing dominant institutions into new forms (e.g. the French Revolution as a reaction to economic and political centralization and, alternatively, the Russian October Revolution as an outcome of an attempt at "building capitalism") or unsustainable socio-economic development (e.g. some Latin American countries).

We know that neoclassical, post-classical and neo-institutional theories have stated the claim of an inevitable domination of the market (exchange) type of economy. According to these theories, redistributive models are complementary and manifest themselves in governmental activities through monopoly regulation, correction of externalities, production of public goods and other actions to overcome market failures. This inevitability is still believed by some economists, especially those from western countries.

But from our point of view, an alternative situation is appropriate for some countries, including Russia. By this bold statement we mean that the redistributive economic model (X-matrix) dominates "by nature" in Russia, whereas '(neo-)liberal' market institutions (Y-matrix) are not dominant but rather complementary. Forming the appropriate ratio (proportional balance) between redistributive and market institutions has a spontaneous character and is the result of the economic system's self-organization under various internal and external conditions and challenges. People and authorities can activity help to achieve this balance faster and more efficiently than just letting history take its course.

2. The Institutional Analysis of Modern Russian Economic Reforms

From the IMT's point of view the essence of Russia's economic reforms is the search for an optimal combination of market (or "liberal") and redistributive institutions and modern forms of their embodiment.

By the middle of the 1980s, on the eve of *perestroika* (term of the Soviet Union) or move to a *transition economy* (term of world social sciences), Russia had an imbalanced institutional economic structure[2]. It manifested itself in the predominant and active development of X-institutions in a redistributive economy only. Y-institutions, which were necessary for the successful growth of the economic system, were under-developed and existed as latent, shadowy or illegal forms only. Such an imbalance in the end resulted in an inefficient social system and led to a large decrease in the nation's economic and social parameters. The need for system reconstruction and rearranging the institutional structure was recognized in Russian society.

We can distinguish two main stages in the transition process during that period. The first one started in the middle of the 1980s when new political leadership (i.e. the first USSR President Mikhail Gorbachev and the first Russian President Boris Yeltsin) began to develop market-based Y-institutions with legislation.

2 In the political and ideological spheres, we also had an imbalanced structure with total domination of X-institutions.

From the mid-80s, new market Y-institutions began to be implemented:

• Privatization (in different forms) of the majority of state-run enterprises and all state-run middle and small enterprises was put into practice to create **private ownership.** What was privatization? Each citizen received a voucher as a right to a 'share' of public property. The process of concentrating vouchers began and gave rise to the first 'capital' formations;

• Decentralization in the economic governance system was made to develop **exchange** transactions instead of redistribution. The state planning system ("Gosplan") and rigid connections between economic agents were liquidated. Price management was stopped;

• New laws about the creation and liquidation of new enterprises and small business in all branches of economy (from finance and banks to trade and services) were passed to develop **competition;**

• **Contract labour** substitutes were enacted for employed (unlimited-term) labour because the state system of manpower training and distribution was liquidated. Relationships between employees and employers became the subject of contracts. Both state salary management and price regulation were cancelled;

• **Profit maximization (i.e. Y-efficiency)** became the main criteria for new enterprises and their owners began acting in an open and competitive market environment.

Nevertheless, the attempt to completely replace redistributive institutions by market ones failed, as we know now. This is evident because there was neither growth in total efficiency of economy nor expected efficiency increases in new companies of that period. In 1998, after Russia's *national default* the state economic policy was turned to searching for an optimal and balanced combination of related market and redistributive institutions[3].

Since the late 1990s and early 2000s (i.e. when President Vladimir Putin and new political leadership took office), more attention has been paid to the modernization of redistributive X-institutions rather than to implementing market Y-institution as before:

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[3] In China such balanced approach took place from the beginning of economic reforms in later 1970-s. It is one of the main courses of their successful «planned economy with market regulation» policy (The China Society Yearbook, 2009:37). This is what we supposed (Дерябина, Кирдина, Кондрашова, 2010).

• **Supreme conditioned ownership** institutions shows up in the creation of large-scale joint-stock companies and holding structures under management (or with control share in capital) by the Russian government or regional governments. Such companies are mainly present in infrastructure building, housing management in cities, information and communication or high-tech branches, including gas, petroleum and energy production, as well as transportation, including railway transport, the motor-car industry, space and aircraft construction, etc.;

• **Redistribution** is presented in new *National Projects* under federal governance and is supported by the federal budget. These projects cover the main spheres of human living, namely education, public health, housing and agriculture. The centralization of National Projects Management on the new level puts the redistribution scheme (accumulation-coordination-distribution) into action. National projects have added to the system of Federal target programs and other forms of centralized state support in various fields of activity, which have become more and more, especially in connection with the financial and economic crisis of 2008–2009;

• **Cooperation** is offered in wherein the state supports creating economic structures in which enterprises interact on the basis of not a competition, but also cooperation. In detail below is considered the case of state corporations (STCorps), actively introduced in 2007, which illustrates this tendency;

• Developing **employed (unlimited-term) labour** is expressed in the following: 1) organizing industry specialists in the education system on the basis of private-and-public partnerships with the state retaining its leading position; 2) new labour policy that is primarily oriented towards the wealth of people working in the so-called "state budgetary financed area" of the economy; 3) growth of non-monetary factors of labour rewards (which is peculiar for the system of employed labour);

• **Cost limitation (X-efficiency)** is expressed in price and tariffs regulation, both at federal and regional levels. The main objective of corresponding commissions (in electric power, railway transport, housing service) is not revenue of the companies but rather decrease of general resources and manpower used, as well as national product expenditure and total cost of its production. Governmental pressure to reduce the level of credit rates for the state, and non-state banks also testifies to expansion of the sphere of action of this X-efficient institute (for more detail see Верников, Кирдина, 2010).

As a result, a new balance of redistributive (X) and market (Y) institutions is being created in Russia at present. The re-development of redistributive X-institutions in the social structure of Russia along with further support of market Y-institutions has formed a more balanced (in favour of the former) institutional structure. The process of this formation has gone along with the recent growth of economic and social development indexes in Russia. In April 2008 (i.e. before the world financial crisis) Russia occupied 8th place on the national GDP index, compared to 18th in 2005.

But the crisis has shown that Russian development was neither stable nor self-dependent. In 2009, Russia had a GDP decrease of more than 8%. In comparison, the Indian and Chinese economies in 2009 resumed growth at about +7 and 10% respectively. Another member of BRIC — Brazil — also had positive growth. The average level of GDP decreases in the USA, Japan and the Euro zone was less than minus 1% (Sources: IMF, Bloomberg).

Why has the Russian economy not proved resilient? Delayed institutional stabilization actions and the backwardness of the post-Soviet economic structure, based mainly on raw material exports, has resulted in the unsteadiness of Russia's economic development. The Crisis of 2008–2009 has shown that we are dealing with long-term, serious problems, namely, the inefficiency of institutional and economic structures. Up until the crisis, neither institutional nor structural modernization was carried out sufficiently or successfully.

3. From a raw materials economy to a hi-technology economy

Though gas and energy carriers still remain major Russian exports, Russia is now actively working out new S&T policies and the strategy of hi-tech sectors development. Ever since 2002, the target of the state policy has been transition to an innovative way of Russia's development. Forming the National Innovation System (NIS) is an integral part of state economic policy (Lenchuk, 2006).

What were the initial conditions? Unfortunately, the structure of the Russian economy has changed notably over the period of market transformations: technological shifts have been obviously regressive. There was a washout of innovation intensive manufacturing industries in favour of mining and raw materials processing branches that practically do not give any impulses to innovation development. In addition, a huge brain drain of potential innovators in science and technology was taking place. Emigration amounted to nearly 1 million people in 1990-2000s or more than 10% of the able-bodied population.

Despite the losses suffered during the transformations from a planned economy to a market-based economy, Russia continued to possess one of the largest scientific potentials in terms of its scientific workers, lagging behind only the USA, Japan and China. The goal for the NIS was to actualize and develop this one world-class scientific and technical potential.

During the first stage of creating the new NIS (2002–2006), the Russian government oriented itself to institutional models tested by world practice in developed countries. But neither businesses nor the state could successfully carry out these models. Here is a list points criticized in the developing the NIS in Russia during these years:

- Attempts at mechanically transferring foreign experience (first of all, from the USA) to Russia for organization of research, development and education system did not take into account the real conditions and history of Russia's development;
- There was no single governmental body was responsible for developing, regulating and defending the intellectual property rights of innovation policies involved in the new system;
- There was not an integral approach to information processing and knowledge transfers in the NIS;
- Coordination between the state and private sectors in developing priorities and measures for establishing financial support of potential research work was weak;
- The activities of large and small enterprises involved in science and business development of high technologies in Russia was low.

At the beginning of 2006, conceptual approaches to forming the NIS in Russia were changed and became more diverse. The main emphasis was laid on the role of increasing and concentrating federal financial support and regulation on activating state-private partnerships. In fact, a different institutional design was proclaimed.

Stronger state financial support and regulations during the second stage of NIS started by forming new financial institutions for innovation development (e.g. the Federal Law of "Bank for Development," adopted in 2006). The Russian state would try (as promised) to completely finance all infrastructure needed for special economic zones, including technical and promotional zones and techno-parks. On January 1, 2008, special measures aimed at forming a more favourable innovation climate were proposed for execution.

What were the main directives for activating state-private partnership mechanisms? The Federal Target Program (FTP) — «R&D along priority lines of developing the Russian scientific-technological complex in 2007–2012» — provides for more active participation of the private sector. Practically all innovation projects in this program are to be financed by the state jointly with private business. The volume of the required off-budget (i.e. non-federal money) co-financing varies depending on the type of project: for researching and developing technologies, co-financing is set at 20-30% of the project's cost and commercializing technologies is set to 50–70%.

4. State Corporations as new institutional forms in S&T policies

The modern forms for concentrating state resources in hi-tech branches in Russia are now called *State Corporations* (StCorps). An integral part of the NIS is in establishing StCorps in the most competitive branches of the economy: nanotechnology, aircraft-building, space, nuclear power-plant, engineering, shipbuilding, and defence of the industrial complex. Within the framework of these fields, federal target programs are formed and questions of funding concrete innovative projects are worked out.

The creation of StCorps in Russia was the first response to modernization challenges and to making effective investments in the high-tech industry. The development of StCorps implied that these businesses could become the locomotives of a breakthrough in the domestic economy.

Russian legislation defines that SCorps can be set up in any sphere that is crucial for the nation. In general, are made to solve problems in spheres that have a significant role for national, social and economic development or for national security; i.e. high risks, with a low rate of return on capital and for large-scale mega-projects. A StCorp is legally a non-profit foundation (i.e. organisation) responsible for the more effective use of managerial and financial resources. The scope of powers and resources, which are allocated by the Federal Government to StCorps, is greater than resources allocated to existing stock-share companies with 100% state capital.

As for the National Innovation System, StCorps have a special role. First of all, StCorps are established with the aim of healing damaged economic ties in high technology industries and consolidating enterprises with a certain kind of branch profile. StCorps are designed to improve the competitiveness of Russia's products on the world market by introducing modern technologies. We know that large consolidated companies have a greater capacity to invest in S&T development than small ones, which is another reason for implementing StCorps. And last but not least, scientific development requires long-term investments, namely, federal budgetary funds are intended to establish "long" money for today's StCorps.

There have been many opinions on the role and prospects of StCorps in Russia. Some economists consider them as unnecessary and a strange form of organization. This opinion was very popular especially before the financial crisis in October, 2008. In spite of that, our analysis conducted at that time (Кирдина, 2008) showed that StCorps were logical and ґnaturalґ for Russian conditions and would probably serve as the long-term institutional form. This analysis was made on the basis of Institutional Matrices Theory (see above and below).

As for the history of establishing StCorps, the article "On State Corporation" amended a special federal law "On Non-Profit Organizations" on July 8th, 1999. There the goal of StCorps was clearly defined as: "the implementation of social, governing and other publically useful functions". The entrepreneurial activity of StCorps is performed only for the sake of the goals it was created for, but not for gaining profit. Each StCorp must be created and grow in compliance with a special federal targeted law, which was passed for this purpose. This law is considered as a Constituent Document for every StCorp. Provisions of the federal law “predominate over the provisions of the Law “On non-profit organizations”, which are applied only subsidiarly”.

The commissioner of every StCorp is the Russian Federation, represented by the Russian Federal Assembly, which passes and approves laws establishing StCorps. The treasury of the Russian Federation contributes assets. In the case of liquidating a StCorps, the real property is transferred to the owner, which is the State. The Accounting Chamber of the Russian Federation controls property usage. Each StCorp has to issue an Annual Report in the official federal mass media, such as “The Russian Newspaper”.

In spite of the fact that legal forms of StCorps have been known for over 200 years in western countries, the idea of such a special StCorp was borrowed by Russia from China. This legally “sleeping” form started to be implemented in Russia only in 2007[4]. The reason given for creating StCorps was the inefficiency of domestic investments in Russia’s economy. According to expert company reviews, 1% growth of assets per employee gave only a 0.4% growth in his or her productivity. The idea of setting up holding companies, which had been popular in Russia before 2007, failed. A holding company is a profit-oriented economic structure, more consistent with the Y-efficient institutional structure. It had been planned in Russia to set up 37 holding companies from 2002 to 2008, but in reality only 17 such companies were created.

As for StCorps, they are rapidly developing in the Russian economy and society. In March 2008, the share of SCorps in the expenditure of State budget was 17%, while accounting for 22% of its income (Государственные корпорации в России, 2008). At present, there are about 10 State Corporations, which have been created to solve the most important investment-demanding problems. For example, «VneshEconomBank» was created in May 2007 to ensure the enhancement of competitiveness in the economy; «RosNanoTech» was set up in July 2007 to develop new nano-technologies; «The foundation for reform of the housing sector», also started in July 2007, with the aim of modernising residential housing utilities; «OlimpStroy», in October 2007 to develop the

[4] Before that only one state corporation «The federal agency on insurance of individual bank accounts» was created in January, 2004.

future Olympic Games constructions; «RosAtom», in November 2007 to modernise the economy's nuclear sector; and «RosTechnologies», in November 2007 to support the production and export of the high-tech industry, etc. It is expected that StCorps will be set up in the finance sector and also in other branches of industry.

Recently the head of the «RosTecnnologies» StCorp said[5] that the corporation was modeled on the Italian group of companies Finmeccanica, established in 1948. The prototype of this group of companies was the State Institute of Industrial reconstruction (Instituto per la Reconstruzione Industriale, IRI), created by Benito Mussolini back in 1933. Now the company places Number 1 in high technology in Italy and 3rd place in Europe, with 16% of the company's revenue invested in R&D[6].

Our institutional analysis shows that modern Russian StCorps correspond to the nature of basic X-economy institutions according to their key parameters. Here are the summary proofs of this situation:

• It is possible to set up a StCorp only according to the special law of the Russian Federation. StCorps report to federal executive bodies, which appoint the StCorpr's General Director and form the Supervisory Board. The state controls the assets of StCorps. In case of its liquidation, all assets are to be returned to the state, as the owner of these assets. These features correspond to the performance of S*upreme Conditioned Ownership institution* of an X-economy*;*

• StCorps have a hierarchical structure, which implies not only the division of labour functions and responsibilities between the levels, but also the organizational and financial subordination according to the level of hierarchy. This corresponds to *the Redistribution institution* of an X-economy, i.e. where the economic center has both a leading and mediating role;

• Technologically dependant enterprises and enterprises belonging to the same industrial profile are incorporated into a single definitive StCorp. This is done so that the enterprises will not compete with each other, but rather so that they will consolidate their performances and business activities. Such a model corresponds to *the institution of Cooperation* in X-economies;

[5] http://www.rostechnologii.ru/archive/3/detail.php?ID=333
[6] http://www.finmeccanica.it

• Profit making cannot be main the aim of a StCorp; this corresponds to *the institution of X-efficiency* (in contrast to Y-efficiency, which aims at profit maximization).

We can see that Russian StCorps do not correspond to typically western standards or expectations. Instead, they correspond to the dominant national institutional framework in Russia, which we call an X-matrix. This dominant form is the result of a long period of successes and failures in Russia's economy, society and politics. At the same time, StCorps are a «Y-influenced» institutional form, in that they got their particular orientation in light of experiences and inter-relations with the liberal market environment (e.g. share capital, budgetary principles, etc.), which is not its opposition, but rather its structural compliment.

Furthermore StCorps have a high potential, not only as «breakthrough» institutions in Russia's national economy, but also as structures that provide new opportunities for mobiliziung both public and private capital working together. StCorps can cooperate both based on market terms (i.e. on the global market) and on state-administered terms (i.e. domestically). The legal mechanism to solve pressing economic and social problems were lacking before the creation of StCorps.

Contrary to the Federal State Unitary Enterprises, the aim of which was to implement Federal Target Programs (FTP), StCorps are supposed to become more financially efficient market players because they have the legal right to secure internal and also foreign loans, to issue bonds, etc. StCorps are thus better partners for the private sector because they have the opportunity not only to have "principal-agent" relations, but also mutually implement different projects on the basis of "public-private" partnerships. For instance, StCorps do not have any legal restrictions on purchasing products and services, which was the case with FTP.

The first functioning years of StCorps identified the following problems:

• Neither clear goals nor clear focus on specific projects (i.e. "dispersion" of resources);

• Vague responsibility for the use of StCorps' available funds and resources;

• Low efficiency and lack of performance evaluation parameters;

• Weak management and misuse of funds and property (e.g. mass media reported that the Accounts Chamber of the Russian Federation revealed financial irregularities such that it was ready to act with charges against StCorps. (But representatives of StCorps deny this information).

In our analysis, further «marketization and liberalization» (in the Y-institutional framework) and «redistributization» (in the X-institutional framework) can help to solve these problems. As for StCorps' "marketization", first of all it is necessarily to mention the transparency of their development. Taking into consideration the public character of StCorps, the standards of their transparency should be higher in comparison with ordinary stock-share companies. The fact that each StCorp is set up by a special federal law gives the opportunity to put such a 'democratic' transparency requirement into practice. Prospects for StCorps' "redistributization" include the development of control and planning tasks for StCorps' performance as well as implementing a system of indicators (i.e. measurements) to show the fulfillment of these plans. Regular monitoring and control over the use of funds (e.g. state budget funds) by the Accounts Chamber is also strongly needed[7].

What is the future of StCorps in Russia? On the one hand, Russian President Dmitry Medvedev said regarding StCorps: "I do not think that this is the correct method of reforming our economic structure. In certain areas we really decided to use state corporations. But their life should be finite"[8]. His governing team proposes instead to reorganize the StCorps into ordinary joint stock companies. On the other hand, the Ministry of Economic Development, Federal Financial Markets Service and Central Bank are preparing a bill to create a new StCorp called the "Russian Financial Agency" (RFA). Its main goal will be to improve management of state assets and liabilities. A Deputy Finance Minister Dmitry Pankin said in September, 2009: "While no governmental decisions on a cancelling of state corporations are present, we have analyzed all legal forms and consider the

[7] "For the purpose of exercising control over fulfillment of the federal budget .... the Accounts Chamber of the Russian Federation is established" -The Constitution of the Russian Federation. Article 101, paragraph 5.

[8] Interview in the newspaper «Kommersant.» June 4, 2009. http://www.rian.ru/economy/20090605/173321132.html

most convenient variant to be the state corporation." So, we see different views being put forward by government officials and agencies and must wait to learn what the next steps will be.

At the current time, a compromise proposal has been accepted for developing and improving the activities of StCorps based on their reorganization. In February 2010, the Ministry of Economic Development of the Russian Federation presented a corresponding plan for the government and the President of Russia. Changes were proposed in the organizational-legal form of StCorps: for them a special category was entered into juridical classifications of "legal entities under public law." The proposal is to make joint stocks for StCorps, which will help to establish the government's more effective control above the activity of the StCorps' management[9].

Our institutional analysis of Russian StCorps leads us to suppose that this relatively new form is in fact a future trend that will assist in further transforming the high-tech industry. It also has the potential to become a much-needed answer to global technological challenges and challenges of innovative modernization. This is why we suppose that the quantity and capacity of StCorps in Russia (and also around the world) will increase. Russian StCorps represent a reproductive "matrix" with the basic institutional characteristics of a redistributive economy. At the same time, they are the result of institutional economic modernization based on responding to market reforms. The continuous reorganization (cf. modernization) of StCorps in Russia confirms this assumption.

Findings and Conclusion

In the early 2000s, Russia started to build an economy based on innovation. The country possesses one of the largest technological and scientific potentials (behind the USA, Japan and China), but its National Innovation System isn't yet formed. Attempts at mechanically transferring western (i.e. foreign) experiences into Russia proved to be failures and not successes. A new institutional model for the Russian innovation system is now developing, by taking into account the real economic history of the country along with current institutional theory. Attempts to find an appropriate balance between X- and Y-institutions in contemporary Russian innovation policy are therefore continuing.

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[9] February 11, 2010 http://slon.ru/articles/284882/

Establishing an effective proportion between redistributive and market economic institutions, is one of the important goals for Russian S&T policy. The "institutional character" of Russia fixes the limits of liberalization and needs the active implementation of Y-institution policies within a framework of modernizing and developing X-institution policies. Our institutional analysis of such new phenomenon as Russian State Corporations allows us to conclude that this relatively new institutional form is a future trend for transforming high-technology. It can become Russia's answer to global technological challenges.

Our prognosis based on Institutional Matrices Theory (or X- and Y-theory) is the following: the Russian innovation system will move from the western-oriented institutional model to the Chinese one. This is because the Chinese model is more appropriate to adopt in the current Russian situation. The aim of Russia's innovation policies must therefore look to balance between X- and Y-matrices, developing a successful combination that will help it move forward confidently as a sovereign nation, moving further beyond the shadow of its Soviet past in the 21st century.

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Duru Arun Kumar

Little Science and Big Science in India — An Academician's perspective

Abstract:

This paper attempts to analyze the significance of 'Little science and Big science' in the post liberalized phase of India's development. Using the terminology introduced by Derek J de Solla Price, research can be called Big Science if projects have numerous researchers, large funding, significant infrastructure and plan to build complex tools and prototypes. Little science refers to research projects which have few researchers, moderate funding, little special infrastructure and is more investigation oriented This is an exploratory study to get a preliminary understanding of the nature of little science and big science as perceived by the scientists. Some of the issues discussed are nature of little science and big science, their relationship with each other and their significance to the growth of scientific knowledge.

1. Introduction

In the rapidly modernizing society of the latter half of the twentieth century, scientific knowledge has been characterized by explosive growth, both in conceptual development as well as in the scale of science activities. A number of new sub-disciplines have developed in the sciences, which require highly specialized educational training, skills and exposure to understand them and to contribute to their development. This has been greatly facilitated by the economic liberalization and communication network. Several scientometric studies (Garfield 2007, Gaillard 1992) have shown the enormous growth in the quantitative measures of science research such as research papers, journals, projects, scientists, institutions and universities. As pointed out by A. M. Weinberg (1967), "on the one hand, many of the activities of modern science — nuclear physics, elementary particle physics or space research — require extremely elaborate equipment and staff of large team of professionals, on the other hand, scientific enterprise, both little and big science, has grown explosively and has become much more complicated".

Besides individual investigative research pursued in universities and private labs, modern science is also identified with large collaborative research programmes (Duque et al., 2005) involving hundreds and thousands of scientists lasting several years. But what is little science and big science?

Derek J. de Solla Price and A. M. Weinberg introduced these terms to denote the scale of research activity (Price, 1963). Little science refers to science research pursued by individual investigators or a group of investigators, with moderate funds and little special infrastructure. Big science refers to the large scale character of modern science requiring extremely elaborate equipment and staffed by large teams of professionals.

Michael Gibbons, in his analysis of change in knowledge production in the broader context of contemporary society, used the terms Mode 1 and Mode 2 to denote the difference. Mode 1 refers to the traditional knowledge generated within a disciplinary, primarily cognitive context. Problems are set and solved in a context governed by the homogenous and largely academic, interests of a specific (scientific) community. The Mode 2 form of knowledge is created in broader, trans-disciplinary, social and economic contexts (Gibbons, 1994). Emergence of Mode 2, according to the author, is profound and calls into question the adequacy of familiar knowledge producing institutions, whether universities, government research establishments, or corporate laboratories. Their contention is that there is sufficient empirical evidence to indicate that a distinct set of cognitive and social practices is beginning to emerge and these practices are different from those that go into Mode 1. Mode 2 operates within a context of application in that problems are not set within a disciplinary framework, nor are they institutionalized within university structures. It is more socially accountable and reflexive. It involves experts from different disciplines and uses functions of division of labour and management control systems. Mode 2 may be basic science, applied science, market driven research, product oriented science and all other forms which are goal oriented.

John Ziman (2002) in his detailed analysis of the nature of science and its organization distinguished between ‘academic science’ and post-modern science or Mode 2 science as having distinctive cultures. The former aims at producing universally valid and value-neutral knowledge and the latter produces knowledge which is more responsive to societal interests and is characterized by teamwork and accountability. The above two important works have not referred to 'big science' directly; however based on their arguments we may consider big science as one of the forms of new developments as they fulfill the criteria of Mode 2 or the post modern science.

From a historical perspective, mobilization of science in World War II has often been taken as the origin of modern big science in Western countries. This rests on the notion of 'big science' as a well defined entity. However, Robert Siedel (Galison and Hevly, 1988) points out that big science in California did not begin with the increased defence outlays of WWII. On the contrary large scale research arose to cope with the problems of providing hydroelectric power to the burgeoning state in the 1920s. Industry and universities allied themselves from the earliest stages of the expansion. Stanford, Caltech, and Berkley were all involved in the problem of power production and distribution. An alternative view might be that big science as we know it today, evolved gradually over the course of the nineteenth and twentieth centuries in organizations like those of German chemical industry, Rutherford's Cavendish lab and the Radiation lab, providing a range of models for research organizations in war time and post war science of which high energy physics was one of the earliest (Galoson, 1988: 38). In recent years, unprecedented attention has been given in the science literature, popular press and television to big science projects, such as Large Hadron Collider, Hubble Space Telescope, High Energy research at CERN, India-based Neutrino observatory.

In India, several big science projects have been initiated such as Chandrayaan, Giant Metrewave Radio Telescope in Maharashtra, India. Many scientists from India are actively involved in these as well as international projects such as LHC. At the same time, a number of scientists are pursuing individual and collaborative projects which may be broadly termed as extension of little science. Whether it is little science or big science, the research is carried out by a scientist, trained in a specific discipline using scientific methods of enquiry, reasoning and analysis. The scientist performs both intellectual and social roles, as a member of his community of scientists. However, the major differences between little science and big science involve the research objectives, scale of activities, infrastructural facilities and the time period. Given these defining features what is the nature of the social dynamics involved in little science research and big science research? What is the impact of these factors on scientists' role as a researcher?

The intellectual demands are the same for both individual nature of scientific activity as well as for large collaborative research. But we also understand that team projects require different group dynamics and division of labor compared to individual research projects. What is the impact of this change in the scale of scientific enterprise on their role as scientists? This is a comparative study to understand the nature of little science and big science from scientists' perspective. The study attempted to enquire the differences between little science and big science with respect to nature of research, role of scientist, financial and political support and organization of research activities, based on scientists' perceptions.

2. Methods of inquiry

The purpose of this exploratory study was to get a preliminary understanding of the nature of little science and big science. This was done by first, analyzing the articles reported in the journals on the major concerns about the big science projects. Second, as practitioners of science the scientists are involved with various social mechanisms to pursue research. Hence it was imperative to get their views and perceptions of little science and big science. Interviews and discussions were held with scientists pursuing research projects, and senior level officials of the governmental funding agencies.

3. Little science and Big science

With regard to big science, scientists explained that when a conceptual and theoretical framework of a discipline (Kuhnian Paradigm) reaches a threshold, that is, everything important that needs to be understood by small science has been observed, there remain certain fundamental questions which require large amounts of highly specialized analytical tools. These fundamental problems are inspired by an important social need and have potentially large impact factor. Big science deals with paradigm shifts and bigger intellectual challenges. To answer or understand these fundamental questions, research investigations are carried out in the form of big science, involving large specialized equipment, infrastructure, science experts from different fields and coordination over long periods.

An important example is the Large Hadron Collider (LHC) which is the world's largest and highest energy particle accelerator, intended to collide opposing particle beams, of either protons at an energy of 7 TeV per particle, or lead nuclei at an energy of 574 TeV per nucleus. The LHC physics programme is mainly based on proton–proton collisions. However, shorter running periods, typically one month per year, with heavy-ion collisions are included in the programme. While lighter ions are considered as well, the baseline scheme deals with lead ions. This will allow advancement in the experimental program currently in progress at the Relativistic Heavy Ion Collider (RHIC). The aim of the heavy-ion programme is to provide a window on a state of matter which characterized the early stage of the life of the Universe.

The other examples are discovery of galaxies and Top Quark (Michalowsky 1999), considered among the many triumphs of "Big Science". They involve expensive, complex, multi-year projects targeted at some of the most difficult challenges that confront modern science. Another interesting observation made in the literature was that huge facilities are not always the hallmark of Big Science. For example, the vast Human Genome Project involves co-ordinating the work of a large number of medium-sized, independently-funded research groups in many countries. Still, a typical Big Science effort requires the expenditure of large amounts of money, and the management of multinational teams of scientists and engineers over many years.

The scientists further pointed out that in big science a core team is in charge of the project. This core team comprises of the elite scientists who also enjoy significant political clout in the government. Their decisions play an important role in influencing the big science trends. Little science is pursued through research projects and individual research plans. The research problems may be a continuation of existing research, testing methods, application based, or they may be termed normal science research in Thomas Kuhn's terminology. The little science projects are primarily career oriented where publishing papers is the main objective of the research.

Little science projects have few researchers, modest funding, little special infrastructure. Some investigations require big infrastructural support, but are carried out by individuals. In the case of little science, the principal investigator is in charge of his project.

4. Role of scientist in little science and big science

A scientist can be part of both little science and big science at the same time. This is greatly facilitated by communication technology. When asked whether scientists would prefer to be part of little science projects or big science projects, most scientists were very content with department level projects. In little science the principal investigator has more freedom and control over decisions in research activities, unlike in the large science projects where the core team makes all the important decisions. "Curiously, all discussions of the LHC experiment are dominated by theoretical physicists; the experimenters seem to be faceless. Modern day big science requires such large teams, with groups having diverse skills, that the individual retreats into anonymity. Conflict and competition, which sometimes seem to play so much of a part" (Balaram, 2008) At the same time some scientists also pointed out that most scientists would like to be part of big science projects because of the challenging nature of the problems and the prestige attached to international projects. But their role varies in little science and big science.

Scientists claimed that in small science projects there is a high degree of commitment, accountability and responsibility. At the same time, the scientists are under greater pressure to publish because it is directly linked to their career growth. We may say that little science projects are more career-oriented.

In big science there is a core team comprising of a few important internationally recognized and influential group of scientists, who are in charge of the project. No deviations are allowed since it is based on long term planning. The role of the scientist is limited as he can not ask or inquire more than required. Publishing papers is relatively easy as it is a collaborative work. There is more scope for interaction with other scientists many of those belong to different specializations. Being part of big science projects gives scientists access to large data which can be used for further research. The scientist is not worried about financial support because he is not dealing with it directly. Big science projects are mainly government supported and have assured funds. Though big science operates like an industry, with management experts, job specifications, and time bound objectives and plans, the scientists interviewed felt that this industrial mode of functioning does not restrict their freedom of science, rather it facilitates interaction with others having similar or different subject expertise.

5. Science research in little science and big science

Big science is interdisciplinary, where experts of various disciplines collaborate. A major component of big science projects is the highly specialized and sophisticated equipment and technology support necessary to carry out research. A large volume of data is generated requiring special tools of analysis. There is a large risk factor (obsolescence, failure of experiment, technical snags, management and coordination problems, unexpected technical problems involved, which is incorporated in the design of the project. However, several benefits of big science were pointed out by the scientists. Big science has several spin off effects such as creating facilities for other investigations, training scientists, building prototypes of highly specialized technology set-ups, setting research trends for organizations and individual scientists, national prestige. The factors which support big science may vary from country to country. They may be socioeconomic, political or intellectual. In big science, industry needs and available technology play a significant role in identifying research problems.

Little science is a very important part of academic set up as the scientists receive their education and training in universities. Little science is very focused, though it may be of incremental value, a small subset of a problem, or setting up an infrastructure. In India, according to the feedback received from the scientists, government agencies are willing to fund small science projects. The big science projects are covered under separate government budget and they do not impinge upon the little science investigations. Rather, as observed by a senior scientist there is lack of original and good science research proposals.

6. Role of industry in research

Industry does not play a role in promoting or supporting science research, big or small. It is mainly interested in buying and using technology which is tested and can deliver without investing time or money. Research and development in industry is restricted to mainly doing cosmetic changes or customizing and adapting the 'ready to use' or implement ready technology. They do not want to invest in research which has uncertainties. As a result, most big science projects can only be funded by government agencies or groups of government. Therefore, allocation of funds for big science requires political support. Most of these projects have international collaboration. Because of political support they also get more media attention. Kowarski (1977) felt that big science requires a big audience whose role is, not to judge the value of the project of scientists and engineers, but to approve, fund and to provide recruits and he emphasized that it is essential to big science. Sharon Traweek (1992) draws attention from the audience of big science to practitioners of big science, those who are authorized to judge between experiments and runs, between discoveries and measurements, he found that these audiences are ranked, not only individually but also by nationality.

There is an increasing tendency among the scientists in top Indian institutes to be part of large, international collaborative projects (Hindu: 2005). According to this report engagement with big science abroad has inevitably meant a dearth of scientists for important indigenous initiatives such as the Indian Neutrino Observatory which is expected to be set up by 2010. It was the lure of global research that led to the abandonement, in 1992, of promising research deep underground at Kolar Gold Mines. Sadly Indian physicists failed to come together to finance and sustain the operation of that unique lab. Had that work continued KGF might well have been in the forefront of international neutrino research.

7. Conclusion

The study gave us an insight into the dynamics of small science and big science as perceived by the scientists. Both big science and little science projects are being pursued without necessarily affecting each other. But little science continues to be the major form of science research. However its social role appears to be primarily career advancement. There are many government funding agencies to support research projects (DST, Various Ministries and Government departments). But bureaucratic procedures, administrative delays, delays in receiving money and constraints with regard to expenditure allocation are major discouraging factors in applying for research project funding.

Little science research objectives in Indian institutes and universities are primarily shaped by Western trends in science research. Also big science helps setting trends for small investigations. Big science was perceived to be an extension of political prioritization of specific fields of science or specific research areas at national and international level. They receive more public visibility and media coverage. It was pointed out by some scholars that good scientists often join international collaborative groups or move to developed countries for want of better working environment and challenges. Big science projects are characterised by, among several other factors, large amounts of data generation, technology spin-off effects, facility creation, and national prestige. In India as of now there seem to be preference for small science due to organizational, managerial and administrative (bureaucratic) considerations. Our conversations with scientists revealed a very optimistic view of the state of little science in India, in terms of institutional, financial and governmental support. They also claimed that India's recognition in international community comes primarily from individual excellence shown by the Indian scientists.

The present study has its limitations. The study was based on the perceptions of the scientists and the available literature. The opinions may be biased and not representative enough of the relevant scientific community. The author proposes to undertake a more systematic study of the state of little science and big science and their relationship with each other using quantitative as well as qualitative methods.

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SCIENCE AND TECHNOLOGY IN STATE AND POLICY

Jaime Jiménez

Science and Technology Policy in Latin America and the Emerging of New Paradigms

Abstract:

Science and Technology (S&T) policy in modern times has developed in a similar ways throughout Latin America. Almost all major countries started their National Commissions of S&T in the 50s and early 70s with the aim of putting S&T in the service of national development, understood as the solving of crucial problems of their population. Regardless of the funds dedicated to research and development, the contribution of Latin America to the global production of knowledge is still a small percentage of the world total. On the other hand, S&T has done little in terms of national development in Latin America, with a few exceptions. At the beginning of each new government, most Latin American countries formulate their national development plans, which in print look really fantastic in the sense of promising the provision of funds for research in fundamental national problems. The reality is far from that since the control of funds is in the hands of a few top scientists who give priority to projects conducted by researchers already established in the world of science rather than to others whose projects are concerned with local, regional and national problems, with a few exceptions.

However, with the globalization of the economy and the arrival of the new information and communication technologies (ICTs), new S&T paradigms are emerging in the world and alternative ways of doing science are put into practice. The example of Mexico will be taken as a case in point to show how alternative views of participation and development are entering into the scene of Latin America.

Introduction

Science was cultivated in Latin America since pre-Hispanic times. The most advanced cultures in Meso-America dedicated efforts to disciplines as Mathematics, Astronomy, Botany and particularly

Natural Medicine as the Aztecs in Central Mexico and the Mayas in North-East Mexico, and in South America, the Incas along the Andes range. See Figure 1.

After the conquest of the native people by the Spaniards and Portuguese in the so-called Colonial times — from the 16th to the 18th centuries — there was a reduced number of Latin American inhabitants that cultivated the Natural Sciences as the Europeans did. At that time there were no boundaries between the different disciplines so a Natural scientist would have the scientific knowledge of all what was known in Mathematics, Astronomy, Botany or Physics as well. Some Latin American scientists traveled to Europe in the XIX century to learn in the major universities of Europe, in England, France, Germany or Spain. Science was practiced in isolation, with a few exceptions, having little or no communication with their European peers. The Latin American schools of thought were permanently mixed with theories, themes and fashions current in Europe or the USA. However, basic concerns of Latin American science were not necessarily current with international thought often observing a time lag. Science in Latin America did not grow in a continuous, harmonious form; on the contrary, it has had advancements and "pull backs".

Scientific activity has been organized around dominant institutional contexts: the university, the institute with exclusive dedication to research, the science museum, the observatory, the scientific journal. The reciprocal relationships of these institutions were determined by the centrality of the university (Vessuri, 1994:43). It was only at the beginning of the 60s that the university's dominance was reduced by the new relationship of scientific institutions that gradually has taken place in Latin America. The State has had a leadership role in terms of scientific activity in Latin America, acting as an active player through the monopoly of higher education via the public university, as well as the creation of institutions dedicated to research linked with the productive or the service sector.

Stages of Development

Vessuri (1994) has identified five stages of development for Latin American science, beginning at the end of the 19th century up to the 1990s. A brief review of Vessuri's proposal follows.

European positivism (end of 19th and beginning of 20th centuries)

During the 19th century most of the Latin American countries engaged in the economic and political reconstruction after the turmoil provoked by the independence from European powers that took place, for most countries, at the beginning of the 1800s. The economy was primarily supported by the exportation of raw materials; and social, political and economic oligarchies were in the process of solidifying. At the time, there were small groups of scientists dedicated to experimental and natural science. Science, education, European migration, and foreign capital were considered the main instruments for national reconstruction. European knowledge and technology were perceived as needed for national advancement. Europeans and North Americans made scientific expeditions to collect data of nature in Latin America, not always with strict scientific interest. Latin American scientists also made extensive data collections on the local fauna, flora, minerals, topography and ethnography.

Positivism was favorably received as a conceptual framework to allocate history and society in the frame of progress. Comte's thought "love, order and progress" was translated into "freedom, order and progress" in Mexico, and "order and progress" in Brazil, still the current motto of this country. However, positivism did not do much for Latin American science. It promoted a social appreciation of science as a source of progress and practical knowledge. However, it did not materialize as a persistent research effort.

Institutionalization of science: foundation of experimental science (1918–1940)

After World War I, enthusiasm about positivism started to vanish. *Progress* has not been achieved and *order* has been understood as the "status quo" maintenance. Science and development promised by positivism weakened by observing what was taking place in Europe. European leaders' inability to maintain ideals of peace and progress reduced expectancies regarding positivism. Latin Americans learned by experience the difference between scientific research and its application to industry. Science not always resulted in applications. On the other hand, industry could very well develop by empirical knowledge.

During the period between the two World Wars, Latin American societies experienced a deep transformation. Workers' strikes and students' revolts were frequent in those years. Political organization of workers was framed by the organization of communist and socialist parties in Argentina and Brazil. The revitalization of Catholic thought was also noticeable in the region, particularly in defense of religious education. The armies of several countries lived a professionalization process. The growth of a new middle class, concerned with the national problems, created a new market for the Latin American authors, hence enlarging the editorial industry. The professionalization and autonomy of intellectual work was more noticeable in Argentina, Brazil and Mexico.

The universities in Latin America have always played an essential role in the S&T development. Particularly, the creation of the schools of sciences within the universities was of paramount importance for the cultivation of Mathematics, Physics and Biology.

The Argentinean universities were ready to carry out their own internal transformation to face the dramatic changes that took place in society and the economy. The universities were a degenerated version of the Napoleonic university (Tunnermann Bernheim, 1979), dragging a heavy Colonial burden in their educational methods, among other inadequacies. A growing feeling of frustration was gradually taking form among faculty and students that eventually derived in the University Reform initiated in 1918 in the Cordoba University. This reform movement was taken up by the rest of both Argentinean and Latin American universities (Palacios, 1957).

In Mexico, the National University had been operating from different basis than the ones of its predecessor, the Real and Pontifical University, since 1910, year of the initiation of the Mexican revolution. The Higher Studies School, also inaugurated in 1910, was the predecessor of the School of Sciences, created in 1939. The National University was benefitted by the insertion of several research institutes of earlier creation. Likewise, from the 30s on new research institutes were created, becoming the most important scientific institution of the country. The agriculture research was taken up by the Ministry of Agriculture since the 30s. The modern medical research started in the General Hospital in 1922. The Cardiology research initiated in the General Hospital in 1924, had a greater impulse with the inauguration of the Cardiology Institute by Ignacio Chávez in 1944. This is one of the most prestigious Mexican health institutes at the international level.

Similar stories could be told for the major Latin American countries that consolidated their S&T institutions during this period. Brazil, Peru, Colombia, Uruguay and Venezuela accomplished an important institutionalization of science in the period 1918–1940.

"Development" decades (1940–1960)

During the 30s and 40s some scientific leaders demanded public support for basic research, as a means to build scientific communities and reach economic development. But the great economic depression and World War II sparked in Latin America a period of both industrial and urban growth, and education improvement, in a political context alternating populist and authoritarian regimes.

This mix of occurrences that apparently leads to progress encouraged Latin American leaders to formulate a "developmental" ideology: *to associate a fundamental role of both science and university for the economic development of the region.* This ideology was indeed supported and sponsored by the United Nations' Economic Commission for Latin America and the Caribbean (CEPAL). CEPAL credo was:

Adapt and combine technological knowledge to face Latin American problems,

Define priorities from the economy planning view,

Organize research to respond to these needs.

In practice, local manufacture of final, consumer products was the priority, to replace imports. However, the technology used for manufacturing was not of local origin but imported, thus stressing technological dependency. Research and development were consequently ignored.

Scientific policy (1960–1980)

Modernization was the current ideology in Latin America in the 60s. Modernization was thought to lead to higher levels of autonomy, self-confidence and social justice. There was an increase in self-confidence, optimism and hope to build societies more just and equalitarian, in the early 60s. This was the йpoque of both economic and social national planning. However, there was lack of institutional coordination, incoherence between short, medium and long term planning, and complete absence of competent personnel, projects and statistics.

In terms of science, with governments willing to invest heavily in research, some scientists, engineers and government officials were able to implement their cherished projects. As examples there was a major project of atomic energy in Argentina that became an apparent success. Similarly, Brazil developed a macro-project in electronics that produced very positive outcomes. Scientists were able to change the rules of the game because of their unexpected successes.

This was a time of development in scientific and technological capabilities, in industry and management, and in skills of the labor force. This progress introduced meaningful changes in the social structures, and created new sets of social actors. Despite these changes, social and economic conditions of the population remained the same. There was economic development based on growth with no social equality. Industrialization grew significantly to satisfy the internal market, biased in favor of luxurious consumption. Products were more expensive than in other countries with comparable income.

There was lack of leadership of private enterprises in key sectors (automobile, chemistry, capital goods in general), fundamental for technological progress. Scarce participation of private enterprises in R&D, under development in enterprise capability, unsatisfactory growth rates, deep regional and sector inequalities, high concentration of income, growth in the adoption of foreign patterns, substantial increase of the external debt.

Authoritarian regimes product of "coups d'état" were settled in Brazil, 1964; Peru 1968; Ecuador, 1969; Bolivia and Uruguay, 1970; Chile, 1973; and Argentine, 1974. There were ambitious attempts to radically modify the traditional university structures and grant a central role to scientific and technological research in the social and economic planning. Scientific and technological research outside the universities received a strong impulse in both the public and private sectors, in both basic and applied research.

The American model of centralized institutes and departmental organization in the universities was adopted. Graduate studies became the norm in universities. Full time employment for academics became a reality. Requisites to register in higher education were lowered. The higher education system grew. Massive attendance became the most crucial problem. Budgets were never sufficient. S&T councils financed research that could not be done at universities.

S&T councils started to define a scientific policy with scarce results. Brazil is a good example of attempts to conduct from the government the scientific development geared by the economic development. It resulted in excessive funds for research compared to scientific capability. Also, short term efficiency and productivity criteria were applied to research evaluation.

Venezuela was subjected to a rapid modernization process due to the expansion of oil revenues. The educational system also grew rapidly at all levels. The Central University of Venezuela (UCV) took science as one of her key objectives. A new university law was approved to make scientific research a priority in universities. To complement functions the Venezuela Institute of Scientific Research (IVIC) was founded as a center of excellence in Latin America, cultivating a number of disciplines like Biology, Medicine, Physics, Chemistry and Mathematics (IVIC, 2009). In the 60s the participation of USA foundations and universities was notorious through frequent visits of experts and the establishment of cooperation programs. Foreign scientists were contracted to open new research lines, thanks to the oil wealth.

The 60s culminated in many Latin American countries with a student renewal movement, in 1968. In Mexico the demand was for democratic freedom. In Venezuela the movement demanded redefining the university to train scientists and engineers ideologically mature and academically well prepared that would join society with political transforming perspectives. In other Latin American countries the call was for the transformation of the university as a place where major societal changes could be advanced for the betterment of the society as a whole. The movement failed and ends up with university intervention, students jailed and more regulations. In some countries, the state itself removed research from universities to allocate it in public institutes and enterprises, particularly in Brazil. After the failure of the students' renewal movement, the next generations of scientists were politically uncommitted.

A new public for science: the industrial enterprise (1980–1990)

The rhetoric of the industrial utilization of knowledge produced by public universities finally reached Latin America with all its might, in the 80s. However, this rhetoric faced two difficulties: on the one side the opportunities for an industrial science and for a highly qualified labor were not large; on the other, a pernicious gap was open between what is supposedly "useful" or at least "saleable", and knowledge that is purely cognitive. New S&T groups appeared in the dispute for scarce funds with the better established and competent scientific groups. The new alliance between academic science and its industrial application began to develop starting its diffusion among nontraditional fields of research. The fields particularly involved were agronomical engineering, bio-technology, veterinary, pharmacy, natural sciences and management. However, in some countries institutions in the exact sciences have a very intense cooperation with the productive sector, even surpassing the engineering sciences, having produced really innovative solutions in industry.

Grilo, Cerych and Vessuri found that this cooperation implied at times the increase in experimental physics research to the detriment of theoretical physics. In other cases there was a division of labor with the university doing the theoretical component and industry the experimental one, meaning that universities are willing to cooperate with industries that have their own experimental laboratories (Grilo, Cerych and Vessuri, 1990).

Public enterprises are the main clients of public universities. This preference is due to the fact that in Latin America many of the big enterprises are public and have the capability of financing research outside. The major areas of participation are oil, power, water, planning, construction and transportation.

For many years it was thought that transnational enterprises that brought their products or services in packages would not need any local adapting. However, it has become clear that the foreign technology or technological devices need the concourse of local "know how" to adapt to local conditions. Therefore, there is a wide field of applications where local technologists play an important role.

Science in Current Times

The harnessing and institutionalization of science by the Latin American governments started in the middle 20th century on with the creation of the national research councils. These councils were designed following the general lines of the USA National Science Foundation, with the purpose of both formulating a national science policy, and supporting research that could not be supported otherwise. A brief description of the most important councils in Latin America follows.

Brazil and Argentina created their science agencies in the 50s. Brazil founded the National Council of Scientific and Technological Development (CNPq) in January, 1951 "to coordinate and encourage scientific research in the country" (Brazil, 2009). The Argentina's National Council of Scientific and Technical Research was created in February 1958, responding to the socially generalized perception of the "need to structure an academic agency to promote scientific and technological research in the country" (Argentina, 2009).

Cuba, following the model of the Soviet Union, created the Academy of Sciences in February 1962. However, years later the country assumed the format most common in Latin America and founded the National Council of Science and Technology, in June 1974 (Cuba, 2009). The Chilean National Commission of Scientific and Technological Research (CONICYT) was founded in 1967: "it promotes, strengthens and spreads the scientific and technological research in Chile, to contribute to the economic, social and cultural development of the country" (Chile, 2009). Originally CONICYT's main role was to advise the President in scientific matters. It has conjointly supported both fellowships for graduate studies and financed research and development projects.

Venezuela gave a great impulse to science thanks to the oil boom of the 60s and 70s. As mentioned earlier, it became obligatory to carry out scientific research in public universities. Although the National Council of Scientific and Technological Research (CONICIT) was founded in 1984 it is clear the science effort in Venezuela started much earlier, during the 60s. CONICIT was born with the same objectives of the rest of Latin American councils: to formulate the national scientific policy and to give impulse to research that was not done in other scientific centers. CONICIT was transformed into the National Fund of Science, Technology and Innovation (FONACIT) to enhance its functions and make it compatible with the Science and Technology Ministry, in 2001 (Venezuela, 2009).

Two institutions were created simultaneously in Colombia for the promotion of science: Colciencias and the National Council of Science and Technology (CNCyT), in 1968. Recently to consolidate the institutional support for science, Colciencias became the Administrative Department of Science, Technology and Innovation, and CNCyT was converted into the National System of Science, Technology and Innovation (SNCTI), both in 2009. This duplicity of institutions is supposed "to produce and provide the knowledge that the well being of people and the development of the country and its regions require" (Colombia, 2009).

The National Council of Science and Technology (CONACYT) in Mexico was founded at the end of 1970 as a public agency autonomous from the Federal Government, as part of the Education sector (Mexico, 2009). In addition to the enhancement of S&T CONACYT is also responsible for scientific policy. It has promoted the creation of S&T centers along the national territory with 10 centers in "exact" and natural sciences, nine in technological development and services, and eight in the social sciences and the humanities (CONACYT, 2006).

The Latin American effort to formalize the support of science has the official objective of putting scientific research in the service of national development, understood as solving crucial problems of their population. Depending on the country, scientific policy has been formulated in Latin America for about 40 to 60 years, with scarce results in general. To conduct science in the desired direction governments, at the beginning of each presidential term, formulate national plans that include S&T development plans. In print, they look very promising with the assignment of funds for research in fundamental problems. In practice, the control of funds is in the hands of top scientists who give priority to projects conducted by researchers already established in the world of science, rather than to other scientists whose projects are concerned with local, regional or national problems. Casas illustrates very clearly how this situation was unintendedly provoked when the government decides to support science in Mexico since the 30s:

In the moment when the first government agency for the enhancement and organization of Mexican science is created (1935), a link between scientists and politicians is established, thus a transformation of the role that scientists have had of isolation in their laboratories and research institutes took place. However, this situation did not favor but a reduced number of scientists, represented by those who were designated by the executive power (the President) to participate in the new agency. This provoked the formation of elites that channeled the incentives to research and the human resource formation in a subjective manner (Casas, 1985:62).

Also funds dedicated to basic problems -health, water, agriculture, pollution, housing, planning- often do not find counterparts in the scientific community, because for years it has been biased towards the cultivation of themes current in the "big science" Meccas, therefore there are not many scientists ready to cope with local problems.

In conclusion, the creation of these research agencies and the formulation of science policies, with the exception of Medicine and Public Health in some countries, and a few instances in other disciplines, have done little in terms of national development in Latin America. However, science institutions have grown in the continent along the years. As Casas asserts:

It is very reduced the influence that these agencies have had in the advancement of scientific research. However, this has not been an obstacle to develop a scientific infrastructure, fundamentally promoted by higher education institutions, thus generating a system of research institutions unlinked from the socio-economic needs of the country (Casas, 1985:62).

A New 'Social Contract' (Jiménez, 2009)

Concurrently, toward the end of the decade of the nineties of the past century, the role that science plays concerning society and development comes under serious scrutiny. In the past, science policy was based mainly on acts of faith. Faith that research activity would conduct naturally to technological innovation, which in turn would guarantee economic growth, and thus social cohesion and peace. It was believed with certain naпvetй that 'what is good for science, is good for humanity', leaving science policy decisions in the hands of scientists.

Currently, such acts of faith are severely challenged in light of the fact that scientific and technological advances that have contributed to economic development, have also brought about irreversible ecological deterioration, technological disasters, and the development of massive destruction weaponry of low cost and difficult dismantling. All of the above unfortunately associated to the exacerbation of social inequality, exclusion, and the increase in the asymmetries between nations, in terms of wealth and power.

The above challenges motivated UNESCO to organize the World Conference on Science: 'Science for the 21^{st} Century' (1999, a & b), in Budapest in 1999. The objective of the Conference was the formulation of a new relationship between science and society, that is, a new 'social contract' (Mayor, 1999), based on the assumption that science is to be subjected to public scrutiny. The debate on the need for a democratic discussion of scientific priorities, the size of its budget, its institutional structure, and the use that is given to the results of scientific labor, was recuperated. It was asserted that such decisions cannot be left simply in the hands of scientists and government officials.

At the Budapest Conference, emphasis was also made on the point that scientists must not orient their research solely toward topics that appear attractive grant-wise, as are military research and research that responds to market requirements, but also topics related to general social interest. Scientific research must not be developed as isolated disciplines, but based on inter and trans-disciplinary approaches that will bring about a convergence between natural and social sciences, as a means to understand reality fully, and to transform it. What is sought here is to confront with greater possibilities of success the challenges that the 21^{st} century presents, in terms of advancing toward a society with greater liberty and equality among men around the world.

From the Budapest Conference it is acknowledged that we must create the framework for a *new social contract with science,* based on the participation of large sectors of society, and not only on those currently having a stake in it. A new contract where decisions are made based on large social networks. This is not to say that organizational forms for decision-making that have been perfected throughout the past and that, in general, have produced good results for the advancement of science, must be dismissed.

The objective is to obtain a wise balance between academic autonomy and social responsibility, access to results and benefits produced by science and the legitimate individual interests of those that promote it, redistribution of knowledge and copyrights, economic growth and ecological equilibrium, demands that originate in the market and those that do not, long-term and short-term projects, collective and individual interests.

The agenda for a new social contract with science appears complicated. On the one hand, it is not clear whether 'hard' scientists would be willing to yield the privileges they have traditionally enjoyed, sharing their decisions with society at large. On the other, it is not clear how social groups can involve themselves in an informed manner. The ideal situation is to identify ways that allow the points discussed in Budapest to be understood as legitimate topics of public interest, subject to new decision-making mechanisms that go beyond those that utilize experts in corresponding sectors. This set of ideas constitutes the 'Spirit of Budapest'. Indeed, this orientation has been discussed in the past in reference particularly to Latin America (Jimйnez and Escalante, 1990). This social orientation of science does not preclude its use for enhancing the economies of powerful transnational enterprises as shown in the paradigm discussed in the following section.

Emerging New Paradigms

Paradigm Based on the 'Knowledge Society' Concept

As the world goes into the 21st century, it becomes apparent that the nations' economic advancement, both of the First and Third world, is based on *the way they apply knowledge*. It is clear that in terms of the globalized economy, those countries of advanced technology have a competitive advantage over the less developed ones. Although the cheap labor factor still constitutes an element of relative importance in the geographical location of 'maquila' plants, this will gradually lose relevance in light of the technological developments that require each time less relatively unskilled labor force, as firms move to second and third generation 'maquilas', involving a more skilled labor force (Gerber and Carrillo, 2006).

Since the end of the twentieth century, the idea that society as a whole was nearing a new era, the 'era of knowledge' (Albrow and King, 1990; Crook et al., 1992; David, 1992) became fashionable. It came as a novelty to associate *the birth of a new Century with the* *beginning of a new era*. But, what is behind the recognition of a new global paradigm?

Globalization of the economy. This trend, which takes its first steps at the end of World War II with the establishment of the *General Agreement on Trade and Tariffs* (General Agreement on Trade and Tariffs, 2006) in 1947, gains momentum in the decade of the 1990s, with the creation of the World Trade Organization (World Trade Organization, 2006) in 1995 and the establishment of diverse free trade agreements, geared to promote, regulate, and standardize free trade throughout most part of the world: as of 1997, these comprehended 90% of all international trade, comprising most countries except China, some former communist countries and other small countries (Anderson and Cavanagh, 1997).

Competition for world markets. The large global economic blocks are engaged in a battle to conquer world markets, where the products and services with greater technological content and lower cost, flood the markets of the entire globe without notice. It is clear for the large corporations that the investment in research oriented to applications and frontier technology, results in economic benefits in the mid and long-term, and at times in a reasonably short-term.

Vertiginous technological development. The scientific and technological research that took place during World War II was the basis for the impressive technological advance observed in the second half of the 20th century. The developments in micro- and nanotechnology, bio-medicine, genetics and other disciplines and transdisciplines, set the pace for the constitution of a society that would not be understood without the contribution of the scientific and technological knowledge achieved in recent decades.

Advancing communications. The speed at which any type of information is disseminated today surpasses the most fertile imagination of the past. This has allowed that both the information related to current research, and that related to international trade, markets and state of global finances, be disseminated almost at the same time of occurrence.

The 'reification' of science and technology. The fact that science and technology is increasingly becoming a commodity, thought in terms of markets, competitiveness and commercial product development (Elzinga, 2004).

The common belief that 'knowledge is power'. This assertion assigns to scientific knowledge the capability of domination in the economic, political and social spheres, as knowledge itself is held to be the most important factor of production.

As stated before, the national economy of any country is heavily dependent upon the degree of advancement of its technology. As a consequence, the importance of both labor and capital has diminished. This does not mean that technology is sufficient to generate advanced products and services. It is, of course, necessary the concourse of both labor and capital as well. Technology does not develop all alone, only by its own impulse, but it is supported by scientific discoveries. Hence, technological advancement is the intelligent combination of both scientific and technological knowledge. Therefore, if a country wishes to improve its lot in the global economy, it must pay attention to the development of both technology and scientific research.

Were S&T absent in the past? Of course not! However it was possible to replace them with labor and capital to a certain extent. Currently, ruthless competition for international markets puts in a prominent role the generation of new knowledge. The key to remain in the market is: *speed of innovation.*

At the end of the twentieth century, some authors observed that in previous years, the way of 'producing knowledge' had changed, and proposed a new model (Gibbons *et al.*, 1994; Nowotny *et al.*, 2001, 2003, 2005). Concurrently, other authors observed that research in universities was undergoing some significant changes in the forms of knowledge it produces (Fuller, 2000, 2003). According to Gibbons and associates, this new way co-exists with the traditional form, and it comprehends not only science and technology but also the social sciences and the humanities, to the extent these areas of knowledge approach the modes of operation of the 'hard' sciences. It affects:

- What knowledge is produced.
- How it is produced.
- The context in which it is pursued.
- The way in which production is organized.
- The systems of reward it activates.
- The mechanisms that control the quality of what is produced.

(Gibbons *et al.,* 1994 : vii).

These characteristics are firmly articulated in the case of the 'hard' sciences: Physics, Chemistry and Biology. Insomuch as the social sciences and humanities have tried to follow the 'hard' sciences in strictness, similar social systems have been implemented to govern production of knowledge in these areas (Gibbons *et al.,* 1994: vii). To distinguish them from the traditional form, these authors denominate the new mode of knowledge production 'Mode 2', and named the classical way, 'Mode 1'.

What follows are some characteristics of Mode 2, *in the context of application*:

- Problems are not restricted to a discipline or a group of disciplines (multi-disciplinary), they are trans-disciplinary.
- The work is carried out in non-hierarchical, heterogeneous and transitory organizational forms.
- No preference to university institutionalization.
- Implies close interaction of many actors.
- In light of the above, the production of knowledge becomes more socially accountable.
- Utilizes an ample range of criteria to apply quality controls.
- Mode 2 becomes more flexible and deeply affects what counts as 'good science'. (Gibbons *et al.*: 3–8).

In contrast, the term 'Mode 1' refers to a form of production of knowledge — a complex of ideas, methods, values and norms — that has been developed to disseminate the Newtonian model to more and more fields of inquiry and insure that what is considered 'established scientific (formal) practice' is observed. Table 1 compares the main characteristics of the two modes of producing knowledge, according to their authors.

Mode 2 includes a larger group of 'practitioners', that are temporary and heterogeneous, that collaborate in a problem defined in a specific and localized context.

According to this orientation, there is a potential imbalance between the *volatility* and the *permanence* of institutions that cultivate Mode 2 knowledge production. This is a new situation that appears as intermediate between stable and flexible organizational forms. The production of knowledge is each time a less self-contained activity. It is neither the 'science' of the universities or the 'technology' of industry (Gibbons *et al.* 1994: 156). Authors assert that a fundamental change in Mode 2 consists in that *the production of knowledge is each time more a 'socially distributed' process* (Gibbons *et al.* 1994: 156), meaning that this type of knowledge is both supplied by and distributed to individuals and groups across the social spectrum. This assertion is based on the following attributes of Mode 2:

- It is highly contextualized.
- 'Marketable knowledge'.
- Porosity of disciplinary and institutional boundaries.
- Interchangeable scientific careers.
- Trans-disciplinarity in other than 'hot' topics.
- Growing importance of hybrid fora in the configuration of knowledge.
- Fora constituted by experts and non-experts as social actors.

(Gibbons *et al.,* 1994: 156).

Policy for technological innovation

The explanation that the proponents give to the emergence of this new model of doing science, is that the economic decline of the eighties in the previous century, and the increased competition on a world scale, forced policymakers to reduce their perspective on the role of science in the achievement of national objectives, and 'straddle' scientific activity of industrial innovation and competitiveness. Science policy moved towards technology as a more effective way of supporting national industry.

In part this change was a response to the lower competitiveness of the United States *vis-a-vis* Japan. In part decision-makers arrived at the conviction that the technological base of the world economy had come to an end.

How does this change impact the University? The vision of the University in Mode 2 consists of going from being a monopoly in the knowledge production, 'a social technology for the production of universal knowledge' (Fuller, 2003: 217), to a 'partner' in the national and international contexts. It will imply a redefinition of *excellence* among academics (professional aspirations, contributions to the discipline, institutional loyalties). Since competition will be more open, the University will need to identify 'niches' of specialization where it becomes more competitive (Gibbons *et al.,* 1994: 157).

According to Nowotny and associates (2005), Mode 2 was espoused most warmly by politicians and civil servants struggling to create better mechanisms to link science with innovation. This linkage not necessarily responds to increased social accountability. Moreover, the research examples given in Gibbons *et al.*, refer to applications benefiting a reduced number of stakeholders, without any reference to general societal needs. Mode 2, despite the claim to that effect, responds more readily to the needs of a market which does not necessarily take into account the needs of society as a whole. Indeed, Jimйnez has found in many places of the world what he calls *Mode 3 knowledge production*, that distinguishes from Mode 2 because it is really *socially responsible*, in the sense that it responds to societal needs, be it local, regional or national (Jiménez, 2004, 2007, 2008, 2009; Jiménez and Escalante, 2007; Jiménez *et al., 2008*).

Some examples of Mode 2 research are the hypersonic aircraft combustion problems at Mach 5 or 6, and specific problems related to the construction of 5th (6th?) generation computers.

How does Latin America do in the context of Mode 2 knowledge generation? It has minimal participation mainly in some topics of Biotechnology, Biomedicine and software production.

New Invisible Colleges Paradigm (Wagner, 2008)

Recently, Caroline Wagner (2008) has worked on the consequences that the new information and communication technologies like the Internet have on the development of modern natural science, globally. As Fukuyama ascertains: "Unlike technology, a great deal of research in basic science has the character of public good: it is hard to exclude people from its benefits, and most important, it can develop only in an atmosphere of free and open exchange" (Wagner, 2008: viii). Fukuyama is convinced that: "*the development of modern science is an emergent social process, international in scope and cannot be effectively controlled by governments.* And yet it is the taxpayers of different nation-states who are asked to fund this process" (Wagner, 2008: ix, emphasis added). Indeed, natural science has become more universal than ever before, and the *networks* created include members of practically all countries of the world. This is an unprecedented phenomenon.

The concept, *invisible colleges,* comes from the 17th century to describe the group of scholars who pioneered observation and experimentation to study nature. Natural philosophers like Sir Isaac Newton and chemist Robert Boyle shared information and insight in *Latin*, in any topic they care to discuss, without disciplinary boundaries. Then as now, *networks* characterized scientific informal organization with scientists corresponding and exchanging ideas and results, in search of knowledge. As the centuries passed, science progressed a long way and became professionalized. Specialized laboratories in biology, astronomy, physics, medicine and others began to appear. The 19th and 20th centuries witnessed the process of nationalization of science. Governments expanded their control over scientific activities and created national scientific establishments, like France's *Centre Nationale De La Recherche Scientifique, CNRS*.

With the expansion of the new information and communication technologies, new and multiple invisible colleges have been created. This has speeded up knowledge production, and has erased borders more than ever. Intelligent use of the CITs may help Latin American countries to make a quantum jump in science development. The key to this new opportunity for development resides on the ability of Latin American academics to connect with scholars at the frontier of knowledge in their mutual areas of interest. That is, to connect universal knowledge with local problems as is the case with the *Regional Scientific Communities* concept in Mexico.

Regional Scientific Communities. This is a concept developed by a group of university professors of agriculture and life sciences. These professors, with twenty or more years of experience in innovative university programs, gathered together to give an answer to the needs of professionals in Veterinary Medicine who needed a higher level of knowledge but lack the time to join a regular graduate program. They designed individual programs that fit the personal needs of students, accommodating to the students' time availability and research interests.

With time, this group created the *Center for Innovation and Educational Development* (CIDE), in the city of Torreon, Northeastern Mexico. The core idea of the Center is to create regional networks for learning and research that respond to local needs, serving students that are dispersed in a particular geographic region. CIDE's educational system is based on *learning* rather than *teaching*, centered on the identification and solution of problems. The way of placing the students in the frontier of knowledge is by the use of powerful search engines in the Internet to identify leading scientists in their field of interest, and contacting them via e-mail. Regularly, the students get a favorable answer from scientists engaging in an interchange of information and even collaboration on specific projects. All this is possible as long as the students can dispose of state of the art information and communication technologies.

Two doctoral dissertations defended in CIDE in 2008 illustrate the creation of networks that connect universal knowledge to particular problems:

"Molecular Identification of Coccidioides Spp in the 'Comarca Lagunera' Region (Northeast Mexico): A New Endemic Area for Coccidioidomicosis", by Rocío González Martínez. The coccidioidomicosis is a lung mycotic illness present in Southwest USA, North of Mexico, and several semi-arid regions in Central and South America. It is produced by a fungus named coccidioides spp currently present in soils with arid climate, alkaline soil, high temperatures in the summer, some freezing weather in the winter, scarce rainfalls, and low altitude. The fungus is transported in the atmosphere by the wind, and then inhaled by the region's inhabitants (González, 2008). This research proved the existence of an endemic area of coccidioidomicosis in the "Comarca Lagunera", Northeast Mexico. This discovery will help to diagnose the illness correctly, often mistaken as pneumonia, thus giving the patient the right treatment, and saving many lives. Figures 2, 3 and 4 show diverse aspects of this research project.

"Hyper-accumulation of Gold Chemically Induced in eight Vegetal Species", by Víctor Manuel Wilson Corral. In 1998, it was discovered that the gold absorption may be induced in plants. This procedure known as *induced hyper-accumulation* has called the attention of both scientists and entrepreneurs (Wilson, 2008). Mexico, with a long mining tradition, did not have a team of scientists to research in "phytomining". Víctor got in touch with the only two existing specialists in the world, one in New Zealand, the other in Switzerland. He experimented with eight plant species. Found that three species yielded a profitable gold "crop". He became the third specialist in phytomining in the world! Figures 5 and 6 display some of the stages of phitomining.

How Has Scientific Production Grown Worldwide?

There are different ways to estimate the growth of science both nationally and internationally. There are no "exact" indicators, however some give a reasonable idea of the distribution of scientific "output" that helps to compare both among countries and continents. For comparative purposes, we chose the "number of papers published" in 1994 (Gibbs, 1995: 76) and 2008, included in the Science Citation Index (SCI, 2009) registered by the Institute for Scientific Information (ISI, 2009) as our indicator. ISI records the publications of "mainstream science viewed through the astigmatic lens of the most influential journals" (Gibbs, 1995: 76). There were some 3300 journals included in the Science Citation Index in 1994. The data for 2008 were collected directly from ISI (2009).

Figure 7 shows how scientific production has significantly grown in Asia from 1994 (19%) to 2008 (24%). Likewise, it may be observed a reduction in the European output, while the North American Continent remained about the same. Latin America more than doubled its productivity, yet remaining as a small proportion of the world total (3.6% in 2008).

Who is responsible for the Asian growth? China, which depicts a growth from 1.4% in 1994 to 7.3% in 2008. India also grew considerably: from 1.7% in 1994 to 2.5% in 2008. These figures clearly show the correlation between economic and scientific growth, once again. Figure 8 shows China's and India's participation in the Asian scientific growth.

Summary

Despite growth in the past 15 years, Latin American science still plays a minimal role in the world of science. According to the number of papers published, registered by the Science Citation Index, although Latin American contribution more than doubled, from a 1.7% in 1994 to a 3.6% in 2008, it still remains as a small percentage of the world total. Figure 9 shows a comparison among Latin American countries between 1994 and 2008. Latin American ranking by countries in terms of paper publications is as follows, in 2008:

- Brazil,
- Mexico,
- Argentina,

- Chile,
- Colombia,
- Venezuela.

Latin American science has been mostly dependent on the scientific “Meccas”. It lags behind advanced countries. A high percentage of research is peripheral to First World current themes. Regardless of national scientific planning, solution of national/regional/local problems is not the priority. A better balance between national/global projects should be achieved. This is not to say that Latin American scientists *should not* participate in the “big science” arenas. Of course they should. However, more scientific potential should be allocated for the solution of national/regional/local problems, as Rocío González Martínez is doing in her fight against the *Coccidioidomicosis (*González*, 2008)*.

ICTs should be used to connect local with global problems, local with global opportunities. There is a wide area of current research done in the First World that could be used to the advantage of Latin American countries in the sense of approaching development of poor, marginal communities, as Víctor Manuel Wilson Corral is doing concerning the exploitation of novel technologies as *phytomining*. Mexico has plenty of abandoned mineral lands where there used to be processing of precious ores (Wilson, 2008). The key to success is to identify the right scientist that would be willing to collaborate with local research.

Finally, is there any hope for a better balance between “big science” and “science for development” in countries like Mexico? Yes, there is! Very recently, in the Yucatбn State is being built a science park dedicated exclusively to research in:

- Water,
- Health,
- Energy,
- Food,
- Education,
- Environment (Morita, 2009).

To give an answer to the regional needs of the Yucatбn State. This initiative is of local origin, that is, it has nothing to do with Federal plans, although some Federal funds will contribute to the creation of the park. This is a sample of what many states in Mexico should do, and, by their own initiative, support the type of science geared towards the benefit of the population at large.

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MODE 1	MODE 2
PROBLEMS PROPOSED AND SOLVED BY A SPECIFIC COMMUNITY	PROBLEMS PROPOSED AND SOLVED IN THE CONTEXT OF APPLICATIONS
DISCIPLINARY	TRANS-DISCIPLINARY
HOMOGENEITY OF RESEARCH TEAMS	HETEROGENEITY OF RESEARCH TEAMS
PERMANENT HIERARCHICAL ORGANIZATION	TRANSITORY HETERARCHICAL ORGANIZATION
PEER QUALITY CONTROL	QUALITY CONTROL BY DIVERSE ACTORS
LESS SOCIALLY ACCOUNTABLE	MORE SOCIALLY ACCOUNTABLE AND REFLEXIVE

Source: derived from Gibbons et al. (1994: 3).

Table 1. Comparison of the characteristics of Mode 1 and Mode 2 of knowledge production.

Figure 1. Map of the American continent showing the Meso-American region where the Aztec and Maya civilizations flourished. The Inca culture settled down along the Andes range in South America, downwards along the Pacific coast.

Figure 2. Survey taken among rural population.

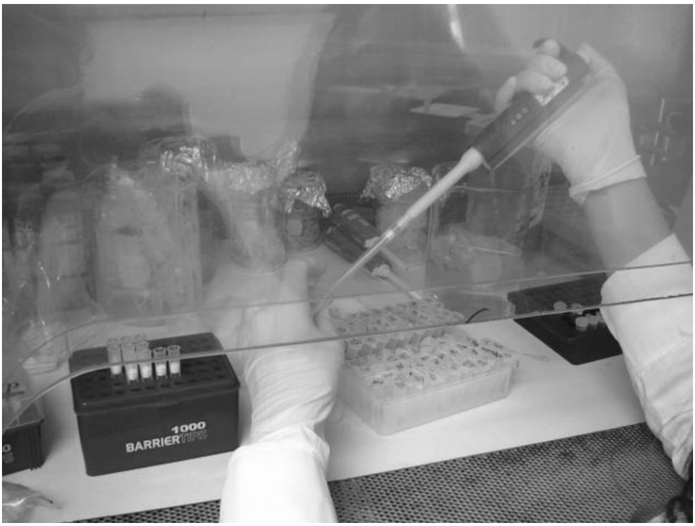


Figure 3. DNA extraction in the coccidiosis research project.

Figure 4. Measurement of coccidiosis epidermis effects.

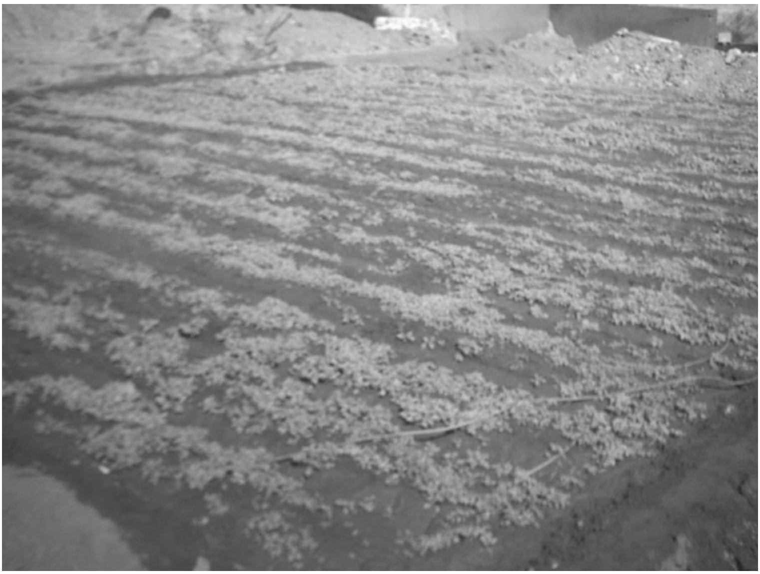
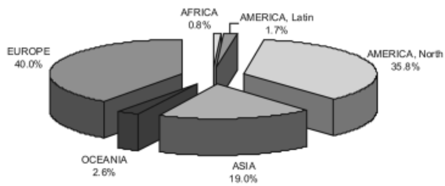


Figure 5. Gold absorption induced in plants.

Figure 6. Phytomining in action.

Ranking by Continent - 1994

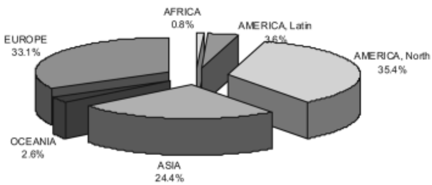
Continent	Participation
AFRICA	0.78
AMERICA, Latin	1.68
AMERICA, North	35.12
ASIA	18.63
OCEANIA	2.58
EUROPE	39.26



Source: Scientific American August 1995

Ranking by Continent - 2008

Continent	Participation
AFRICA	0.80
AMERICA, Latin	3.61
AMERICA, North	35.41
ASIA	24.43
OCEANIA	2.65
EUROPE	33.11

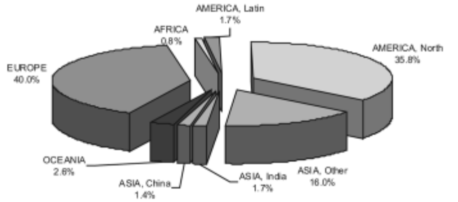


Source: Articles indexed in the ISI Web of Science, corresponding to year 2008.

Figure 7. Scientific productivity measured as the number of papers published in international prestigious journals, by continent, for 1994 and 2008.

Ranking by Continent - 1994

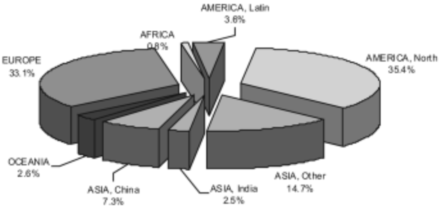
Continent	Participation
AFRICA	0.78
AMERICA, Latin	1.68
AMERICA, North	35.12
ASIA, Other	15.65
ASIA, India	1.64
ASIA, China	1.34
OCEANIA	2.58
EUROPE	39.26



Source: Scientific American August 1995

Ranking by Continent - 2008

Continent	Participation
AFRICA	0.80
AMERICA, Latin	3.61
AMERICA, North	35.41
ASIA, Other	14.65
ASIA, India	2.51
ASIA, China	7.27
OCEANIA	2.65
EUROPE	33.11



Source: Articles indexed in the ISI Web of Science, corresponding to year 2008.

Figure 8. Scientific productivity measured as the number of papers published in international prestigious journals, by continent, showing the production of China and India separately, for 1994 and 2008.

Ranking by Country - Latin America

Country	Continent	Published Articles	
		1994	2008
Brazil	AMERICA, Latin	38.54	53.70
Mexico	AMERICA, Latin	19.81	16.41
Argentina	AMERICA, Latin	21.00	12.03
Chile	AMERICA, Latin	10.50	7.65
Colombia	AMERICA, Latin	1.13	3.52
Venezuela	AMERICA, Latin	5.55	2.58
Cuba	AMERICA, Latin	1.73	1.54
Uruguay	AMERICA, Latin	0.00	1.06
Costa Rica	AMERICA, Latin	0.00	0.67
Ecuador	AMERICA, Latin	0.00	0.55
Jamaica	AMERICA, Latin	1.73	0.30

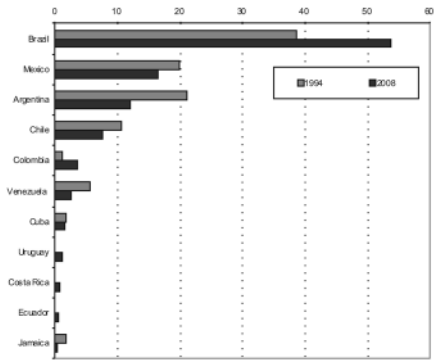


Figure 9. Scientific productivity in Latin America measured as the number of papers published in international prestigious journals, for 1994 and 2008.

Tatiana A. Petrova,
Valentina M. Lomovitskaya

Scientific Elite and Power in Post-Soviet Russia

Abstract:

The topic of the elite, its connection with power structures and society is not new for Russia. It attracted the attention of such Russian philosophers as Berdyaev, Frank, Struve, and Fedotov. The attention of thinkers to the problems of culture, intelligentsia and intellectual elite was not accidental. At the beginning of the 20th century the country anticipated global historical changes. Nowadays the situation is analogous — the country is looking for its place in the social space and changing.

The intellectual atmosphere at the beginning of the 20th century was characterized by the popular ideas of equality, democracy, and service to society and sacrifice in the name of the people. Not everybody was of the same opinion. In his book "Man`s Destiny in Modern World" Berdyaev writes: 'culture undergoes the greatest danger in the process of democratization and equalization'. And later 'justice in democratization which joins masses to culture, has the other side — that is lowering the qualitative level of culture' (Berdyaev, 1994:355–357). Sometime later the Russian philosopher-emigrant Fedotov says: 'Shaken by the fact of social inequality namely really immoral and destroying, the possibility of real national communication we missed the value and eternity of spiritual hierarchy'. However it does not mean that Russian thinkers denied the very idea of national character of culture. Later Fedotov says: 'The national character of culture did not mean the correspondence of the cultural level of masses and the way its orders were implemented. The national character of culture expressed the popular spirit; a man of genius could express it better than the masses' (Fedotov, Vol. 2, 1991:215).

The same ideas as at the beginning of the last century were characteristic for the intellectual situation of Russia in the Soviet period. Only in the new political situation formed after the 1917-year revolution the principles of egalitarianism were not criticized.

In Soviet times research in the elite problem was forbidden due to ideological causes. Social structure was studied in a simplified way:

two basic classes (working class and peasantry) and intelligentsia as an important social group. The prevailing ideology of social equality did not admit the acknowledgment of 'upper' and 'lower' classes, elites and masses in the social structure. When studied, the elite problems were analyzed only critically and applied to capitalist society.

For the first time in many years the concept of egalitarianism was questioned in post-Soviet Russia. There are two causes to account for it. First, the spread and support of ideas of liberalism in society as a whole. Second, the radical changes of the social system, which led to stratification and the appearance of 'upper' and 'lower' stratum. That gave rise to the recognition of a number of theoretical problems and the liberalization of their studies. The problem of intellectual elite is one of them. We consider scientific elite as the intellectual elite. In modern Russia the ideas of such thinkers as A.J.Toynbee, M. Weber, N.Berdyaev, and P.Sorokin gain more and more popularity. They characterize elite as the real creator and transmitter of culture, the one expressing people's spirit, 'bearer of vital passion'. Its mission is to provide adequate 'answers' to 'challenges' of the epoch, to be the true subject of intellectual history. Neither scientists nor power structures oppose the study of the elite problem. Now the following topics are widely discussed within science studies: elite definition, characteristics of its place and role in society, revealing its indicators, the analysis of its reproduction, the study of cognitive and social functions .

Why does society need an elite?

The activity of the intellectual elite is widely acknowledged as a necessary condition of science and society existence. National, political, scientific, financial, art and other elites are the power that potentially and in fact is capable of becoming 'the bearer of vital passion,' the true subject of social history.

At the present moment the role of the scientific elite in the development of Russia is being questioned. Sometimes one can hear such words as: "Russia cannot afford large Soviet science," and "More important practical, economic and social tasks are on the agenda." The position of the state, power, and the corresponding scientific and technical policy are based on the same assumption. In our opinion, such a policy is not only shortsighted, it is distracting for the country, which aspires to a better future.

Modern thinkers have clearly formulated the perspective of future society, where science and knowledge as a whole will play a decisive role. The well-known philosopher Liotard believes that 'in post-industrial and post-modern epoch science retains and strengthened its importance...' 'As informational goods knowledge is and will be the most important stake in the world competition for power'. Further he says; 'More than that knowledge and science are the foundation for the national independence and freedom'; 'all peoples have the right for science, thanks to the dissemination of new knowledge among the people the nation itself gets the possibility to win its liberties' (Liotard, 1998: 19–20, 79–80).

Western world, shocked by the first Soviet sputnik (satellite) and appreciative of Soviet science achievements immediately responded increasing subsidies in education and science. The famous American sociologist B.Barber recollects: 'American contempt for Russian science was thrown away and extensive resources flew to the universities. The only new scientific subject that came to life at that time was studies of history and social aspects of science'. (Barber, 1996:28).

Russia, now looking for its own way in the complex contradictory modern world, cannot do without science and the intellectual elite, its creators.

In the 90s, the Russian state practically "turned its back" on science. Funding for science was sharply curtailed; "the state order" practically did not exist. The scientific and technical policy of the state was inadequate, it did not exist. This situation gave birth to a number of negative consequences: unique scientific laboratories disintegrated, young promising scientists emigrated, the prestige of scientific work sank.

Under these conditions the role of the elite increases as never before. This is because of the important functions the elite implements; here cognitive development is crucial. The essence of this function is the free search for scientific information, creating new scientific knowledge, and rational, theoretical reproduction of reality, providing description, explanation and understanding of the world. While engaging these tasks, science does not limit itself to stating facts; it also goes on to practical action and forecasting possible developments in society. As a cognitive function, forecasting occupies an important place. Here we discover in what way the scientific elite enters a practical area when investigating problems of cognition, becoming the subject of social activity, capable of setting cultural, political and economic orientations for the nation's development.

In Soviet Russia, it was rather difficult for the scientific elite to carry out its cognitive functions. Duing that period, social conditions were the main obstacle. The important condition of the intellectual elite functioning properly is the free search for scientific information. At that time in Russia, scientists had no possibility to choose the area of their investigation by themselves and were not free in opinion exchange. Information and communication with the world scientific community were limited.

In post-Soviet Russia, the implementation of social-political and power functions by the scientific elite turns out to be no less important than the cognitive ones. The scientific elite can put into practice these functions only if it perceives its social duty and mission.

The sense of elite social and political functions is in the following. First, destroying the status quo of power relations the elite assumes power obligations by participating in power structures. There are such examples in the history of modern Russia. In the recent past, the intellectual elite has joined the organs of higher state power, though previously it was in opposition to this power.

Second, the intellectual elite may remain in 'eternal opposition' carrying out a critical function and refusing to join power structures. A. Solzhenityn, our famous thinker and writer, is the brightest example. In this case, elite intellectuals question "state directions in the name of civil society as its members, if they consider that the state does not represent adequately the society" (Liotard, 1998:89).

Third, under present-day conditions the management of scientific and technical development is exceptionally important. This means that the scientific elite has to undertake new power functions, in other words, responsibility for managing scientific and technical development, minimizing the social risk brought by it. A scientist is a representative of the scientific elite who finds himself involved in processes of social and political management when lobbying the interests of scientific community and society as a whole. These interests concern positive decisions regarding scientific and technical problems. Subjectively, most successful scientists are not eager to take part in management. But under the sense of duty and social responsibility, they actively participate in scientific management.

We believe that the above named social, political and cognitive functions of the scientific elite prove the necessity of having an intellectual elite for civil society and the state. But, society and the state must not only support it; they must work out an effective policy in respect of science and its elite. The elite partaking in the management of scientific and technical development is a more effective way of its realizing power functions than direct participation in power structures. The elite is duty-bound to influence both power and public opinion and to increase science prestige. It has to look for instruments of persuading power so that constructive policy is created; the elite must explain to power the importance of science as a base of high technologies, which will allow the country to transfer from a raw material-based economy to a high technology one.

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Sujoy Kumar Saha

Role of Parliament in Framing and Implementation of Government Science, Technology and Innovation Policy in the Post Liberalization and Globalization Days

Abstract:

Science, technology and innovation system and its governance is becoming more and more complex as the time roles on due to liberalization and globalization. World parliaments have to play an important role in framing and implementing the science and technology policy and its governance. This paper makes an in-depth review of the complex science and technology governance and the interaction between the dealings of parliaments and the fields of science and technology. Parliaments must deal with the science and technology legislation in the ambit of their structures and processes and must play a definite role for the scrutiny of government policy. The paper deals with UNESCO's initiative on Inter-Parliamentary Fora on Science and Technology which unequivocally states that government policy-makers, parliaments, scientists and technologists, industry, the electronic and print media and peoples' representatives of the civil society must engage in an active and effective dialogue for better governance of science and technology. The paper also includes the conclusions and recommendations of seminars on parliamentary science, technology and innovations organized by UNESCO, ISESCO and other partners to help and advise member states in science and technology legislation.

Introduction

Science and technology contribute to eradicate poverty and promote sustainable development and fast track economic growth. Scientific fields for policy-making and capacity building include agricultural production, energy use, water resources management, health services, knowledge sharing network in societies, the digital divide and gender equality. The experience of newly industrializing countries such as India shows that this requires a major reform of national science, technology and innovation systems with UNESCO acting as an advisor to governments for integrating their sustainable development priorities into their national science policies. Good practices for strategic planning must be promoted in the interest of evaluation of research and development in science and technology. Basic science and technology education must be major priority actions of the government. There has to be enhancement of scientific capacity through the national, regional and international centers of excellence and mutual cooperation. The parliaments of the world can take initiative in this regard and their positive and definite actions can go a long way for the sustainable development of the world as a whole.

Objective of this paper

The objective of this paper is to discuss the role of parliament in framing and implementation of government science, technology and innovation policy, especially in the post liberalization and globalization days.

Main Text

At present research in science and technology deals with macro, meso, micro, nano and still smaller space scales and different time scales. Science and technology systems are evolving at a break-neck speed replacing the conventional practice of the science and technology. Thus better understanding of scientific and technological process with its associated uncertainty is very important. Much deliberation is necessary before framing the government science and technology policy in different areas of extended human knowledge domain.

Now, these deliberations are to be made in the institutions of governance, i.e. unicameral or bicameral parliaments. These days virtually there are no sphere of human activity unaffected by the scientific and technological developments; therefore, there is a basic need of political action and decision. Scientists and technologists cannot avoid their responsibility of providing politicians with much needed knowledge data and information. Political leaders, in their turn, must analyze those valuable data and arrive at policy decisions implying far-reaching consequences and impact.

Members of parliament must have access to the adequate specialized scientific and technical skills necessary to arrive at policy decisions and governance. Parliamentary institutions must overcome the difficulty in addressing the fragile developments in modern societies confronting technological revolutions and knowledge developments. Parliaments must have the room for debates on controversial issues created by genetic engineering, human cloning, etc.

Parliaments must be concerned and engaged with key issues in every human activity under the sun dealing with science and technology, e.g., economics, commerce and industry, financial institutions, any kind of research, primary, secondary and higher education, technical education in particular, public health care, information technology, bio-technology, oceanography, life sciences, ecology and sustained development, flora and fauna, environment, natural resources, etc. Parliaments are responsible for the development of an overview and framing regulations to be enforced in the land under governance. Dissemination of knowledge of uncertainty in scientific theory and predictions beyond the walls of conference and seminar halls is not that easy. These uncertainties seldom appear in the parliamentary debates, in the court hearings or in the print and electronic media. Framing a policy in such matters becomes additionally more complex and decision makers are baffled with hurdles blocking the emergence of a scientific and technological decision. This has become increasingly more transparent in the post liberalization and globalization days.

Citizens, now-a-days, in general are better informed. They are aware of complex scientific and technological innovations and discovery. However, the common people are reluctant to develop a public opinion in controversial issues and they expect their elected representatives in parliaments to take the lead and scrutinize and after that take positive and effective legislation.

There has to be a healthy interaction between the state, the market and the civil society. Parliaments often look forward to the inputs from government agencies, non-governmental organizations, public and private industry, academic institutions, research establishments, labor unions, professional associations, etc. for developing a cozy environment necessary for strategic decision and policy implementation.

Members of the parliaments, therefore, need proper education, training and experience to deal with the whole complex array of problems, processes and new developments with its entire technicalities to aid the federal and provincial governments they scrutinize for science and technology policy decisions.

Now-a-days, any policy making is done after a long interaction with government representatives, private enterprise as well as non-governmental organizations. Complex dynamics in the contemporary world makes new forms of regulations and governance replacing established government norms. Government policy framing and implementation is largely affected by market agents with diverse economic interests, public interest groups, social movements and activists, self-help organizations and various professional associations with different motivations and goals of political, economic and idealist dimensions, e.g., industrial and labor market conditions, environment, natural resources, consumer interests, genetic engineering and gender differences.

Participation of stakeholders of policy decisions is very important. Stakeholders mean the technology providers and users who will be potential beneficiaries of the policy; on the other hand, those who might be badly affected by the policy. Public participation in this regard has to go a long way and it is still evolving. Decision-makers must be mandated to invite public debate before adopting a science and technology policy and the development, deployment and regulation of a particular technology.

In this paper, parliaments need not necessarily mean national level parliament; these may be supranational European Parliament of the European Union, etc. with definite technology assessment service. A parliament may be uni-cameral or bi-cameral; members of a particular chamber of the parliament may have specific relevance to science and technology.

Parliaments may have formal structural committees, formal procedures for debates or informal structures of various unofficial groupings. Parliament may mimic a ministerial structure of government it scrutinizes. Parliament may address science and technology issues in several ways as follows:

- Parliament may have a permanent autonomous science and technology committee which may interact with other permanent committees as and when necessary
- Science and technology may be within the remit of a trade and industry or commerce or economic affairs or education and research committee which will also take care of the wealth creation, innovation and ennobling aspects of science and technology

- Science and technology may be segmented area wise and each segment may be assigned to a subject area committee
- There may be a temporary commission or delegation comprising of parliamentary as well as non-parliamentary members for science and technology policy to take care of some kind of crisis as an urgent measure
- Since science and technology is often manifestly an inter-ministerial matter, the Prime Minister may directly look into this through a specific prime ministerial agency. Also, there may be a more evolved parliamentary technology assessment structure over and above a traditional science and technology committee to assist a wide range of committees.

There may be archetypical formal parliamentary procedural debate, sometimes in a plenary session, on annual reports prepared by different science and technology agencies on different issues. These parliamentary debates may emerge as formal legislation followed by a law of the land under governance. The legislation may include the proposition of budget and means of fund mobilization.

Standard parliamentary procedure may be followed where questions may be asked by the members of parliaments or senior civil servants to individual ministers who will answer systematically and regularly on science and technology related matters.

Mood of the parliament may be expressed by the members of the parliament by motions or petitions giving their opinions and under certain circumstances this may have debate eventually leading to even legislation.

There may be informal party-based parliamentary groupings to discuss science and technology issues and the summary of this discussion may be given to government ministers. Also, clubs, associations of members of parliaments and non-parliamentary professionals and experts in the field of science and technology may interact on critical issues. The non-partisan structure and operation of such clubs and associations may be ensured by the parliament to avoid and lobbying influence on parliamentarians.

Non-parliamentary entities like science and engineering academies, learned societies, technical trade unions and associations, corporate sector having science and technology base may have parliamentary liaison offices for dialogue with the parliament and these organizations may have specific lobbying function.

Parliaments may cater to the need of science and technology policies through committees, delegations, libraries and research services. Parliaments may also have special support services dedicated to science and technology. Parliaments are ephemeral in the sense that the same members are often not re-elected and, therefore, support services of parliaments may have its secondary function as permanent institutional competence and memory. Parliaments may have clerk, specialist assistant or committee specialist to do the science and technology policy related jobs. A central research and information service or specific science and technology section of the parliament with dedicated adequate budget may be meant for research studies. There may even be a dedicated parliamentary science and technology interface to render the assessment services.

- Parliamentary technology assessment services may be of different models:
- A specific office within the parliament where the internal staff primarily prepare the research studies or the office can act as a research manager and the studies are done by outside contractors
- A specific parliamentary committee which remits the functions of science and technology policy issues among jobs of other parliamentary committees. This committee is different from specific orthodox science and technology committee which does only the science and technology related jobs
- A specific office external to the parliament which gives fixed-term contract to the office, and the office may or may not do the government jobs. This parliamentary contract to the most favored office partner may be on regular basis or may be occasional.
- The ephemeral nature of parliament may be counteracted to some extent by creating a sense of permanent involvement in the psyche of the parliamentary staff and a sense of ownership among the parliamentarians.

UNESCO and ISESCO take the initiative to arrange periodically international roundtable on science, technology and innovation policy and parliament perspective in parliaments' structures, methods and concepts framework to deal with the policy. International fora of parliamentary science committees, the scientific community and the representatives of civil society have been created for closer cooperation, exchange of information and experience, strengthening of the capacity of parliamentary science committees and partnership of the stakeholders, harmonizing the principles in great diversity of circumstances. This is done by convening workshops, seminars, etc. at provincial, national, regional and international levels, publishing newsletters, maintaining websites, etc. Regional pilot projects and inter-parliamentary science and technology policy fora of UNESCO make this cooperation more effective by providing a platform for dialogue, identifying good practices and developing parliamentary mechanisms for governance of science and technology. There is a definite need of closer cooperation between parliamentarians, policy makers, scientists, public and private sector industry and the print and electronic media at all levels, from the sub-national to international. The parliamentarians need to be trained in future scientific developments and UNESCO as an international platform of cooperation can serve as a clearing house for all existing procedures. Partnerships between academic institutions and industry could be facilitated by agencies such as technology parks or incubators. The government should establish appropriate institutional and financial mechanisms, including programmes of capacity building and training, to ensure that the national science, technology and innovation development policies can be implemented and the coherence and consistency of science and technology policy can be improved.

Conclusion

The role of parliaments of the world in framing and implementing the government science, technology and innovation policy in the present days of liberalization and globalization of research has been discussed in detail.

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Suprakash Chandra Roy

Challenges in Scientific Research and Science Policy

Liberalization and globalization go hand in hand. If we Google the word 'liberalization', the number of hits is more than 3,460,000 (about 3.5 million) while the corresponding number for 'globalization' is 24,800,000 (about 25 million). Globalization is thus discussed more than liberalization. If we trust the definitions in Wikipedia, we find that "globalization in its literal sense is the process of transformation of local or regional phenomena into global ones. It can be described as a process by which the people of the world are unified into a single society and function together. This process is a combination of economic, technological, socio-cultural and political forces." The term 'liberalization' on the other hand, "refers to a relaxation of previous government restrictions, usually in areas of social or economic policy". In the arena of social policy it may refer to a relaxation of laws restricting human actions like travel, marriage, or importing equipment, among others. Legalising anything does not necessarily lead to its implementation immediately. Liberalization, in a true sense, is coming out of an orthodox setup, to accept changes for the benefit of humanity. Acceptance and implementation of any change requires a liberal attitude in the receiver. For example, in recent years inter-faith marriages are being accepted much more willingly than, say, fifty years ago, because we are now more progressive in our understanding and attitude.

From these definitions it is clear that liberalization and globalization are intimately connected. Liberalization is the first step in the process of globalization. In social life also, we could embrace the whole world as one, as '*basudhaiba kutumbakam*' (entire world is your own people), if we are liberal in our attitude.

Neither liberalization nor globalization is anyone's invention; it is a law of history. Liberalization is a process which gets invoked automatically as science advances. Historically, scientific research has been characterized by individual work. And liberalization (or even globalization) is an indispensable process required to march forward in science and technology. Europe, for example, procured intellectual traditions from other parts of the world, specifically from China, India and the Middle East[1]. The windmill had come into Europe from Persia, the compass had come from China, many fundamental mathematical concepts (including the notion of zero) had come from India and the idea of an organized social space for learning had been an Arabic innovation.

Excellence in research in science and technology depends on the policy of the country. The policymakers hold the future of a country in their hands. The more liberal the science policy is and the more knowledgeable, pragmatic and liberal in attitude the policy holders are, the more likely is it to achieve excellence in science and technology. Liberalization is important not only for the advancement of science and technology, but also for the upliftment of society which results in a better economy as measured by the GDP. Here is an example from 'Nation Building through Science and Technology', an article by R.A. Mashelkar[2]. "I remember the legendary Indian Industry leader JRD Tata saying in desperation in February 1978 that Telco, which was his company, was not allowed to develop a car. It was only in July 1991 that India liberalized its industrial policy and opened up. It was in 1993 that Ratan Tata who succeeded JRD Tata, was allowed to make a car. He gave this challenge to 700 engineers who had never designed a car before in their life. Spending only one tenth of what major auto manufacturers would have invested, he and his team designed and developed a new Indian car, Indica, that was world class. The creative ability of his 700 engineers from Telco was always there for all to see, but it got "expressed" only when the government policy changed through opening up and liberalization".

The liberalization of India's science policy is a relatively recent phenomenon. After independence, Jawaharlal Nehru was focused on building science and technology institutions to create scientific spirit within the country which would ultimately help overall development, even not immediately. Indira Gandhi believed that self-reliance in technology will help India to take an independent position in the world. It was during her time that an attempt to link S&T with economic planning was made for the first time, and was never repeated. Her tight control over the import of equipment and foreign technology impeded the development of science and technology. In India liberalization started in the eighties, although its actual implementation occurred in the nineties. In scientific research it was Rajiv Gandhi who lifted import restrictions and introduced more liberal policy for importing scientific equipment and technology. He realized that in order to compete with the advancement of science and technology worldwide, it is imperative that modern equipment be made available to scientists instead of investing time to build it indigenously. There is no denying that this liberalization helped the country in building up a scientific infrastructure and attitude comparable to many advanced countries, and thus helped advancement of scientific and technological research enormously in certain areas. However, building up of scientific infrastructure and modern laboratories does not automatically benefit the economy of the country or elevate the status if the poor although that should be the ultimate objective of science and technology. In 1927 Mahatma Gandhi visited the Indian Institute of Science and remarked, "Unless all the discoveries that you make have the welfare of the poor as the end in view, all your workshops will be really no better than Satan's workshops."

One of the major objectives of liberalization is to reduce the gap between developed and developing nations in areas like economy, facilities, infrastructure and knowledge. Here, I shall only be concerned with the creation of knowledge and its dissemination. The purpose of the present paper is both 'inward looking' and 'outward looking'. In the first category we suggest policy recommendations so as to improve the quality of human resources which is the vital ingredient for improvements in scientific and technological research, and to keep open the space for challenging research activities, while in the second category we suggest methods to obtain an equitable academic environment through international collaboration and agreement. The creation and dissemination of knowledge is a prime constituent factor for creating an appropriate academic environment.

It will be relevant here to deliberate how Latin America, particularly Brazil, has changed its education and science policy in the last few years not only to avoid the catastrophe it was heading to but also to appear as one of the emerging developing countries in economy, education and science and technology. Till mid eighties to all universities in Latin America the model aspired to be one of the best US or European research universities. But at that time most of the higher education institutions in Brazil were just teaching institutions and it was ridiculous to aspire to be like Harvard or Cambridge without strong research base in universities. Brazil through its new constitution under the civilian rule insisted that in higher education teaching and research are inseparable which implied that good education as such was an unworthy goal for the country's higher education establsihments[3].

During the military government in Brazil in the seventies, ambitious projects like nuclear programme, rocket and satellites, nuclear submarine, etc. were undertaken on one hand and on the other hand American-style graduate programmes, research programs and fellowships were undertaken. As reported[3] "this alliance between the military and academics was a notable feature of those years, particularly because of the opposite political ideologies usually held by leading figures of the two sectors. Nowhere was this alliance as strong as in the failed attempt to develop an indigenous computer industry in Brazil, in the same very years that the microcomputer revolution was starting to sweep the world". The ambition to make Brazil a world power started fading away in the early eighties when the military regime started to crumble and disappeared when the power was handed over to the civilians in 1985. But this short-lived alliance was enough to produce a significant number of researchers and research institutions claiming for public support. In the early eighties Brazil had about one thousand graduate programmes in all fields of knowledge, about fifty thousand people were living on research money distributed in the form of fellowships, grants, and salaries etc. But the quality of scientific environment produced due to this rapid growth in the seventies was very uneven except at some universities which had scientific and technical traditions for many years. Brazil, like India, tried to protect the industry from the competition from foreign firms and introduction of foreign technology under the disguise of import-substitution policy with the assumption that national industry may not be efficient at the beginning but would mature and eventually compete internationally in an equal basis. As a result industrial products became too expensive and could not compete internationally and economy failed.

The policy for science was similar in many respects, the assumption was that even if a research group is not very good, provide them support and eventually it will improve. The policy was soft without discriminating the good and the bad, because if the projects were evaluated by stricter criteria by funding agencies, very few research institutions will finally qualify. Consequently the resources for research started to be meager and the number of people requesting funds for science kept increasing. The situation became worst in 1986-87, when inflation was at its peak and it was impossible to allocate resources for science and technology because most of the funds spent in paying salaries to the employees in the form of fellowships. This might have been an appropriate strategy to combat the situation at that time, but later when the currency is stable and the situation more favourable, 70% of the resources allocated to the National Research Council went towards paying salaries only. The change in policy started with the recommendation that the country should maintain and protect whatever capability it has and also in trying to improve on that. At the same time, mechanisms should be created to stimulate closer links and association with users of scientific knowledge and competence, both in the private and in the public sector. There should two mechanisms for science support, one based on strict criteria of quality, the other strongly influenced by criteria of social and economic relevance and one should influence the other. Brazil followed these recommendations and the results are imminent.

The first task in this kind of study is to understand what are the standard assumptions and what is the real situation, only then one can challenge it for a change. The standard model is based on the so called "endless frontier" model of science which assumed that scientists are free to pursue any kind of research they feel like and if you can support the interests of individual scientists with enough funds, everything else will follow: good education, good training, technology and economic development, as was assumed in Brazilian science policy in seventies. This assumption is at the centre of belief in many countries including India and our scientists are long clamoring for this. However, this is just an ideology (ideally science should be like that) and it has many pitfalls. Unless there is some sort of realistic monitoring and scope to take corrective measures it will ever remain unproductive.

This ideology of providing scientists enough money for pursuing science, giving them freedom on the assumption that they will always do good things, is enjoyed more by those who pursue pure science than those who do applied science. If we look at the international scenario today, what is changing is not that science is becoming more linked with the applied science but the whole ideology of 'basic science' (sometimes interpreted as fundamental science) is being challenged. Scientists sometimes interpret this challenge to pure science as a threat to their independence and autonomy. In order to accept this change we need liberalization of our attitude towards science.

When I said monitoring of the works within the frame work of independence, obviously the word that came into your mind is the accountability which is *lingua franca* among the policy makers and bureaucrats. This term was introduced politically in all spheres of English public life by Margaret Thatcher—as daughter of a small-town grocer it was natural for her to quantify any process of evaluation—and crossed over to Indian shores in the early days of economic liberalization. Accountability has different meanings in different contexts—outside the world of economics, its intention is to make one responsible and answerable to someone or to an authority. Accountability in terms of economic return is relevant to industries and businesses because they follow a linear model: maximum economic output is expected to be delivered by a given direct input of resources used in production[4]. However, this linear model might not be true for general research, particularly in the case of fundamental research. The general perception of science is to see a tangible result, and hence applied research tends to receive more public support in terms of funding compared to fundamental research.

Now the question is how can one make the money given to research and higher education more relevant and meaningful to society? Obviously there are two opposing views. One view insists that the amount of money spent in science research is much less than expected and needs to be increased and giving the size of the country the number of research students and scientists are small and some wastage is unavoidable. The opposite view is that the whole system is a waste of resources and government should stop supporting basic science research and only support industrial and applied research. One may cite the example of Japan who developed modern technological capabilities without significant system of basic research.

'Basic science research' and 'fundamental science research' is not the same thing although scientists use them interchangeably according to their convenience. It is hard to distinguish between basic and fundamental research. Fundamental research is the research which leads to a fundamental discovery or produces an entirely new knowledge or concept. All basic research is not fundamental but all fundamental research is basic research. Basic research may lead to a fundamental discovery, and one can appreciate its significance only after it is discovered. However, most of the research work done here in the name of basic research is 'routine research' which merely results in some addition to the existing knowledge. Any discovery out of such work which is fundamental in nature has to depend on serendipity[4].

Fundamental research can not be made accountable either in terms of its economic returns, or in terms of its immediate recognition of application. It is an ingenious outcome of a brilliant mind which does not follow any fixed rules and regulations and should be left to flourish on its own. For this a distinction between the fundamental science research and basic science research is needed. And the freedom of intelligence and time and effort to satisfy the curiosity will be granted only for a few selected scientists. Thus any form of accountability is irrelevant in the case of fundamental research. Basic scientific research, however, usually makes the scientist answerable to the funding agency. In order to make a scientist accountable, he is given a definite target to achieve within a specified time and one can evaluate the performance after that period.

Scientific research is a process of discovering knowledge. With globalization, scientific research is becoming more and more challenging. With the tremendous improvement in communication system and liberalization, scientists are forced to play in a level field competing with other countries, not only with scientific discoveries but also to handle complex issues such as pollution of the air and water, global warming, etc. These issues will remain an important agenda for all scientists to address. The days of traditional individualized research to achieve personal fulfillment are no more, and the need of the hour is to work collectively to promote interdisciplinary programmes and institutes. I do not agree with the blanket remarks made in the World Bank's World Development Report[5] that developing countries differ from developed ones not only because they have less capital but because they have less knowledge. This might be true for some nations, but should not be mistaken as a generalization. It is true that creating knowledge in the form of books, journals and other materials is more difficult in developing countries than in developed ones due to disparity of economic circumstances. With the availability of digital technologies and the Internet, it is not impossible to move far beyond the physical boundaries of a library to access journals and books from any other library in the world. The agencies like DST, CSIR etc. which support science and technology research pay subscriptions for electronic version of all relevant journals and create a portal accessible to all scientists of institutions supported by them and thus save the cost of subscription of journals to individual institution separately. This also prevents stocking of every journal or book in each individual library thus conserving scarce financial resources. The policy of creating regional library like regional instrumentation facility set up in the country to avoid duplicate set of equipments will not be a good idea considering the dismal experience scientists have generated from complex many-body problems.

Scholarly journals have been the traditional outlet for disseminating knowledge, and affording such journals in developing nations is becoming increasingly difficult. In order to reduce this disparity in creating knowledge, it is imperative that efforts are made so that knowledge will be available to everyone everywhere irrespective of geographic and political boundaries. The libraries of tomorrow will be different from those of today. This can be achieved by international negotiations and collaborations. Similar access to laboratories and classrooms are possible through virtual visits without significant investments in developing countries (assuming a reliable Internet backbone is available). These means of communication will open up a new form of intellectual discourse, and clearly the process of discovering knowledge will be enhanced when scholars of different disciplines are linked and communicate rapidly.

In order to understand the factors affecting science research, one has to understand the framework within which research and institutes of higher education operate. In India, basic research is mostly funded by public money through funding agencies like Department of Science and Technology (DST) and Council of Scientific Research (CSIR). Ironically however, the Indian public is largely unconcerned about science and its effect on human life. For the most part, Indian scientists still prefer working for their own satisfaction, rather than working collectively to attack and solve national issues. In order to excel in scientific research, the most crucial element is human capital, i.e. people who are inspired to work towards achieving these goals. Simply increasing fellowships and salaries cannot be the only method of attracting such talents.

The creation of knowledge not only requires proper environment and infrastructure, but more importantly, human resources. Knowledge is created from ideas and ideas come from creative people and knowledge comes from education. For good education, a significant portion of government money invested in science research should be invested in universities. Science research should run through public-private partnership. Instead of building more research institutes, which is the current trend in this country, more universities and educational institutions need to be built up. Although many ideas may remain latent in the creative minds of people, their extraction and utilization require the implementation of proper policy and creation of a suitable environment as well as an appropriate infrastructure. In order to attract the best students in research, research needs to be more challenging in the areas of public utilization. The problems of acid rain, ozone depletion, greenhouse effect, waste disposal, and other matters of public concern should be an important agenda for research and public policy. We have found almost all research institutes lamenting the lack of good research students, despite substantial increase of research funds. In order to attract quality students and for sustainable research, it is necessary to make research more challenging, and to transform the results of research to all who can use it, to benefit society, and to serve the economic and national interests of the country. Present generation wants to perform, wants to face challenges, wants to see the result, wants to achieve and so it is the opportune time to set challenges before them to solve. Laboratories without aspirations, projects full of quirks of scientists no longer attract bright students.

It is the duty of the policymakers to identify national issues and societal problems, prioritize them and open up those challenges to the scientific community to come up with solutions. "Thrust areas" or "Frontiers" of science needs to be categorized on the basis of the need and capabilities of the country and not following the trends of science research in West Europe or USA. Unless such an environment is created, talents will continue to be siphoned off to other sectors and countries. Many of our scientists are ensconced in the narrow professional interests of their discipline, completely oblivious to the broader mission of serving the public for which the institute is funded. Moreover, in India the link between academic research and industry is tenuous at best, and therefore the reward should not come merely from the number of publications or the number of patents acquired, but from the originality of ideas, so that the methods of solving emerging issues are rewarded. Provide them good salary comparable to the corporate sector, if possible, but assess them properly to plug the wastage of resources and also to inculcate value-based culture in the system. Increment and tenure needs to be performance-based. I am happy to note the trend has started in recruiting faculty in the newly formed Indian Institute of Space Sciences and this is liberalization from orthodox ideas and concepts.

A system to register the ideas similar to the National Innovation Foundation[6,7] needs to be created. This would allow any individual to freely register an idea in a public database. As long as the depositor is affiliated to an organization, no permission would be needed from the institution to register the idea. This open access system would then be accessible to any individual, organization or agency to review and comment. Ideas would remain in the public domain for enough time to give a chance to be criticized, improved upon and for further development by any interested party. In addition, these ideas would be evaluated by a board of experts from time to time to assess their feasibility and suitability for further application. If an idea is found to be novel and practical, the originator would be rewarded. If the idea is used commercially, the party or parties responsible for generating and nourishing the idea would get a monetary benefit based on mutual negotiation. The entire system could be conducted and managed by an independent non-government board without interference from politicians or bureaucrats, either in terms of functioning or funding. By communicating directly with the public through their website, the board could increase general awareness of challenging national issues including security and health, as well as matters of commercial importance that would develop the national economy. Similarly, an open access portal describing national issues and problems regarding societal issues can be hosted by the government inviting scientific community to participate and come up with solutions. Besides 'big' issues like pollution, garbage disposal etc., it should contain problems and issues of regional and of local demand, problems that may not fall under 'fashionable' research, but will benefit the society. Scientifically correct and feasible solution to a given problem after debate among the scientists and experts will be given all sorts of support to achieve the goal. It will be a two way 'open' dialogue between the scientists and the policy makers, a connection between the solution seekers and solution providers. This will act as a window in its true sense. A window is not merely a hole in the wall, but a relationship between the outside and the inside, between darkness and light, between warmth and cold. A window is not a thing — it is a connection.

Research institutes and universities in India are, in general, ineffective in packaging and delivering the goods (knowledge) necessary to make research interesting. The link between universities and research institutes, and between research institutes with industries is required to be more interactive. In order to compete with other nations and to be an effective player in the field of science, a science policy needs to be formulated to strengthen human resources as well as generating an atmosphere conducive to the creation and dissemination of knowledge.

The economic model of funding scientific research by the public exchequer through government agencies like the Department of Science and Technology, etc. is not very sustainable, and investment in research by private players should be encouraged in applied research. At the same time, the number of patents granted or the number of published papers should not be the criterion for funding. As Terence Kealey[8], a researcher and professor in clinical biochemistry at the University of Cambridge, remarked in his book *The Economic Laws of Scientific Research*, "The Market Place does not worship false Idols, it makes empirically correct judgements. It is the government funding of science that is an Idol of the Tribe". Fundamental research needs to be fully supported by the Government, while 'routine' research should be supported by private-public partnership. According to him eventually science runs up against the limits of taxpayer generosity, and even if funding keeps growing, but at a slower rate, there is much pain and frustration as anticipated career paths do not materialize. Kealey contends that not only would the free market have provided amply for basic research, it would have treated scientists themselves better. Liberalization should not be taken in a narrow context of relaxing the regulations of the existing laws but requires coming out of the orthodox set up as a whole. Time has come to rearticulate the need and demand for a public funded research.

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S&T POLICY AND INDUSTRIAL INTERACTION

Pradosh Nath

R&D Management in Developing Countries: Issues from the Perspective of Catch-up

Abstract

The paper distinguishes between issues of R&D management that are internal and external to the R&D organizations. The distinctions become important from the perspective of developing countries' quests for catching-up with developed countries, where effectiveness of R&D becomes the core issue of R&D management. Effectiveness is defined by the role R&D organizations play in the overall economic agenda of a country. R&D is one of the contributors in that agenda and has to work in tandem with many other non-R&D organizations for attaining effectiveness. It is in this context that issues of R&D management external to the organization become much more important than those internal to the organization. The paper argues that in this situation R&D organizations have to be linkage driven, with a concern for literature about 'National system of innovation.' Instead, this issue is generally ignored in the literature on R&D management, which is more concerned with matters internal to the organization.

Introduction

Selection, monitoring and evaluation, human resource development, cultivating clients, and technology transfer from laboratory to the industry are the most discussed and researched R&D management issues. In fact, these are the keywords for debates that have grown in prominence over the last two decades. Interestingly, most of these debates are offshoots from problems generally faced by the R&D system in industrialised countries or in developed countries. Are they, therefore, irrelevant for developing and less developed economies? This is an irrelevant question because most of the findings on the relationship between R&D and economic development are actually based on the experience of developed countries. Many of the findings thus may not have much meaning for less developed economies (Williams, 1971).

Developing countries, in the midst of an economic race, have tried to copy the R&D route to economic development of developed countries. In the process of economic development, developing countries have actually copied a mere appearance, which is oblivious to the essence of the R&D system. In simple words, the problem is putting the cart before the horse. Create a R&D infrastructure, as it exists in many developed countries, within an industrial milieu of archaic practices where 'innovation' is a generally unheard word, and all of the issues or problems mentioned above will surface. The question is: can we resolve those above mentioned issues when the horse is still tied behind the cart?

The experiences of Japan and Korea, however, which successfully managed to catch-up with the developed world within a very short time span, tell us a different story. The lesson from this story is for countries in the quest of catching-up to create the right approach with vibrant industrial activities and to build up their R&D infrastructure in synchronisation with industrial development. The challenge is to address and attend to the needs of the production system. The R&D system must be created and allowed to grow instead of superimposing a borrowed structure on a non-responsive production system.

While studying the Indian R&D system, for example, Bell observed that in the absence of pressure for technological competitiveness, in-house R&D was not aggressive enough. So far, government-funded industrial R&D is concerned with the chain of laboratories that were created long before the objective conditions of technology-driven industries were in place. As a result, these laboratories were not groomed to match the gruelling work culture that characterised the industrial research (Bell, 1993). In brief, the main issue is to manage R&D by seeking effectiveness. The rest of the paper deals with this perspective of R&D management.

Defining the Effectiveness of R&D

What we suggest is the need to begin from the end result of R&D management issues. The only question usually asked is whether or not R&D is effective. Is this a cliché? We suggest it is not if the implications of effectiveness on R&D management are elaborated. But before that, we need to define the effectiveness of R&D.

What is the goal of R&D? The goal of R&D is not development of a particular technology that has potential use in a production system. The goal of R&D is to make a contribution to a well-defined economic achievement (Nath 2007). Development of technologies is the means and not the end. Technologies are one among many factors that contribute to economic achievement. R&D organization is one organizational type that is needed for focused economic development. Unless and until innovation and technology is in complete sync with the other contributing factors and R&D organization is also in sync with other organizations set up for achieving economic goals, it is more likely that technological development will be a futile exercise and R&D organization will remain a stand alone annex of the economic programme. Rosenberg (1990), after examining the relative failure of R&D in India, writes, "History suggests that the countries that have managed to grow rapidly have done so by doing many things right, not just one or two things. With respect to such policies, it appears that potential pay-offs may be very high, but only if science and technology are perceived as complements to effective economic policies, not as substitutes." In India, this notion of complementary actions requires more direct attention and concern.

The example of Korea's development of its electronics industry epitomises the argument above. When the Korean government decided to promote the electronics industry in 1966, Korea was ten years behind Japan in terms of technological capacity. In 1977, the Korean government identified 77 areas, including TV and computers, for intense promotion. Korean policies actively supported the development of the electronics industry for 20 years, from 1966 to 1986. During this period the government established an industrial estate for the production of semiconductors and computers; it established an Electronics and Telecommunication Research Institute in the estate for product development; it protected the domestic market against foreign competition; it restricted direct foreign investment in electronics, but it also allowed joint ventures with major business groups like, Hyundai, Daewoo, LG, and Samsung. These companies were competing with each other through new product development, entering new technology areas and moving towards the frontiers. In the end, Korean companies achieved the same footing with Japan and the USA for development of 256M DRAM (Amsden, 1989; Kim 1993).

In contrast to the Korean story is the Indian case of developing a CFC alternative refrigerant. This is quite miniscule compared to the 77 areas for electronic industry targeted by Korea. The Indian R&D organisation entrusted with the task took its own time to develop the technology at the laboratory level. This is just one instance of a lack of synchronisation between the economic goal and the R&D goal. In fact, in this case there was no well-defined economic goal that was to be achieved by developing the technology of a CFC alternative. The project was the result of an impending global ban on CFCs and the expectation of a crisis to find alternative refrigerants. The goal, therefore, was mainly technological, and was outside the domain of effective R&D. The laboratory level technology took more time to be upgraded to the pilot plant level only to discover that there were too many players in the market with an established economy of scale who could challenge for competitive space. Was the R&D effective? For the R&D organisation it was because in the end they developed the intended technology. At the same time, for the rest of the country and also for the rest of the world the project had no meaning. We should of course not ignore the development capability aspect of the project or the fact that some time in future R&D activities the capability might be of some use. But until that time there cannot be any second opinion about the project's lack of effectiveness.

What the Korean story shows is the value of synchronising many factors to work together to achieve a well-defined economic goal within a defined time frame. It is noteworthy that there was no existing research institution that preceded the need as defined by the economic goals. As a result, the specific research institute did not have to spend time on the clichés mentioned above. A more detailed study of the Korean story reveals the policy of "walking on two legs" for effective R&D management. The one leg was domestic industry, which was to address and to attend to the needs of the industry, while the other leg was in the domain of accessing critical knowledge from the best sources. For the latter, Korea adopted a policy of sending its scientists to work in US organisations in order to acquire critical knowledge in specific areas.

Elsewhere (Nath and Mrinalini 2002), we have suggested a model to describe "effectiveness" in terms of the knowledge gap between R&D organisations and the production system. Briefly, the model suggests that the knowledge gap between R&D organisations and industry defines the effectiveness. A big gap in favour of R&D organisations implies redundant R&D — many developing countries suffer from this. A gap in favour of industry implies that R&D organisations cease to be knowledge generating organizations. No gap implies that industry can use R&D organisations' services, but only for their assets of technical-physical knowledge.

Effectiveness and Implications for Management

Is it possible to accommodate existing R&D organisations as active partners in the process of achieving well-defined economic goals following the Korean example? The answer to this question lies in the fact that in the Korean case the R&D organisations were the outcome of the felt need in a specific context and they were organically linked with an economic goal. An organisation standing outside of this cooperative linkage will have organisational and management practices that are governed by a different set of priorities, e.g. cultural and institutional commitments.

As observed by Araoz (1994), this type of R&D organisation has a few critical characteristics. Many of them choose R&D activities of their own interest without focusing closely on the changing technological needs of market enterprises. The result is a lack of success in the commercialization of their R&D results. These organisations are largely perceived as 'laid-back'. They are often complacent due to the assurance of public funding even if they fail to deliver productive results. Most of them are not able to tune their activities to the competitive market situation and are unable to assist in enhancing competitiveness. Why are they so? Is it because these organizations are staffed by useless people? That would be a ridiculous argument. But as we shall argue later, much discussion about the performance of these R&D organizations actually leaves a hint, which can be read from various corrective recommendations, that manpower in these organizations requires more scrutiny and tighter monitoring.

There are two aspects that generally escape our attention. The first one is more trivial. If an organization is actually a collection of useless people, then this reflects the leadership of the organization ahead of the people in it. But the more important aspect is how to understand the organization itself. Any action is organized because it may not take place automatically or on its own. Again we may like to give the action a particular direction, shape and speed. So we build up facilities and bring in both human and physical resources to achieve a certain action in a defined time frame.

All organizations have to manage internal and external issues. A R&D organization has both internal and external management issues. The internal issues are much easier to handle because those are under direct control of the organization's leadership. A large body of R&D management literature is devoted to issues of internal management. They deal with issues like project selection, monitoring, human resources, accountability, time budgeting, etc. We have already talked about two kinds of R&D organizations; one that is created with the hope of catching-up with developed countries even though the objective conditions of the production system are lagging far behind. The other follows the Korean practice where the effectiveness of R&D is defined by its role in economic achievement. In this case, R&D organizations are created according to the need of focused and planned industrial development. In the first case, R&D organizations stand alone. Their existence is not conditioned by other factors that contribute to economic achievements. The external issues of R&D management, therefore, are not important for them. They are organized in such a way that the effectiveness of their activities is assessed internally. As a result, management issues internal to the organization become the most important R&D management problem.

In the second type of R&D organizations, their very existence is defined by mutual collaboration with several other organizations (non-R&D organizations) created for attaining defined economic goals. Management issues external to the organization, therefore, become predominant. In fact, all internal management issues are then determined by the requirement and resolution of issues external to the organization. Let us take the example of a few issues internal to the organization. Selecting R&D projects is thus no longer an autonomous act of the R&D organization. Similarly, human resource requirements are determined by the specific purpose that led to the creation of the organisation. All text book prescriptions of time and budget management as purely internal issues become superfluous because of the interdependent functioning of several organizations, wherein the tolerable level of default is very low.

One way of looking at this aspect is to understand "linkages" that define the effectiveness of R&D. The importance of linkages has escaped the main body of R&D management literature in India. However, the literature on other national systems of innovation places great emphasis on linkages as the core of innovation (Lundval 1992, 2002, 2007; Nelson and Nelson 2002). In a recent study (Arora, 2008, also see Bhattacharyya and Arora, 2005 on linkages of Indian universities and their implications for R&D achievements), it has been argued that successful innovation is actually the ability to establish linkages for acquiring privileged access to various kind of resources ranging from access to knowledge, human resources, physical resources, and commercial resources. The empirical findings in the literature have firmly established that the linkages and interactions among various R&D and non-R&D entities as the main stay of the innovation. In fact, the literature is abound with studies on the firm interaction or linkages for getting 'access to complementary and supplementary capabilities' such as knowledge or market for successfully commercializing innovations (see Arora and Gambardella 1994, Kogut and Zander 1992).

The second type of R&D organizations, in our discussion, is the product of linkages that have been visualised as necessary arrangements for achieving an economic goal. These organizations do not exist sans these linkages. Internal management practices of these organizations are defined, tuned and framed according to the needs of establishing, accessing and strengthening these linkages.

Going back to the question raised in the beginning of this section, the main problem of transforming the first type of R&D organisation to the mode of functioning of the second type lies in the management practices internal to the organisation. The mode of linkages, which is the life line of the second type of R&D organization, is different in the first type. Here other organizations have to change their practices to accommodate the R&D organizations, and thereby become subservient to the internal practices of the organization. Linkages, therefore, become constrained and ineffective. Changing the internal management practices of the first type of the R&D organizations will mean redefining the organization itself. In most of the cases, experts, reviewing the performance of these organizations, have neither the mandate nor the courage, or, in many cases, required wisdom to suggest anything beyond cosmetic changes in the internal management practices.

How is it different from market driven R&D?

It is important to understand that the second type of R&D organization, or R&D organization in linkage mode (let us call it linkage driven R&D), is different from another clichй; that is ‘market driven’ R&D. Market driven R&D, in simple sense, will mean R&D in response to demand from the market. This will mean different things in different economic situations. In a highly industrialised developed economy demand from R&D organizations will be governed by technological competitiveness. In a less developed economy market demand from the R&D organization will be rudimentary in nature. The worst case of market driven R&D was cited in Nath & Mrinalini (2002). This was a case of a textile research organization. The organization was under pressure from the government (the funder) for becoming self-sustaining and more market driven. The organization sensed the market demand and introduced short duration weaving courses for under privileged youths and earned substantial revenue to claim initiatives towards self-sustainability. This R&D organization is different from linkage driven R&D organization in many ways. The linkage driven R&D organization has been created to fill up a gap of technological need within the overall programme of economic achievement. This was created because there were no other organizations that could fill that gap. In other words, if there were other organizations to do the same task, this R&D organization would not have been created. The argument we are trying to draw is that the legitimacy of an R&D organization is its ability to do things that others are not capable of. In our example of textile research the organization got engaged in things that does not need the expertise of a R&D organization. Even in that, the organization has lowered its activities to the extent where its activities can be done by any experienced weaver. This is an example of a low level trap of effectiveness of R&D. The market driven R&D has this trap laid for less developed countries. Linkage driven R&D is demand driven. In this case, however, demand is not what is signalled by the sleepy market of the less developed economies. Instead it is policy driven, where market is being led by a foresight of catching-up with the developed world.

Concluding remarks

We have argued that most of the issues of R&D management, as generally highlighted in the literature, have become non-issue in the context of developing countries. The R&D system of the developing countries is plagued with dual problem. They are carrying the burden of large structure of scientific and industrial research copied from the developed countries. It was perceived that these R&D organizations would become the source of necessary technological capability for faster economic development. They are also blind of the fact that transformation of these R&D organizations means change from autonomy driven to linkage driven mode of R&D. The task is difficult because it calls for redefining the R&D and its organization. It also calls for redefining the understanding of effectiveness of R&D. We have argued that in the context of developing countries R&D has to be a part of an economic programme, and its effectiveness has to be defined accordingly. The Korean case is cited as an appropriate example for integration of R&D in the economic programme, where development of a technology is not the R&D achievement; achievement is its contribution in economic programme. In this way R&D is not autonomy driven or market driven. It is policy driven that creates and brings together R&D and non-R&D organizations and direct them towards a defined economic goal. We have argued that this throws an altogether different set of R&D management problems. Those are problem of creating and managing linkages for acquiring privileged access to technological and non-technological, market and non-market, human and physical resources etc. These issues are external to the organization, and internal issues of R&D management become subservient to these priorities. In this new set up much of the popular debates in the R&D management literature will become non-issue. Basic vs. applied R&D, market driven R&D, technology transfer, project selection, evaluation and monitoring etc. are the issues for an autonomy driven R&D organization. For a policy driven organization all these issues are settled by the dynamics of linkages.

Once industry becomes dynamic, technology oriented, and innovation driven, as it is characterised in the case of industrialised developed economies, R&D organizations can play an autonomous role. That is how KAIST in Korea or many advanced R&D centres in Japan emerged once the industries in those countries became driven by technology competitiveness. It is to be noted that in all the developed countries R&D system followed the industrial development, it was never other way round.

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Raghuvir Sharan

Industry-Academia Interaction: Some General Points and a Case Study

Introduction

Interaction between Educational Institutes and Industry is considered to be very desirable. However, one observes that in practice there is a great deal of dissatisfaction with the state of this interaction. Let us explore the reasons for this difficulty. Initially one can consider the nature of interaction between any two entities 'A' and 'B' and difficulties inherent in this endeavour. We face this situation when we engage in a conversation in which we attempt *to interpret across boundaries* existing between two persons. This boundary is simple if 'A' and 'B' use the same language for communication and belong to the same culture. They share common undefined notions and 'B understands' what 'A intends' in a conversation. The situation gets more complicated if 'A' and 'B' use different languages and belong to different cultures. Then they have smaller set of undefined notions and 'B does not understand' all that 'A intends'. One may face similar situation when one brings together people from academia and industry and motivate them to converse. Another metaphor that may be useful in this context can be borrowed from Electrical Engineering. A student of EE learns at an early stage that if maximum power flow is to be reached between two subsystems then their impedances must be suitably matched. In many situations this task is achieved by use of a transformer or other such unit. That is, one uses an entity 'C' to help match the needs of interaction between 'A' and 'B'. As we go along, we would observe that sometimes 'C' can be embedded in 'A' and/or 'B'. Samtel Centre at IIT Kanpur can be an example for illustrating this situation. At other times the size and nature of the task would require the conceptualization and design of a separate entity 'C'.

Nature of Industry-Academia Interaction.

The mandate of academic institutions is to educate young people and to be active in research to generate new knowledge. Mostly, young graduate students at the level of Masters and Doctoral work participate, along with the faculty, in research. Typically, the time scale for this operation is two years for masters and four years for doctoral work. Initially, the students go through relevant course work, which help developing the 'language' for conversation between faculty and student. During the course of research, there is a freedom to choose the problem on which work will be done. This freedom is utilized by scholars to look for a problem, which the peers would consider to be novel, and which can be solved within a reasonable time with limited available resources. Generally, one looks for problems and solutions, which can be published in prestigious journals after peer review. Here the dream is to work towards a Nobel Prize! This requires a mindset that searches for things which are novel, whether these are immediately useful or not, becomes a secondary issue.

The mandate of industry is to produce goods and generate wealth. To do this industry needs capital, labour and ideas. Universities are supposed to be the places full of people with ideas, may be weird ideas, but ideas all the same. The spirit of research work done in universities and its propagation is very well captured in the preface of a book "Principles of Theory of Solids" (Cambridge university Press, 1964) by Professor J.M. Ziman. He says:

"The Frontiers of knowledge (to coin a phrase) are always on the move. Today's discovery will tomorrow be part of the mental furniture of every research worker. By the end of next week it will be in every course of graduate lectures. Within the month there will be a clamour to have it in the undergraduate curriculum. Next year, I do believe, it will seem so commonplace that it may be assumed to be known by every schoolboy...The process of advancing the line of settlements, and cultivating and civilizing the new territory, takes place in stages. The original papers are published to the delight of their authors, and to the critical eyes of their readers. Review articles then provide crude sketch plans, elementary guides through the forests of the literature. Then come the monographs, exact surveys, mapping out the ground that has been won, adjusting claims for priorities, putting each fact or theory into its place... Finally we need textbooks...."

In an analogous sequence, industry converts new ideas to products at all the above stages of generation and consolidation of knowledge. The stage of textbook writing is like setting up standards for mature technologies. Based on this analogy one can classify industries as utilizing emerging knowledge or mature knowledge. Before proceeding, one must note that what is mature knowledge today would have been emerging knowledge sometime back. Thus the classification of emerging and mature technologies makes sense only in a chronological framework. Moreover what is emerging technology for developing nations today might have already become a mature technology for developed nations. Thus the notion of emerging and mature technology is different in developing and developed countries. Now let us imagine two examples of industryacademia interaction. Case (i): A (a university in **developed** nation) interacts with B (an industry in **emerging** technology in **developed** nation) Case (ii): A (an university in **developing** nation) interacts with B (an industry in **mature** technology in a **developing** nation). One can think of several other cases, but the example of these two extreme cases clearly shows that any one paradigm of industry-academia interaction is not going to work in all the cases. It has been our experience that very little attention has been paid to managing situations like Case (ii). **By default we start applying methods of handling Case (i) to Case (ii) and run into difficulty**. *The importance of Case (ii) arises because a very large proportion of industries in developing countries are based on mature technologies*. For example, in India, where a large part of industrial knowledge (at the present) has come by diffusion, there is need to use the services of universities to apply emerging technologies to increase the competitiveness of industries. In the following, mostly this aspect of industry-academia interaction will be under consideration.

When one wants university and industry to interact, one wants to bring together the strengths of the two. That is, universities should continue generating knowledge and industry should continue generating wealth. An extreme opposite situation would be that industry starts behaving like university and vice versa! That would be an undesirable situation. *So, we want the university to only slightly shift its focus and industry also to only slightly shift its focus.* But only slight shifts may not achieve the purpose, particularly in developing countries where the industrial knowhow is generally achieved by diffusion. However these slight shifts may become of value if major task of interaction is taken by an independent entity, say ‘C’. Thus university would devote most of its energy on generating and transmitting knowledge, industry would concentrate on generation of products and wealth, and an independent unit ‘C’ would be organized to become intimately and deeply familiar with the work being done in universities and utilization of these to bring competitiveness in industries. For the time being let us conside unit ‘C’ as Industry Academia Interaction Enabler (IAIE). IAIE has the following characteristics.

1. This entity is neither a university nor an industry, but to an industry it appears as a university, and to a university it appears as an industry. **It is aware of the knowledge that is being generated in academia, and is also aware of the problems that are faced in industry. It has empathy to both industry and academia, and is well aware of the different time scales and different motivations that drive the two.**

2. ***The entity ‘IAIE’ interacts with industry to locate ‘suitable’ problems and has the ability to decompose these problems into smaller components. Some of these small components, which require generic knowledge, can be solved in the university; some, which require domain knowledge, would get solved in the industry; and still others have to be solved by third parties external to both the university and the particular industry, which has generated the problem.***

3. Crucial expertise of entity ‘IAIE’ will be in (i) selecting the right problem (ii) in decomposing the problem in several components (iii) in knowing which components can be solved with help of university, which ones with industry, and others which would require efforts of outside agencies,and (iv*) in persevering to see that all the components are solved, as even one small unsolved component can null the massive efforts made.*

4. **The entity ‘IAIE’ has to be different from university as well as from industry.** Unlike a university, it would focus on a product or a process and would persist till the end results are achieved. Unlike an industry, it would have an intimate knowledge of the expertise of the faculty, and would know what faculty within reasonable time scales can achieve the desiredresult with proper help provided. **It would handle the difficult task of operating at two time scales, in two different cultures, with different motivating factors.** This

entity will have a small work force, but the workforce would be agile to work with equal facility on various problems of very different kinds. **This work force would necessarily require credentials so that it is respected by both academia and industry.** It is anticipated that hiring a suitable manpower would be the greatest challenge in setting up an entity like 'IAIE'. Also this entity would be low on need of infrastructure, because it would learn to effectively utilize the resources available with industry and university.

5. Needless to say that a personnel of 'IAIE' have to be very good in cost-analysis of the projects. Professors in universities, generally, are very poor (pun intended) in this aspect. In our experience, many university-academia interactions fail because they don't succeed in balancing altruism and hard business sense of competition and survival. Either they become too costly or unrealistically cheap so that the task itself remains undone.

6. One last point about entity 'IAIE' may appear to be both trivial and subtle simultaneously. The point is that 'IAIE' has to learn to live with a situation, **where a large proportion of tasks that it would initiate would not fructify**. Not getting demoralized by many failures is a prerequisite for success in high-risk games, but it is to be noted that sparse successes are of such value that they provide the psychological sustenance.

Case study (The Samtel Centre for Display Technologies)

So far we have considered entity IAIE in general terms. Let us now look at a case study, but of somewhat different kind because it does not qualify to be called IAIE in the sense mentioned above. It is an approximation to it.

- In March 2000, Samtel Group of industries and the Indian Institute of Technology, Kanpur signed a memorandum of understanding for interaction in the area of display engineering. This understanding was possible because of an enthusiastic administration at IITK and the initiative shown by a successful Indian company (Samtel Group), founded by a distinguished alumnus of IITK, Shri Satish K Kaura. The mandate in the MOU, amongst other things, is to do basic research in the area of display engineering and to undertake short-term projects of interest to both units.
- Starting March 2000, this interaction faced three main difficulties. These were: (i) difficulty in appreciating the differences

in the mode of working of an educational institute and an industry, (ii) the choice of problems which would attract the interest of faculty and would be of benefit to industry, and (iii) differences in facility with mathematics required to solve realistic engineering modeling and simulation problems, keeping in view that an engineer working in an actual industrial plant has a sword of 'quarter' perennially hanging on his head.

• We attempted to bridge the gap of understanding between different modes of working in university and industry by simply bringing the faculty and engineers together, say on a Saturday, and let them tell each other what they were doing. Nothing more than an interaction and mutual appreciation of work of each other was expected as an outcome of these 'get-togethers' at the initial stage. It took an enlightened industry to appreciate this effort and provide material resources to carry this on. Finally, this effort has culminated in regular very short -term courses and brain storming sessions of smaller groups. Typically, these sessions last a day and half with four or five lectures, some practice in laboratories, and get-togethers to decide the topics to be taken up in the next meeting. Sufficient effort is made by faculty to provide reading material and references so that follow up work becomes easy and focused.

• Selection of problems that would attract the attention of faculty and would be of benefit to Samtel has proved to be difficult. ***Choice of problem, the decomposition of problem in smaller components, obtaining solutions / reconstructing the main solution from partial solutions, matching of time scales, cost-analysis of project have all proved to be difficult***. Apparently, the main reason is to attempt to get a system going with part time attention, whereas the nature of this work demands full time attention. This has been the motivation for conceptualizing the entity 'IAIE', which is different in detail as compared to Samtel Center at IIT K. Let me hasten to add that smaller problems can still be tackled without 'IAIE'. In the last one-year, we have succeeded in formulating about half a dozen small short-term projects, and are putting efforts to see that they come to some fruition.

• Samtel center at IITK is also pursuing research in the area of Organic Light Emitting Diodes (OLED). It is expected that OLED based displays may become commercially viable. Then the know-how learned at IIT Kanpur may become of use to Samtel Group of Industries. It is important to mention here that the activity in OLED is of a very different kind than what has been discussed in this article under industry academia interaction. It is basically focused research in an area supported by an industry or government agencies and is commonly known as sponsored research. This type of activity has matured in India in the last fifty years and has helped in getting foothold in emerging areas of technology. Success rates of these kinds of activities are very large. With this experience, now we can attempt not only more productive, but also more failure-prone activity of the type mentioned before.

Conclusion

The course of evolution and social shaping of industry in India has been very different from that of western countries. But the educational patterns of India and the west have great similarities because of the usage of similar syllabus, curriculum and textbooks. The research problems pursued in educational institutes in India have greater empathy with the global or modern western concerns than with those of **majority** of Indian industries. Hence one faces difficulties in adapting models of interaction that are prevalent in the west to Indian condition. Some originality of thought and conceptualization of a few novel institutions may become helpful. IAIE is a concept of this kind.

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Nimesh Chandra

Knowledge Transfer Strategies at Indian Institutes of Technology

Introduction

With increasing demands placed on innovations, predominantly science based; many academics seem to re-orient their research that suit industry needs. This trend caught up in the United States of America in 1980s while in India particularly in Indian Institutes of Technology (IITs), industry participation increased significantly since the late 1990s[1]. Whilst listing the significance of academic research output and their transfer to the users, this paper looks at the different modes of knowledge transfer at five IITs as a representative set of academic research institutes particularly in science and engineering in India. The emergence of new ways of transferring knowledge from academia is seen in recognition of the sudden surge in patenting activities as also in the new start-up companies being established at academic campuses. This study however shows that knowledge transfer from academia is still guided through the most common and basic form of alliance with government and industry in the form of sponsored research and industrial consultancy assignments.

The paper is organized as follows: the first section describes briefly the guiding theoretical perspectives followed by the section on the institutional arrangements for knowledge transfer at five time-honoured IITs namely Bombay, Delhi, Kanpur, Kharagpur and Madras which entail different policies and processes followed and/ or initiated at IITs. This also gives an account of the emergence of technology transfer offices and highlights the organisational and institutional factors that exist for facilitating knowledge transfer including government initiatives. The third section discusses the knowledge transfer strategies as practiced at IITs. The focus is

[1] This largely owes to the enactment of the Bayh-Dole Act in 1980 which strongly encouraged the universities to take intellectual property rights (IPR) on their research outcome. In India, there are demands voiced for a legal instrument similar to Bayh-Dole Act in India, particularly by the Knowledge Commission (see National Knowledge Commission, GoI, 2007; *Biospectrum*, July 2005)

on the status of sponsored research and industrial consultancy assignments at each of the five IITs and their impact and the emergence and eminence of incubation units/spin-offs. This section also gives a brief outline of industrial research coalitions. While the penultimate section briefly discusses knowledge transfer at model academic institutions, the last section summarises the main findings and gives concluding remarks.

Brief Theoretical and Literature Overview

The approach in this paper builds on the view that the essence of the relationships between institutions and associated actors can be captured from among the different concepts on innovation including the 'triple helix' framework[2]. This framework is pertinent because 'triple helix' observes academic institutions to be playing a dominant role in the innovation system. 'Triple helix' has evolved gradually from a simple understanding of university-industry 'double helix' to trilateral reciprocal relationships between academia, industry and government and lately to a more intricate adaptation of innovation and sustainability as 'triple helix twins' working together as a dynamic yin/yang pair that advance sustainable economic and social development[3]. Etzkowitz et al. (2000) argue that there is a widespread movement among the academic research institutions to adopt a more complex entrepreneurial model, one that emphasises commercialisation of knowledge and the fuelling of private enterprise in local and regional economies. Broadly speaking, this paper builds upon the theoretical premise of Etzkowitz et al (2000); Etzkowitz and Leydesdorff (1997, 2000); Lundvall (1992, 2002) wherein we examine how academic research institutes in the Indian context contribute to innovation system.

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[2] The other important theoretical concepts are: the NSI framework (Nelson, 1993; Lundvall, 1992, 2002) which emphasizes how innovations are introduced and spread in the context of a country and attempts to explain as to why national economies differ. To a certain extent, it also explains why certain actors are important to the overall dynamism in the system of innovation. *The New Production of Knowledge* (Gibbons et al., 1994) explain two distinct ways in which knowledge is produced: 'Mode 1' and 'Mode 2'. In 'Mode 1', knowledge is generated in an autonomous university: in self-defined and self-sustained scientific disciplines and specialities, and is governed by peer group scientists who have a say in telling what constitutes science and truth and what does not (also see Gibbons, 1998, 2003).

[3] For details see Etzkowitz and Zhou (2006)

There are limited numbers of studies addressing innovation system in India that focus on academic institutions. Chidambaram (1999) focuses on patterns and priorities in Indian R&D. Gupta and Dutta (2005) give a macro picture of innovation system in the Asia Pacific region; Krishna (2001) looks at the changing status of academic science in India; Abrol (1983) addresses the issue of scientific research in Indian universities and Menon (2002) focuses on technology incubation systems in India. Even though history of science and technology and social sciences including history and economics of education, among other sub-disciplines, are well developed in India with substantial research contributions. However, these studies have given little or residual research attention to the subject of changing role of universities and particularly on IITs, there are rather very few studies.

There are apparently no studies specifically on IITs and their research contribution to industry from a social science perspective. There are limited studies from which scattered view-points are known on the functioning and industry interface of IITs[4]. For instance V S Raju (1995) opines that, there is a crucial need for building bridges between academia and industry. In the Indian context, IITs are one of the earliest to promote and have institutional mechanisms for working with industry. Indiresan (2000) observes IITs as premier institutes in terms of their academic credibility and excellence but he also highlights the problems they face. According to Indiresan and Nigam (1993) while the achievements of the IIT-system are considerable, it has faced criticism on issues, such as, high cost of technical education, brain drain, urban and elitistic orientation, and inadequate interaction with industry. Sengupta (1999) also observes that Indian industry has so far preferred to go for international collaborations rather than to academic or domestic R&D organisations in search of new technologies. In the recent works, while Chandra (2008) highlights academia-industry interaction and treatment of research output at IITs; Basant and Chandra (2007) focus on the role of academia and their research and development in clusters.

[4] One generic study on IITs is by Deb (2004) who primarily gives an account of the functioning of IITs. It is more of an inside account of the life in an IIT system and successful profile of IIT graduates and alumni.

Institutional Arrangements for Knowledge Transfer at IITs

Institutional framework, comprising of policies, practices and appropriately trained human resources, are imperative for meaningful knowledge transfer from academia. While direct economic benefits are derived for the institutions stemming from their involvement in sponsored research projects, consultancy assignments and from their intellectual property; there are also high spill-over advantages that germinate from public-private collaborations in the form of increased economic activity such as start-up firms and employment. It has been generally observed that the intellectual assets developed by researchers in academic institutions — their inventions, technologies and know-how–are not transferred to industry and they are rarely put to any practical or commercial use such that they could be employed in activities that stimulate economic growth. One of the prime reasons for the same is that the institutional framework necessary for transfer of technologies/know-how from academia to private sector is not well developed in many developing countries including India.

Policies and Institutional Processes in Knowledge Transfer

Knowledge transfer involves institutionalising relevant policies and processes. IITs have institutionalised policies and arrangements for facilitating knowledge transfer, more so in the last decade. Some of these policies and processes are discussed in this section including licensing of technologies and patents, revenue sharing, industrial consultancy, mobility of faculty to industry, incubation units, joint IIT-industry centres and research/technology parks.

Licensing of Technologies and Patents

The licensing agreements reflect the near end of the innovation process at ARIs. Usually licensing agreements involve selling a firm the rights to use a university's inventions in return for a revenue in the form of a fee usually paid in advance at the time of signing the agreement and/or annual running royalty payments that are contingent upon the commercial success of the technology in the market[5]. This agreement entail the terms, conditions, and

[5] The firms are usually required to provide ongoing evidence of their efforts to develop the invention and ability to commercialise it, as well as to report on specific performance 'landmarks.' These firms are also required to provide project proposal, business plan, company specific details like year of incorporation, financial strength, number of employees etc.

payments as agreed upon in the negotiations between the licensee and usually the institute's TTO. The licenses can be negotiated to be either exclusive or non-exclusive. Many researchers state that first a technology needs to be protected, and then the choice between exclusive/non-exclusive licensing should be made after finding the appropriate licensee(s). Exclusive licensing is often necessary to interest private industry. Non-exclusive licensing is more appropriate when the potential market for a technology is large enough to accommodate many firms or when there are many potential direct or spin-off applications of a technology. The term of the licensing agreement depends upon the assessment of the technology in a product market that is often uncertain and thus difficult to evaluate (Feldman, 2002).

The Policy of Revenue Sharing at IITs

One of the key policies in knowledge transfer is the policy that specifies distribution or sharing of revenue earnings from intellectual property of the academic institute. When any inventor(s) realises that his/her idea or invention can have (or already has) commercial potential, they get an incentive in the form of a share in the revenue earnings arising from the venture that has to be (or has been) commercialised. The sharing of royalties elucidates the fact that compensation is offered for research and collaboration efforts of the team and it is the use of those resources within the academic institute that indirectly lead to inventions. The most common formula in sharing of revenues in academic institutes is the equal sharing formula where the inventor, the department and the academic institute get 33 percent each. The other fairly common alternative is an equal 50-50 sharing between university and the inventor (Graff et al., 2002). Interestingly the sharing patterns for five IITs in this study are different (table 1).

Industrial Consultancy

Apart from teaching and research, faculty, technical staff and often students of IITs take up many assignments of direct relevance to industry. This activity is known as *industrial consultancy* and includes testing and certification of industrial products; development of prototypes and their testing; exploring new approaches to design and manufacturing; help design new products; investigate or rectify problems; offer specialized programs to industry to keep them abreast

TABLE 1: REVENUE SHARING POLICY OF IITS FROM INSTITUTE-OWNED INTELLECTUAL PROPERTY

Institution	Revenue Sharing
IIT Bombay	Inventor(s) get a share of 70 percent while IIT Bombay receives 30 percent. This holds if the net earnings do not cross a threshold amount for any inventor.
IIT Delhi	Inventor(s) gets a sixty percent share while IIT-Delhi and FITT get twenty percent each
IIT Kanpur	For the first fixed amount, the inventor(s) get sixty-five percent share while IIT Kanpur and service account get twenty-five percent and ten per cent share respectively. As net earnings increase, inventor's share decreases and institute's share increases, service account is constant.
IIT Kharagpur	Equal distribution of proceeds to creator(s) and to IIT Kharagpur. In case of a third party involvement (funding agency), institute's and creator's respective share is calculated on the net receipts after deducting the third party's share
IIT Madras	Fifty percent of the revenue is credited to IIT Madras while remaining revenue is divided equally among inventors as per the royalty sharing agreement. Out of IIT Madras share five percent is transferred to the concerned department development fund and two percent to IC&SR overhead and balance to the institute corpus fund.

Source: Annual Report of respective IITs and their websites

of latest developments; and assisting in technology up-gradation. The present focus of consultancy services at IITs is to expand interactions to a multidimensional mode by building strong R&D partnerships with industry.[6] All the five IITs have institutionalised a policy of industrial consultancy which is administered collectively with sponsored research. We will discuss more about consultancy and TTO of each IIT in the upcoming section.

Mobility of Faculty to Industry and Vice-versa

Mobility of faculty members to industry and vice-versa encourages cross-fertilization of ideas, exchange of varied experience and more

[6] The consultancy projects are provided largely for small and medium scale industries as also for large industries; for national agencies such as department of space, defence, atomic energy, information technology and so on; for national missions, government departments, financial institutions, banking and insurance sectors and for international organisations

importantly an effective way of knowledge transfer. It was evident in interviews from faculty members at respective IITs that mobility to industry was limited. It was only when there were seminars and conferences or when there were specific industrial based research projects that most of the faculty interacted with industry personnel. In order to have a long-term association with industry it has been recognised to have a greater mobility of IIT faculty to industry. There are recommendations made by IIT Review Committees and by National Knowledge Commission for increasing academia-industry interface through personnel exchange and interaction. Pitroda (2008) suggest a possibility of secondment of faculty and researchers to industry during vacations. To promote greater linkages between IITs and Industry it has also been recommended that faculty should spend compulsorily one of their sabbaticals in industry[7]. Academia and industry should engage in joint research to encourage innovation and competitiveness in the global economy. The Principal Scientific Advisor of Government of India has moved a proposal to allow industry to send some of the engineers, recruited during placement interviews and having talent for research, to pursue higher studies in IITs leading to PhD in the field of engineering and technology. These engineers according to him should be encouraged to in the broad area of interest to the company without limiting them to solve short-term problems of the company and at the same time be paid the same salary if he were holding that job for which he has been recruited[8].

Initiatives for Entrepreneurship

Several initiatives have been taken at IITs for promoting a culture of entrepreneurship among faculty, staff and students. Entrepreneurship is taught as a course, primarily at the department

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[7] Report, IIT Review Committee, 1986: Recommendations of the IIT Review Committee, http://education.nic.in/cd50years/f/G/J/0G0J0E01.htm

[8] The Review Committee (2004) has also observed the need to devise a mechanism that encourages, and rewards mobility between various sectors through a National Pension Scheme. According to the scheme, all faculty members would be eligible automatically to such a scheme where a faculty will carry a national pension record. Wherever he/she serves in segment, approved by the Council of Institutes of Technology, his/her actual service is recorded. With such a scheme an IIT faculty would be able to move freely to R&D organisation, industry, other engineering colleges and institutions. To promote greater linkages between IITs and Industry and IITs' involvement in national development projects, it is recommended that faculty should spend compulsorily one of their sabbaticals in industry

of management studies at various IITs, for instance innovation & entrepreneurship, and business entrepreneurship development is taught at IIT Bombay; technical entrepreneurship course is offered at IIT Delhi. While c**orporate innovation & entrepreneurship is taught at IIT Kanpur, e**ntrepreneurship development course is offered at IIT Madras. In another notable development, a School of Entrepreneurship is being set up at IIT Kharagpur at an estimated investment of Rs 80 million and will provide appropriate knowledge and skills to aspiring entrepreneurs. This will be the first IIT in India to set up a dedicated entrepreneurship school[9]. Separate entrepreneurship cells have also been established at IITs to imbue the IIT community comprising of faculty, staff, researchers and students with the spirit of entrepreneurship, and encourage them to take on entrepreneurial challenges. These units assist them in their efforts to launch and run business ventures (also see Table 8).

Incubation and joint IIT-industry centres

The role of incubation in promoting innovative start-up firms (or spin-offs) is that it helps in creation of a democratic new venture with infrastructure support, reducing entry barriers. The upfront risk is also shared and chances of success are enhanced while failure rates are reduced. In 'triple helix' universities and other knowledge producing institutions co-exist with industry including high-tech start-ups and government at various levels — local, regional, national and transnational; there is a movement towards a new global model for management of knowledge and technology which is explained by changing relationships between academia industry and government (Etzkowitz, 2002). The spin-offs can be classified into direct spin-offs and indirect spin-offs (also see Yencken, Cole & Gillin, 2002)[10]. Direct spin-offs are companies that are created

[9] Staff Reporter, *The Hindu* (2007) IIT Kharagpur to set up entrepreneurship school, *The Hindu,* Dec 29 and also in Mukherjee P (2008). IIT-K to set up school of entrepreneurship, http://in.rediff.com/money/2008/feb/06iit.htm

[10] Spin-off companies fall into a number of classes of varying importance in the institutional wealth creation process (Thorburn, 1997). The two classes that contribute directly to research commercialisation are direct research spin-off (DRSO) companies, where there are ongoing intellectual property rights and (usually) equity links between the parent research provider and the spin-off company; and the indirect spin-offs (ISO) or Start-ups, usually opportunistically initiated by university staff or students but with no IP or equity link back to the parent organisation.

in order to commercialise academic intellectual property. It usually involves licensing and personnel association to the start-up firm. Indirect spin-offs are companies set up by personnel usually former students and faculty/staff drawing on their experience acquired during their time at any of the IITs. Spin-offs are considered to be an important mode to bring innovations, technologies and products to market and make use of opportunities that otherwise would have been left unexploited or undeveloped. The innovative small firms created through the spin-off process can be a source of new jobs, accelerate regional economical growth, create a new, or renovate an existing industrial base, and increase a region's competitiveness (see Audretsch and Thurik, 2001).

Strategic Research Coalitions

The emergence of joint industry centres at IITs or long-term Strategic Research Coalitions (SRCs) as we may call them is lately a notable feature in the ecology of academia-industry interface. These SRCs emphasise on basic and strategic research and the sponsor firm also takes the responsibility of building research laboratories and buildings in the academic institution. There are formal contracts over intellectual property rights and the research projects/processes/services involve a mutual agreement between the corporate and academic personnel. The SRCs are different from sponsored research or endowments and other traditional linkages in the sense that they involve financial support to undertake long-term strategic research and training from which the sponsoring firm is able to take new ideas for development purposes. This arrangement is unlike contract research where firms can specify in advance their requirement and academics are asked to deliver.

Research/Technology Parks

Besides knowledge and technology, successful ventures require vision, understanding of market, venture and working capital, organisation building capabilities, and managerial skills. A quality research and development ecosystem like the IITs have faculty who encompass vast knowledge and expertise, students, R&D personnel and entrepreneurs. Research/Technology Parks combine quality R&D ecosystem with the above mentioned requirements of a successful venture. A Research/Technology Park is a property-based venture that has infrastructure intended primarily for private and public research and development facilities, inhabits high-technology and science-based companies, and support services and has a contractual and/or formal ownership or operational relationship with one or more academic research institutes. The Park has a significant role in promoting research and development by the ARI in partnership with industry, assisting in the growth of new ventures, and promoting economic development, as also it has an important role in aiding transfer of technology/know-how and business skills between ARI and industry tenants.

IIT Madras Research Park, a recent initiative, has been promoted by IIT Madras and Alumni with the mission of creating a collaborative environment between industry and academia to enable, encourage and develop cutting-edge technology and innovation that exceeds global standards. The Research Park intends to leverage IIT Madras's technological capabilities to innovate and promote entrepreneurship by navigating research into ideas, developing the ideas into products/processes, incubating products/processes into ventures, and nurturing ventures into enterprises[11].

Industrial Consultancy to Emergence of TTOs

In the early 1970s, in some IITs (Kharagpur and Madras), efforts were made to formalise industry interaction through research projects and consultancies and as a result industry liaison agencies were established. In other IITs, such functions were carried on by other departments as the quantum of research collaboration with industry was not large. In last two decades, as the Indian industrial growth witnessed considerable growth and technological sophistication the demand of knowledge and know how from leading institutions such as IITs increased. This has led IITs to build institutional processes and mechanisms to promote knowledge transfer. Before we understand the various modes and the process of knowledge transfer, it is important to look at the organisational

[11] IITM Research Park will have a built-up space of 1.5 million sq.ft., one Innovation cum Incubation Centre (IIC) that will be the fountainhead of R&D and Entrepreneurship Development, three R&D Towers housing about 100 Companies and Organisations pursuing serious R&D activities which would be large, medium and small industries and enterprises from India and overseas. The park also plans to have over 10,000 engineers, scientists, researchers, innovators in diverse technologies. The finishing school at the IIC plans to groom around 5000 new entrepreneurs in the future.

and institutional support structures that facilitate academic innovations. One of organisational innovations that became very common, particularly in the United States, was the establishment of technology transfer offices (TTOs) or technology licensing offices (TLOs) or industry liaison offices in universities. Here the marketing model introduced a business element into the academic institutions which exemplified an aspect of the triple helix model of one institutional sphere 'taking the role of the other'.

In the past the R&D department of IITs normally undertook the task of commercialising intellectual property generated within the institute but now new systems have developed. The establishment of TTOs, some of which are autonomous bodies; framing of innovation specific guidelines and policies (for instance licensing policy, revenue sharing policy, intellectual property policy); technology business incubation units are such dynamic formations that have compelled the academic institutes to evolve or start attempting in evolving innovation strategies. This section deals with such developments in five IITs[12].

TABLE 2: THE INDUSTRY INTERACTION AND ENTREPRENEURIAL INFRASTRUCTURE AT IITS

Institution	Industry liaison agency/ TTO & Year	Head/Key Personnel
IIT Bombay	Industrial Research and Consultancy Centre (IRCC); 1970s	Dean (R&D); Associate Dean; Chief Technical Officer
IIT Delhi	Foundation for Innovation and Technology Transfer (FITT); 1992	Managing Director; Executives- technology transfer; IPR
IIT Kanpur	Innovation and Incubation Centre (SIIC)*; 2001	Dean, R&D; Manager (SIIC)
IIT Kharagpur	Sponsored Research and Industrial Consultancy (SRIC); 1971	Dean (SRIC); Professor-in-charge (IPR & IR)

[12] Most of the information in this section has been collected by visiting the IITs and also referring to institute's website

IIT Madras	Centre for Industrial Consultancy and Sponsored Research (IC & SR); early 1970's	Dean; Chief techno-economic officer

* Small Industries Development Bank of India collaborated with IIT Kanpur to set up SIIC

The other mechanism, apart from licensing, for technology transfer that many ARIs are experimenting with is equity participation.[13] In an equity based license agreement the focus shifts from negotiating on price and performance of a technology to agreeing on ownership shares, which means how much stock does the academic institute receive for the right to use the developed technology. However, this mode has not been common at IITs[14].

Knowledge Transfer Strategies as practiced at IITs

Having discussed the general issues, policies and norms at IITs, it is appropriate to now discuss in greater detail about the knowledge transfer strategies as practiced at individual IITs. The discussion on technology transfer offices/ industry liaison agencies gain much importance in understanding the role that these agencies play in intellectual property protection, and knowledge transfer through the licensing route and through spin-offs with or without a formal incubation unit.

Role of Government Schemes and Initiatives

There are other modes through which IITs undertake knowledge transfer in which an intermediary external entity is involved. Some of these facilitating agencies are:

National Research Development Corporation (NRDC)

[13] The studies by Feldman et al. (2002), Thursby et al. (2001) and Jensen and Thursby (2001) among others give an account of universities in America which consider equity participation as a technology transfer mechanism for promoting the commercialization of academic research and generating revenue from university intellectual property.

[14] The three advantages of opting for equity position as against licensing fees according to a study done by Feldman et al. (2002) are that firstly, equity provides a university with options or financial claims on a company's future income streams, secondly, since the equity alternative offers part ownership of the company, the interests of the university and the firm are aligned towards the common goal of commercialisation of technology and finally the advantage lies in the fact that equity may serve a certification function that provides a signal to relevant third parties that the university is entrepreneurial.

NRDC, established in the early 1950s based on UK model, was meant to transfer technologies developed by national laboratories and universities. Rather, NRDC was supposed act as TTOs and as an intermediary for knowledge transfer. The IITs also sometimes seek the services of NRDC to commercialise their technologies. For instance in 2006–07, one of the IIT Delhi's incubatee company assigned four processes to NRDC for their commercialization. This practice was prevalent earlier much more than at present prior to the setting up of TTOs at IITs.

Science and Technology Entrepreneurs Parks (STEPs)

The scheme initiated by the National Science and Technology Entrepreneurship Development Board (NSTEDB) under DST in 1984 aims at promoting entrepreneurship among science and technology persons, forging close linkage between academic and R&D institutions on the one hand and industry on the other and providing R&D support to small scale industry. IIT Kharagpur was one of the earliest to set up a STEP in 1986. This STEP reportedly works in harmony with IIT Kharagpur and acts as a conduit between IIT and external agencies to facilitate technology transfer and to convert research outcomes of IIT researchers to commercially viable propositions[15]. Initially there were twelve (12) STEPs[16] across the country in different stages of development which have been successful in promoting nearly 400 enterprises in different areas like electronics, mechanical engineering, biotechnology, material sciences, computers, machine tools etc. However, at present 9 STEPs are functional and only two have performed exceptionally well. STEPs have been instrumental in development and commercialisation of more than 350 products/processes[17]

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[15] The faculty and researchers particularly from the department of Agricultural and Food Engineering at IIT Kharagpur have been instrumental in transfer of technology through STEP. Some examples: Technology for production of Polyphenol from green tea leaves has been transferred to Rangpur Tea Estate; the technology for production of Nutraceuticals (Probiotics- newly discovered microorganism) and industrial enzymes has been transferred to Pangene Biotech Pvt. Ltd.

[16] The NSTEDB, jointly with the financial institutions like IDBI, IFCI, and ICICI have so far established 15 STEPs in different parts of the country having developed close to 340 technologies till 1999.

[17] DST Annual Report (2000)

TIFAC, TDB and HGT

Often the IITs and other ARIs are supported for the financial requirement as well as technical know-how on new ventures with commercial potential by government bodies. Technology Information, Forecasting and Assessment Council (TIFAC) is an autonomous society under the DST which was established in the year 1988, following the technology policy statement of 1983 and the recommendations of the Technology Policy Implementation Committee. The objectives of TIFAC are to promote key technologies, undertake technology assessment and forecasting studies in selected areas of national importance, and to look for global technology trends so as to formulate preferred options for India (TIFAC, 2001). The important programmes and activities relating to promotion of new technologies and entrepreneurs include the Technology Development Board (TDB), Home Grown Technology Programme, Technopreneur Promotion Programme (TePP), Technology Project in Mission Mode, Technology Vision 2020, Programme Aimed at Technological Self Reliance (PATSER) of DSIR and Patent Facilitating centre.

The association of IITs with TIFAC has grown over the years. Apart from several projects that IITs have sought support of TIFAC for further development, there are some major initiatives under which IITs have contributed a lot. The first is the Advance Composites Programme (ACP), the other is the National Mission on Bamboo Applications (NMBA). The other initiatives where IIT researchers have benefited are the Fly Ash Utilization Programme, Technopreneur Promotion Programme (TePP), and Home Grown Technology (HGT). Most of the schemes promoted by the government have been instrumental in filling up the void created by the minimal presence of venture capital industry or lack of angel investors in India. Most of the projects are funded (to the tune of 50-60%) at a very low interest rate (as low as 5 per cent per annum given by TDB[18]) to meet its commercial success. For instance the TDB provided loan assistance of Rs 15.4 million against the total project cost of Rs 30.9 million to Electronics Corporation of

[18] Source: Enabling Commercialisation: Publication of the Technology Development Board. The interest rate is effective from 13th May 2008 as accessed on June 27th 2008). The Board does not levy processing, administrative, commitment charges or royalty

India Ltd for developing a prototype after obtaining the approval of Department of Telecommunications for CorDECT (Digital Enhanced Cordless Communication) Wireless in Local Loop-IIT Madras, Midas communications (a spin-off from TeNet group at IIT Madras) and Analog Devices Inc USA came together to develop the DECT based WLL technology.

Sponsored Research Projects at IITs

In addition to the primary objective of teaching and research, the faculty members and research personnel of IITs undertake several sponsored research projects. Sponsored research includes research in areas of current relevance, new investigations, product or system development and so on, usually proposed by faculty. These projects are generally funded by government agencies, national research councils and both public and private industry (national and international). These projects provide for bringing in new resources to the institute and also permit technical staff to be employed for specific durations to carry out the research.

Examining sponsored research projects and industrial consultancy (SRIC) jobs at five IITs, it is observed that the combined SRIC earnings increased from as low as 12% in 1999-2000 (see IIT Kharagpur and Madras) to as high as 60% of the total government grant-in-aid in 2004–05 (see IIT Kanpur). If we add the income from other sources (tuition fees, endowments), this share would slightly fall, but the important thing to note is that the earnings through SRIC, technology transfers, licensing and spin-offs has seen a sizeable growth in a short span of five years and this trend is likely to continue. However one should also note that the majority of earnings are from government sponsored research projects funded through national agencies like the Department of Science and Technology (DST), Defence (DRDO), Atomic Energy (DAE), Space (DoS), Agriculture (IARI), Medical Council (ICMR), Information Technology (MIT), Biotechnology (DBT), and Council of Scientific and Industrial Research (CSIR). The ratio of sponsored research to industrial consultancy typically in any of the above IITs is 4:1 even though there is huge variation in different years (variation ranges from 2 to 10 at different IITs). Typically at any IIT, the share of public and private industry in seeking consultancy is evenly balanced. Based on a study by *Outlook* (2006)[19], the share of government vis-a-vis private players in sponsored research projects was as high as 97% public against 3% private in case of IIT Delhi and 89% public against 11% private in case of IIT Bombay. IIT Kharagpur had 92% sponsored research projects funded by government. In case of industrial consultancy, the *Outlook* study showed 53% public sector/government backing at IIT Delhi while at IIT Kharagpur, the private sector accounted for 38% of total consultancy assignments.

TABLE 3: COMBINED EARNINGS OF SPONSORED RESEARCH AND INDUSTRIAL CONSULTANCY PROJECTS (SRIC) AS A PERCENTAGE OF THE TOTAL GRANT GIVEN TO IITS

All values of Earnings and Grants in Rs million

IITs	Earnings through SRIC (99-00)	Government Grant to IITs in 1999–2000	Earnings through SRIC as a percentage of total grant (99-00)	Earnings through SRIC (04-05)	Government Grant to IITs in 2004–2005	Earnings through SRIC as a percentage of total grant (04–05)
IIT Bombay	197.6	671.5	29	380.0	1024.0	37
IIT Delhi	185.5	820.0	23	385.6	1000.0	39
IIT Kanpur	84.4	628.0	13	590.0	980.0	60
IIT Kharagpur*	121.0	1003.0	12	500.1	1050.0	48
IIT Madras	112.8	943.7	12	435.5	1100.0	40
All Five IITs	701.3	4066.2	17.2	2291.2	5154.0	44.4

*IIT Kharagpur, grant-in-aid in (2000–01); Source: Computed from the Annual Reports of respective IITs

Analysing the data on individual IITs, over the last five years i.e. from 1999–00 to 2004–05, on an average, the number of projects and earnings in Rs million are as follows for sponsored research projects (Table 4)

19 See Datta (2006)

TABLE 4: SPONSORED RESEARCH PROJECTS AND THEIR VALUE: 1999–2000 TO 2004–2005 (AVERAGE)

VALUE IN RS MILLION

IIT BOMBAY		IIT DELHI		IIT KANPUR		IIT KHARAGPUR		IIT MADRAS	
No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
169	219	102	205	102	273	126	262	76	183

Source: Calculated after compilation from Annual Reports of IITs

There has been an overall increase in the sponsored research projects at different IITs (see Figure 1), which indicates that both government agencies and industry are increasingly looking towards IITs for their technological needs and potential source of innovations as well as for building trust for long-term relationships.

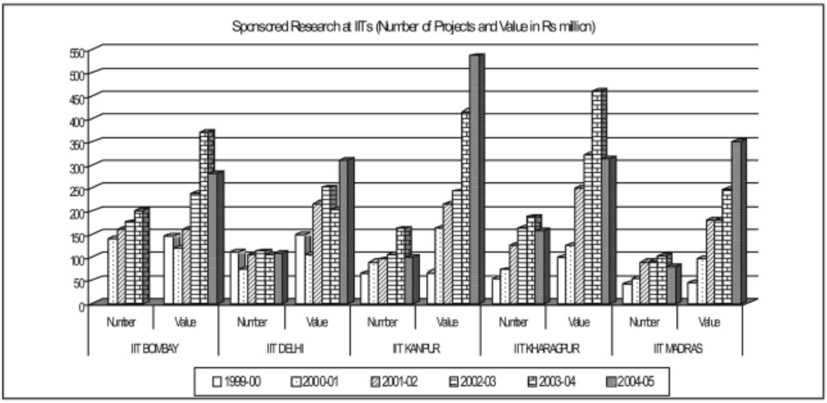

Figure 1: Sponsored Research Projects and their Value at IITs

Source: Compiled from Annual Reports of respective IITs (1999-2005)

Industrial Consultancy at IITs

The assignments of direct relevance to industry, offered in the name of industrial consultancy include testing and certification of industrial products; development of prototypes and their testing; exploring new approaches to design and manufacturing; helping in

TABLE 5: INCREASE IN SPONSORED RESEARCH PROJECTS AT DIFFERENT IITS
(ALL VALUES IN RS MILLION)

	1999–2000	2004-2005	Percentage Increase (%)
IIT Bombay	145.6	280.0	92
IIT Delhi	147.5	310.6	111
IIT Kanpur	139.1	414.9	198
IIT Kharagpur	99.7	312.4	213
IIT Madras	45.0	351.6	681
All Five IITs	576.9	1669.5	189

Source: Compiled from Annual Reports of respective IITs (1999–2005)

development of new products; investigating/problem solving; and offering specialized programs to industry and keeping them abreast of latest developments. Undertaking consultancy jobs has been an effective way of making available the expertise of the IIT personnel for the benefit of industry, government and others. Its value to IITs in stimulating further interactions and research collaborations has been well recognised, in addition to the professional and financial benefits obtained by the academics themselves. The consultancy jobs also show a significant rise at all the IITs (see figure 2 and Table 6), though not as significant as in sponsored research.

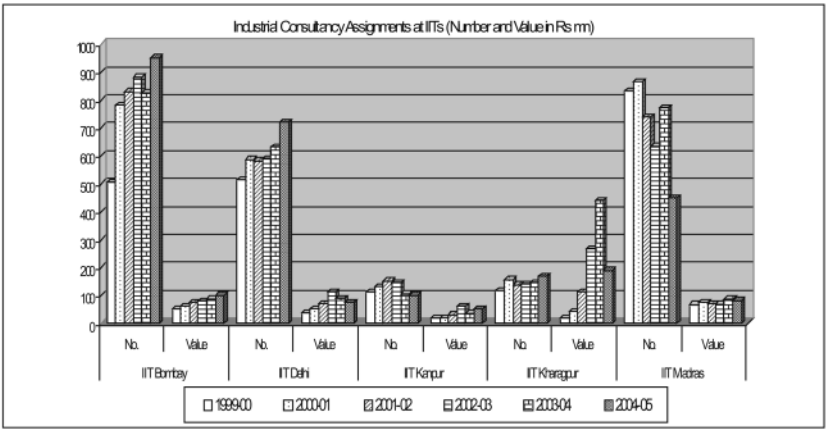

Figure 2: Industrial Consultancy Assignments at IITs and their Value
Source: Compiled from Annual Reports of respective IITs (1999-2005)

TABLE 6: INCREASE IN CONSULTANCY ASSIGNMENTS AT DIFFERENT IITS
(ALL VALUES IN RS MILLION)

	1999–2000	2004–2005	Percentage Increase
IIT Bombay	52.0	100.0	92
IIT Delhi	38.0	75.0	97
IIT Kanpur	18.4	53.5	191
IIT Kharagpur	21.3	187.7	780
IIT Madras	67.8	83.9	24

Source: Compiled from Annual Reports of respective IITs (1999 and 2005)

The growth in consultancy has been phenomenal over the last two decades for instance in IIT Delhi in 1985–86 and in 1989–90, the total consultancy earnings were Rs 2.66 and Rs 5.5 million respectively as compared to Rs 75 million in 2004–05.

TABLE 7: INDUSTRIAL CONSULTANCY ASSIGNMENTS AND THEIR VALUE: 99-00 TO 04-05 (AVERAGE)
VALUE IN RS MILLION

IIT Bombay		IIT Delhi		IIT Kanpur*		IIT Kharagpur		IIT Madras	
No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
796	75	603	72	168	41	144	178	716	75

* Average calculated on the basis of data available for three years (except 2001-02 and 2002-03)
Source: Calculated after compilation from Annual Reports of IITs

At IIT Bombay, the proactive departments engaged in industrial consultancy were seen to be Metallurgy, Civil and Chemical Engineering. The most sought after departments in IIT Delhi by industry for their consultancy services were Civil, Mechanical, Energy Studies and Industrial Design. The most prolific departments at IIT Kharagpur in getting industrial consultancy jobs were Mechanical Engineering followed by Computer Science, Metallurgy and Rubber Technology. At IIT Madras, the top three departments were Civil, Ocean and Mechanical Engineering. About ninety percent of faculty in the department of Ocean Engineering were involved in industrial consultancy while close to three-fourth faculty at department of Civil Engineering engaged themselves in consultancy assignments.

Incubation and enterprise creation or spin-offs

Incubation and enterprise creation or what is known as spin-offs (we define spin-offs as companies that develop from academic institutions through commercialisation of intellectual property and transfer of technology developed within academic institutions) has come into prominence and sharp focus in the literature on Triple Helix. It is regarded as one of the main indicators for entrepreneurial universities. In our study, while IITs at Kanpur, Delhi and Bombay adopted the conventional approach of creating formal incubation units, the spin-offs at IIT Kharagpur and IIT Madras (with the exception of Rural Technology and Business Incubator-RTBI) were created without the formal incubation setup. This phenomenon of enterprise creation without the benefit of formal structures may be regarded as unconventional mode of spin–off creation (Basant and Chandra, 2007). The Telecommunication and Computer Networking (TeNeT) group at IIT Madras comprises of faculty members from electrical and computer faculties who came together about 14 years back in 1994 with the objective of fulfilling socio-economic agenda of innovation in ICT for development. The group has incubated over 16 enterprises. The RTBI established in 2006 has created 12 companies in a span of little over two years, all of which have a specific focus on rural development . Similarly there is a Technology Incubation and Entrepreneurship Training Society (TIETS) and a technology transfer group (TTG) at IIT Kharagpur which are largely initiatives promoted by students under the auspices of sponsored research and industrial consultancy, IIT Kharagpur. The TTG has been founded recently in 2007 and has the dean of SRIC, and few faculty members as advisors.

Irrespective of the developmental trajectory all the five IITs in the last five years have shown significant growth in promoting spin-offs (see table 8) thus becoming an integral part of the support system for the growth of knowledge based entrepreneurship particularly in the SME sectors. The total number of spin-off firms from all the five IITs since 1994 up to January 2009 is 101. These business incubators were set up with the primary objective to improve the entrepreneurial base and facilitate economic development. It is also a known fact that quite a few IIT graduates have done well as entrepreneurs; some of them are self-made near-billionaires (Indiresan, 2000).

TABLE 8: INCUBATION AND ENTREPRENEURIAL INFRASTRUCTURE AT IITS

Institution	Incubation Unit & Year	No. of Incubatee /spin-offs (from 1994 till January 2009)	Prominent Areas of Expertise of Incubatee Units	Other Entrepreneurial Infrastructure*
IIT Bombay	Society for Innovation and Entrepreneurship (SINE); 2004**	33	IT, computer science, electronics, design, earth sciences, energy & environment, electrical, chemical, aerospace	Entrepreneurship Cell
IIT Delhi	Technology Business Incubation Unit (TBIU); 1999	19	computer science, electrical, chemical engineering, inter-disciplinary areas, life sciences, chemistry, IT, BT	Entrepreneurship Development Cell
IIT Kanpur	Innovation and Incubation Centre (SIIC); 2001	13	IT, design, weather insurance, navigation systems	Entrepreneurship Cell; Electronic and Animation Cell; Small Scale Industry Cell
IIT Kharagpur	No formal set up Technology Incubation and Entrepreneurship Training Society (TIETS)***; 2005	8	IT; computer science; ceramics; energy	Entrepreneurship Cell ; STEP; Biotechnology Park; TTG
IIT Madras	Rural Technology and Business Incubator (RTBI) Dynamic groups like Tele-communication Network Group (TeNeT); 1999	12 16 28	IT; telecommuni-cations; computer science; energy	C-TIDES; Research Park

Source: Compiled from TTOs/Industry Liaison Agencies at IITs

IT: Information Technology; BT: Biotechnology; STEP: Science and Technology Entrepreneurs Park (helps in promoting entrepreneurial activities, and technology transfer; TTG: Technology Transfer Group (an initiative by students of IIT Kharagpur); **C-TIDES**: Cell for Technology Innovation, Development and Entrepreneurship Support (initiated in 1998 bridges the gap between established entrepreneurs and aspiring students of IIT Madras)

* Entrepreneurship cells in IITs are largely students initiative; Technopreneur Promotion Programme (TePP) is conducted at IITs by Indian government for promoting individual innovators to become technology based entrepreneurs

** An IT business incubator was set up at Kanwal Rekhi School of Information and Technology, IIT Bombay in 1999 prior to the existence of SINE

*** IIT Kharagpur is building up a formal unit — Technology Business Incubation for Innovation and Entrepreneurship (TBIIE) as a part of a grant from Department of Science & Technology, Government of India

The establishment of incubation units at IIT Delhi (TBIU), IIT Bombay (SINE), IIT Kanpur (SIIC), IIT Kharagpur (TIETS) and IIT Madras (RTBI) are relatively recent development in aiding knowledge transfer. Here we need to mention that such initiatives have been supported by the government of India mainly through Department of Science and Technology and the Ministry of Communication and Information Technology by extending seed grant support. The strategy for setting up of incubation units involves the selection and recruitment of start-up technology businesses such that these ventures graduate from early stage incubation to mature firms generating resources on their own. The start-up firms in the IIT campuses are provided with fully furnished offices with computers, telecom and internet connectivity. The incubator has modern support systems like meeting rooms, conference rooms which are equipped with audio and video conferencing, pantry facilities and other shared facilities. Apart from the physical infrastructure, SINE aims to facilitate networking and mentoring support, organise showcasing events for incubatee companies and conduct training programmes which are relevant for the entrepreneurs. It is expected that further growth of these businesses would lead to their relocation outside the academic campus. The concept of a research park near IIT Madras also has additional features. Apart from the pattern of incubation, maturation and relocation which is seen to be a key element in the strategy for the expansion of the Research Park, there is a 'real estate' component of attracting established businesses and laboratories to the park. The businesses housed in the research park also propose to offer internships to students.[20]

The establishment of spin-off firms is seen as is an important commercialisation mechanism to hold and develop intellectual property where a high return is foreseen from future sales. A comprehensive analysis of the firms which have begun life within IITs, provide an interesting picture. Amongst the 101 firms examined, nearly 41 firms (41%) across the five IITs focus on IT software sector. If we add the firms operating in the communication software, 60% of the total number of firms operates in the software realm. The hardware sector in both IT and communication area has 13 firms (13%). This domain primarily is dominated by firms operating as a part of the TeNet group at IIT, Madras. Firms operating in the area of energy and environment (8%) and pharmaceuticals & biotech (6%) and others (12%) constitute the rest. Table 9 shows the type of activities these firms engage in.

TABLE 9: DIRECT SPIN-OFFS FROM ALL IITS

No	Type of activities	No.
1	IT hardware	4
2	IT Software	41
3	Communication Software	19
4	Communication Hardware	9
5	Energy and Environment	8
6	Biotechnology & Pharmaceuticals	6
7	Others	12
	Total	101

Source: Author's compilation

[20] We can draw a parallel with the University of Cambridge which has indirectly played a key role in the development of the area through the Science Park since it has been at the origin of virtually all the new companies in one way or another. Some 17 per cent of the firms were formed by people coming straight from the university, while others were indirect spin-offs of research conducted at the university. Other start-ups owe their existence to the presence of the university nearby. Most of those companies are very small, with an average of 11 employees. The success of the Cambridge Science Park is widely recognized and is part of what has come to be known as the "Cambridge phenomenon," which is regarded as a symbol of the innovative milieu.

As several studies have correlated high technology firm formation with research and development intensity (Cohen and Levin, 1989, Scherer 1980), and appropriability conditions (Arrow 1962, Levin et al. 1987, Nelson and Winter 1982) not to mention other crucial factors like capital accessibility, industrial concentration, size of the firm and such factors, there seems to be a correlation in the formation of spin-offs at IITs. For instance, the R&D activities at Kanwal Rekhi School of Information Technology (KReSIT) at IIT Bombay; at the Telecommunication and Network Group (TeNet) IIT Madras have shown that maximum number of firms are established in IT and telecommunication domain. We may say that the accessibility to seed capital is easier in software sector given the favourable micro and macro factors in this sector.

In case of start-up firms, it is observed that serious consideration is given to the nature of the technology in terms of its applicability to several markets and the availability of firms that are capable of bringing the technology to the market place. For instance in one of the cases in IIT Bombay, because the technology had a broad application, and there was no company suitable to develop that technology in the region, creating a spin-out company was the possible route to go. Although the availability of formal incubation centres is not necessarily a significantly beneficial factor in the amount of start-ups (as we see in the case of TeNet, IIT Madras), they do benefit the success of the spin-offs generated. The way a spin-off program is set up can significantly influence the success of the IIT in generating spin-off firms. This has been observed by Locket et al. (2003), who for instance, indicate that universities with more explicit and proactive policies towards the development of university spin-offs are more successful in generating them. Gregorio and Shane (2003) also show several specific areas in which university technology transfer policies can have a significant effect on new venture creation.

The founding member(s) of spin-offs at IITs included the inventor academic(s), some of who were currently affiliated with the IITs, while some did at one point of time and some without any affiliation. The spin-offs allowed the founders to preserve their professional identities while acquiring new roles in the process of commercialising technology. Out of the four stages identified by Vohora et al. (2004)

on the process of the spin-off formation — namely the research phase, the opportunity framing phase, the pre-organisation, and the re-orientation before reaching onto the next stage — it is the last stage where the spin-offs at IITs had the maximum difficulty. In this stage which again comprises of four phases: opportunity recognition, entrepreneurial commitment, threshold of credibility and threshold of sustainability, the entrepreneurs need for funding was seen to be linked to various factors that could provide them seed capital.

In IITs, it has been noted that during the last 6–7 years, the numbers of spin-off firms outnumber the numbers of licensing agreements every year and so is the revenue generated. This result is similar to what we saw in the study by Bray and Lee (2000) who observe that spinning-out is a far more effective technology transfer mechanism compared to licensing, as it creates 10 times higher income, and thus argue that license positions are only taken when technology is not suitable for a spin-off firm.

At IITs, there is an increasing eagerness among the academics with substantial research performance in seeing the potential outcomes of their research being realised. For some incubators in the campus, it was possible to realise revenues directly, while for others, the economic return was indirect, but for both categories, it was reportedly found that the social return was considerable.

Indirect spin-offs

A different view and insight, which is often ignored or overlooked in the case of IITs, is the significant contribution to Indian high technology industry in an 'indirect form' through their ex-students. For instance, many of these ex-students of IITs are either owners or chief managers of big firms. IIT trained engineers who have made a big name in the Silicon Valley, USA, through associations such as The Indus Entrepreneurs (TiE) and Silicon Valley Indian Professionals Association (SIPA) have a good deal of influence in the evolution of Indian software clusters in Bangalore, Hyderabad and Delhi (see Saxenian 2000, 2002 and Krishna 2007). The impact of indirect spin-offs is not a new phenomenon and is being considered in other academic research institutes elsewhere, for instance the study by Lindholm Dahlstrand (2006) observes that the direct effect from university research in Sweden in the form of university spin-offs is not very impressive, but including the indirect spin-offs (where industry and university own the company together) and in addition taking into account that many ideas that generate jobs in the private sector originate in academia, the impact is that 3 percent of all new firms (and 20 per cent of high tech firms) stem from academia[21]. The entrepreneurs and those who are at the top rung of management in big firms have achieved their respective positions that can be attributed to their training at IITs. These key people are contributing/have contributed to the economy in their own way primarily in creating employment opportunities and through their products/services. There are several examples of such indirect spin-offs.

Industrial Research Coalitions

Apart from the core ways of knowledge transfer that we discussed in the previous sections, there are other ways in which knowledge moves from ARIs. The significant ones comprise of strategic research coalitions usually with industry and facilitating intermediaries usually promoted by the government. Lately we see the emergence of long-term strategic research coalitions (SRCs) at IITs (see table 10). Most of these SRCs have been established in the emerging area of computer science and information technology. These coalitions echo the significance of basic research to industry. Some of the typical characteristics of SRCs are that they are usually single firm sponsorship of a particular research domain and have a long-term vision and duration.

TABLE 10: PROMINENT STRATEGIC RESEARCH COALITIONS AT IITS

Location	SRCs at IIT	Research Domain
IIT Bombay	Xilinx FPGA Laboratory (2004)	FPGA Technology Field-Programmable Gate Array
	Tata Infotech Laboratory	Computing & Communication technologies; Information Technology

[21] See http://www2.druid.dk/conferences/viewpaper.php?id=309&cf=8 as accessed on May 24, 2008 as accessed on May 24, 2008

	Intel Microelectronics Laboratory	Microelectronics
	Tata Consultancy Services (TCS) Laboratory (2000)	VLSI Design and Device Characterization
	Laboratory for Intelligent Internet Research (TCS)	Internet, web architecture
	Texas Instruments Digital Signal Processing (TI-DSP) Laboratory	Digital Signal Processing
	Wadhwani Electronics Laboratory (2001)	Electronics
	Cummins Engine Research Laboratory (2004)	Internal combustion engines, renewable energy — alternate fuels
IIT Delhi	IBM Solutions Research Centre	Computer Science, IT
	NIIT- Centre for Research in Cognitive Systems	Computer Science, IT
	Tata Infotech Research Centre	IT
	Intel Technology Lab	Computer Science
	Microsoft Advanced Technology Lab	Computer Science
	Philips Semiconductors VLSI Design Lab	Integrated Circuits — VLSI
IIT Kanpur	Samtel Centre for Display Technologies (2000)	Display Technologies
	Prabhu Goel Research Centre for Computer and Internet Security (2003)	Computer security
	BSNL Telecom Centre of Excellence	Telecommunications
IIT Kharagpur	OPTEL — IIT Optical Fibre R&D Centre	Communications

	Post Harvest Technology Centre	Agriculture
	Space Technology Centre	Space Technology
	Micro-electronics Research	Microelectronics
	General Motors-Collaborative Research Laboratory	Electronics, Controls & Software
IIT Madras	Automotive Research Centre	Automobile
	Microsoft Laboratory	Computer Science, Electrical Engineering; Embedded Windows technology
	IBM Centre for Advance Studies	Computer Science
	Tata Consultancy Centre of Excellence in Computational Engineering	Combination of computing technology with applied engineering disciplines

Source: Websites and Annual Reports of respective IITs

Whilst talking about research coalitions, we also need to mention about the sponsored chairs at IITs which play an important role in strengthening academia-industry interface. The total number of sponsored chairs in IITs increased from 46 in 1999–00 to 56 in 2002–03 with IIT Delhi having the maximum of 25 and IIT Kanpur, the least with 3 such industry sponsored chairs. IIT Bombay, Kharagpur and Madras had 8, 12 and 5 sponsored chairs respectively in the same period.

IITs, MIT and other Institutions in Knowledge Transfer

The IITs set up on the lines of Massachusetts Institute of Technology (MIT) invariably has an umbilical linkage with the latter[22]. The land-grant university status of MIT at the time of its establishment did catch attention of IITs with respect to the institute's role in economic development of the local region and cooperation with industry. One of the core distinguishing factors of MIT and IIT is the basis of contrasting models of innovation. While most of the ARIs illustrate a 'linear model of innovation', which

[22] See Interim Report of the Sarkar Committee, 1946

Etzkowitz (2002: 19) says "is by going from academic research to practical use, traditionally through publication of research results that have been adapted for product development by interested industrial scientists; the 'land grant universities' on the other hand exemplify a reverse linear model of innovation which start from societal needs (primarily those represented by farmers and their agricultural produce) and forms the basis for formulating research projects". The innovation model at MIT as observed by Etzkowitz (2002) is a combination of both these formats: linear and reverse linear model of innovation which he calls as non-linear interactive model of innovation.

The dual role of one institutional sphere 'taking the role of the other' in ARIs has particularly been extensively debated in the Indian context. TTO have apparently proved to be not so successful in academic institutions except for a select few in USA, and other countries in Europe, Asia and Australia (Nelsen, 1998). University technology transfer mostly functions as an administrative office to arrange payments for contracts with firms, rather than determining worth and marketing the technology developed in university.

The perception with respect to comparison of IITs with model institutions is noted in one of the comments by an IIT administrator: "I think comparing with MIT will just leave us almost frustrated. MIT is in a different league by itself. If you look at other universities, MIT and Stanford are in a different league by themselves in industry — institute collaboration, but the other universities are more comparable. Even there I am not going to talk about detail, but compare some structures, that makes the interaction meaningful and make some comparisons between the US and India and the experience of the IIT"[23].

The Effectiveness of Knowledge Transfer

In most of the academic institutions in developed countries where TTOs were founded, the need for evaluating the performance of such offices was also felt. While Sandelin (1994) argued that in academia, patenting and licensing are useful and obvious measures of technology transfers, Trune (1996) suggested using the number

[23] Ananth, M. S. (2006), Scaling up higher Education, in an Interview to The Hindu, September 11, Source: www.**thehindu**.com/edu/2006/09/18/stories/2006091800360300.htm

of invention disclosures, and the number of licenses/options executed. Even though not many ARIs in India emphasise on the number of invention disclosures by their researchers, it is one of the most useful indicator of knowledge generation in other parts of the World. The number of invention disclosures is a reflection of passive technology transfer elements such as taking into account the publications of research results in scientific journal articles and conference proceedings. The study by Muir (1993) also used such indicators as invention disclosures, evaluation of inventions by prospective receivers in industry, income generating and industrial R&D support agreements, patents, and institutional support for

TABLE 11: PERFORMANCE INDICATORS OF TTO/TLO IN US & UK ARIS VIS-A-VIS IITS (2005)

TTO/TLO affiliated to the Institute	No. of TTO staff	No. of invention disclo-sures	No. of new patents Filed	No. of start-ups	No. of Licenses granted	Gross Revenue
MIT	30	512	312	20	74	$ 46 million
Stanford University	21	433	76^	12	84	$ 48 million
University of Cambridge	30	127	41	3	40	J 4.3 million*
Oxford University	36	141	55	4	38	J 2.7 million#
A Small US research university	1	3	6	-	2	$25000
Typical IIT	8	60	16	3	3–4	Rs 3-5 million
All five IITs	35-40	300-325	88**	13–15	15–20	

* Licensing Revenue of J2.71 million and consultancy earnings of J1.58 mn; ** Year 2005-06; ^ U.S. Patents only

Sales Turnover in 2005; University of Oxford, Oxford; Source Data: http://www.isis-innovation.com/documents/IsisAnnualReport2005.pdf as accessed on April, 04, 2008

a TTO to evaluate the performance of academic TTOs. Rogers et al. (2000) utilized six variables to measure the effectiveness of knowledge transfer from a research university: the number of invention disclosures received; the number of US patents filed; the number of licenses or options executed; the number of licenses/ options yielding income; the number of start-up companies and the gross licensing income received. In other words, as per the management evaluation techniques, it is the quantum of revenue earned through technology commercialisation and other such measures and the number of active licenses, equity participation, research projects and consultancy assignments that decide the performance of academic research institutes involved in knowledge transfer. Table 11 gives a comparative picture of such quantitative indicators for institutions engaged in research in the US and that of a typical IIT.

The legal view and international 'emulation' of the Bayh-Dole Act

The US Congress has enacted several legislations that attempt to restructure the post war science and technology policy. In USA, one of the major public policy initiatives with regard to academia industry interface include Bayh Dole Act of 1980 in which academic institutions are granted the authority to license the federally funded research and development results to commercial entities[24]. With demands for similar legislation in India, it is worthwhile looking at some of the issues pertaining to such legal initiatives[25].

It has been noted that the limited evidence on Bayh-Dole Act's effects (both positive and negative) has not prevented a number of other governments, from pursuing policies that closely resemble the Bayh-Dole Act. It has also been observed that akin to Bayh-Dole Act, "these initiatives focus narrowly on the "deliverable" outputs

[24] Other initiatives include: the Stevenson-Wydler Technology Innovation Act (1984, amended in 1986) that authorizes the public research laboratories to transfer technology to industry and allows to establish centres for industrial technology at academic institutions and non-profit organizations to foster exchange of science and technology personnel in academia, industry and federal laboratories; and the Cooperative Research Act (1984), which permits universities, and businesses to form technology transfer alliances without undue fear of anti-trust litigation.

[25] See National Knowledge Commission (2007) and Biospectrum (2005)

of university research, and typically ignore the effects of patenting and licensing on the other, more economically important, channels through which universities contribute to innovation and economic growth[26]".

Looking at the developments in the context of policy initiatives similar to Bayh-Dole legislation, especially in the OECD countries, it is the ownership issue that has been at the centre of debate. The intellectual property rights are sought to be owned by either the academic research institutes or the researcher[27]. In some academic institutes such as those in Germany or Sweden, the researchers own the rights for intellectual property resulting from their work, which is being debated to shift to the institution. In Italy, it was the other way round where the legislation adopted in 2001 shifted the ownership from academic institutions to research individual. There is no single national policy that governs ownership of IPR within the British or Canadian academic systems, although efforts are underway in both nations to grant ownership to the academic institution rather than the individual researcher or the funding agency[28]. In Japan, ownership of IPR resulting from publicly funded research institutions is determined by a committee, which sometimes awards title to the individual researcher.

Discussion and Concluding Remarks

The institutional arrangements for knowledge transfer examined at IITs suggest that apart from the established policies, processes and other infrastructure, including policies for licensing of technologies and patents, revenue sharing, industrial consultancy and so on and the process for technology commercialisation through industry liaison agencies (or TTOs); there have been several recent initiatives to promote knowledge transfer. These include specific initiatives for entrepreneurship, setting up of incubation units, joint IIT-industry centres and research/technology parks.

Knowledge transfer from IITs has been guided through the most common and basic form of alliance with government and industry

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[26] Such emulation according to Mowery and Sampat (2004) is based on a misreading of the limited evidence concerning the effects of Bayh-Dole and on a misunderstanding of the factors that have encouraged the long-standing and relatively close relationship between U.S. universities and industrial innovation.

[27] See OECD (2002)

[28] Mowery and Sampat (2004)

in the form of sponsored research and industrial consultancy. This mode seems to dominate and figure as the most preferred route for knowledge transfer or channel. The growth in sponsored research and industrial consultancy (SRIC) has been substantial if we look at the combined earnings of sponsored research and industrial consultancy projects. The growth has been from a little over Rs 700 million to nearly Rs 2300 million in five years or an increase of 227%. This mode has been by far the most successful mode as it involves many faculty members and researchers at IITs for instance in IIT Madras there are more than 70% faculty involved in industrial consultancy in departments such as ocean engineering, composite technology centre, civil engineering and applied mechanics[29].

Even though the administration of the SRIC activities is done through the industry liaison agencies/TTOs, there are other roles that the TTOs play. The management of patents is one of the critical responsibilities of the TTO. However, so far the numbers of patent applications handled by TTOs at IITs is comparatively insignificant to justify their importance (16–20 in IITs as compared to 75–80 in Stanford and 310–315 in MIT which we saw in Table 11). The formal transfer of knowledge through the TTO to the industry is historically seen to be dominated by the practice of licensing. However at IITs, it has been found that commercialisation of technologies through this channel do take place but are limited in number.

The upcoming and promising strategy for transferring knowledge at IITs is increasingly seen through building an entrepreneurial culture and the growth of incubation units and spin-offs. The direct spin-offs are on the rise at all the five IITs. The indirect spin-offs through IIT alumni have made colossal contribution to the teaching and research infrastructure at IITs as well as immensely to the economy and society. The achievements under this strategy are indicative of the possibility of making use of academia spawned knowledge that becomes a viable and valued option.

[29] As per our study, taking into account the number of faculty involved in consultancy projects across departments from 1999 to 2005. Similar is the case with sponsored research at IIT Madras where the composite technology centre, department of physics and metallurgy have over 75% faculty involved in such projects.

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Sudhir K. Jain,
B Koteswara Rao Naik

Management for Research Excellence in Developing Countries in WTO Era: A Study of Indian Premier Technical Academic Institutions

Uruguay Round of General Agreement on Tariffs and Trade (GATT) negotiations started in 1986 and the controversial issues related to Trade Related aspects of Intellectual Property Rights (TRIPS), Trade Related Investment Measures (TRIMS), market access, agriculture subsidies etc. got resolved with the Dunkel Draft getting nod of the 123 participating countries, leading to formation of World Trade Organization (WTO), replacing GATT, with effect from 1st January 1995. The provisions of WTO regarding TRIPS leading to protection of Intellectual Property Rights (IPRs) with increased minimum term of protection along with product patent for all inventions including those related to pharmaceutical, chemical and food products, lowering of customs duties leading to higher international trade, increased opportunities for investment in other member countries through national treatment, strong dispute settlement system etc have led to globalization. As a result, the global competition has increased among all WTO member countries and, accordingly, this has provided global opportunities to all members. Increased international competition is associated with need for cost cutting and higher Research and Development (R&D) in technology fields leading to growth in inventions which are required to be protected through patenting for deriving competitive advantage. Thus, the WTO era has witnessed a rapid growth in International Joint Ventures (IJVs), international Transfer of Technology (ToT), R&D and patenting activity all over the world. When Multi-National Corporations (MNCs) derive competitive edge through R&D, the need for excellence in Science and Technology (S&T) research and management for achieving the same is imminent. This paper presents essentials of S&T research excellence and some findings of a larger survey of Indian Premier Technical Academic Institutions (PTAIs), and discusses management implications for excellence in research.

Essentials of S&T Research Excellence in Academia

The S&T research is undertaken in the industry as well as academic institutions, but with a difference. The R&D in the industry is oriented towards commercial innovations and inventions in the line of firm's business activity whereas the academic research is generally exploratory in nature and is undertaken with the primary objective of publications of research findings of the experimentation work in peer reviewed journals. While a firm would like to derive the best possible output from its R&D personnel and accordingly provide them the necessary inputs, environment, compensation, incentives etc, the research in academia is more self motivated and undertaken with several constraints on all fronts. Thus, the most important requirement for S&T research excellence is the availability of financial resources for the R&D. Financial wellbeing of the faculty is also equally important in ensuring their full commitment towards research. Some examples can well demonstrate this point. Just visualize the hyper or running inflation economies of the communist block countries during the 1990s when their currency devaluation rates were extremely high. The salaries paid to academia, mostly in the government sector, were not keeping pace with the prevailing inflation, whatsoever the increase in salaries was. This led to continuously declining purchasing power of all salaried employees including those in the academia. The impact was serious and could be seen in terms of people leaving academic and other R&D jobs and taking up low skill requiring jobs in foreign organizations, including diplomatic missions, who paid several times higher salaries in strong international currencies such as U.S. dollar which worked out to be several times more than what they were receiving in academic institutions in local currencies. Where the situation was less bad or in case of those who could not get dollar salary jobs, the academicians although continued in their previous jobs but took up additional part-time jobs to supplement their income. Different shades of this syndrome could be observed even in other developing countries, including India where the increase in academicians' salaries could not keep pace with the inflation during 1970s and 1980s. Thus, financial wellbeing of R&D professionals, including academicians, needs to be considered a pre-requisite for excellence in research.

R&D competence of S&T professionals is obviously the most important and basic determinant of excellence in research, but it is not non-available. However, what is more important is the commitment of R&D professionals and academicians to research excellence. Such commitment is largely inherent, but a lot can be done to develop and maintain it through management policy prescriptions and interventions. When the young talented brilliant graduating Indian students from PTAIs used to go to the USA due to lack of suitable good opportunities within the country in the 1970s, it was popularly said that 'brain drain is better than brain in the drain'. These talented S&T professionals have been largely instrumental in the development, growth and success of Silicon Valley.

Quality of support by the Support Staff is also an important pre-requisite for excellence in research. In S&T research, if the equipments are not available or maintained well or prototyping work is not done appropriately, it would hamper the entire research activity. Timely availability, maintenance and competent handling of equipments need to be provided by the support staff employed for this purpose. Sometimes they do not work with commitment, particularly in government institutions, due to no-fear of job-loss or even an adverse performance appraisal if their unions are strong — which is generally the case.

International collaborations and Faculty Exchange Programs (FEPs) with other good S&T institutions and universities help the academicians in knowing about the latest research and benchmarking with the best. S&T research leads to new scientific theories which get published in professional journals and also the innovations and inventions which result in patents. Among these, the 'commercially worthy patents' result in transfer of technology (ToT). The industry benefits from ToT and gives new useful products to the society. Thus, S&T R&D is important. However, it is a matter of empirical research to find out the comparative importance of different research facilitating factors across various S&T fields. This paper presents the survey findings of a study conducted in India.

Data and Research Methodology

This study is based on the primary data collected from six PTAIs viz., Indian Institute of Technology (I.I.T.) Bombay, I.I.T. Delhi, I.I.T. Kanpur, I.I.T. Kharagpur, I.I.T. Madras and I.I.Sc. Bangalore.

The sample for this study consists of six oldest PTAIs set up in early-1960s or earlier and which have become well known worldwide for their excellence in education. All PTAIs have been designated as institutions of 'national importance' through independent Acts of Indian Parliament. Each of the selected PTAIs has 300 to 500 faculty members and 2000 to 5000 students in 22 to 38 academic Departments and/or Research Centers. All faculty members in these PTAIs are involved in research activity through doctoral research supervision as well as sponsored research and have good research publications to their credit. Some of them have got patents for their inventions and some have transferred technology to the industry. Data for this study were collected through structured questionnaires which were sent to all the faculty members of all Departments and Centers of the selected PTAIs, through email. Out of the target faculty population of about 2000 in the sample PTAIs, after repeated reminders, 247 faculty members sent valid responses.

Each responding faculty member was classified into one of the following broad research field depending on his/her affiliation to the department or center: (a) bio-technology (including bio-sciences, agricultural & food engineering, biochemical engineering, biochemistry, bio-engineering, biomedical engineering, molecular biophysics, molecular reproduction, genetics and related areas), (b) chemical engineering (including metallurgical engineering, materials science, polymer science, rubber technology, textile technology, chemistry and related areas), (c) civil engineering (including atmospheric, oceanic science/engineering, naval architecture, earth science, ecological sciences, geology, geophysics, mining engineering and related areas), (d) electrical engineering (including electronics, computer science/engineering, telecommunication engineering, information technology, energy, physics and related areas), and (e) mechanical engineering (including applied mechanics, cryogenic engineering, industrial engineering, industrial tribology, production and design engineering, instrumentation, aerospace engineering, rural technology and related areas).

The responses of the faculty members about the importance of various 'Research Facilitating Factors' as well as their availability to the respondents in their institutions were taken on a 5-point scale.

Survey Findings

Table 1 shows the importance as well as availability of some basic research facilities or research facilitating factors (RFFs) as indicated by the sample respondents in the selected science and technology fields viz., bio-technology, chemical engineering, civil engineering, electrical engineering and mechanical engineering. The difference between the importance and availability of RFFs for various technology fields are shown in Exhibits 1 to 5.

It is observed that for biotechnology professionals the research funds availability from government, promptness of HR support and material/equipment procurement efficiency are considered the most important RFFs whereas research funds availability from internal sources as well as private corporate sector are considered least important. In terms of the gap between importance of various RFFs and their availability to the respondents, ‘procurement efficiency’, ‘research funds availability from the private sector’ and ‘technical manpower support’ show the highest gap whereas ‘Research funds availability from internal sources’, ‘Availability of time for research’ and ‘Research funds availability from government sources’ show the least variations. The availability of time for research assumes importance in view of the teaching commitment and various administrative responsibilities (Exhibit 1).

In case of respondents from the field of chemical engineering, the highest gap is observed in case of ‘Research funds availability from private corporate sector’ and ‘technical manpower support’. The difference between importance and availability is found to be the lowest for ‘Research funds availability from internal sources’. This is likely to be due to lower level of importance as well as availability of internal research funding (Exhibit 2).

In case of civil engineering field, the pattern observed is similar to that of biotechnology respondents. It is observed that the availability of research facilities related to ‘Technical manpower support’, ‘Promptness of HR support’ and ‘Procurement efficiency’ show the widest gap from their importance to the respondents. Unlike this, the lowest gap is found to be in ‘Research funds availability from internal sources’ (Exhibit 3). In case of respondents from electrical and mechanical engineering segments, the pattern observed is quite similar to the civil engineering respondents (Exhibits 4 & 5). Thus it is observed that in all the fields of technology, the availability of research facilities and their importance differs most in the following RFFs: 'Research funds availability from private corporate sector', 'Procurement efficiency' and 'Technical manpower support'. Contrary to this, the gaps between importance and availability of 'Research funds availability from internal sources' and 'Research funds availability from government sources' are the lowest across all the subject fields.

Management for Research Excellence in PTAIs: Desired Interventions

The research findings of the present study have important policy implications. It is extremely important that in the WTO era the requisite research facilities need to be provided in PTAIs for the desired excellence in research. This assumes higher significance because of the difficulties faced by the industry in innovations and inventions due to high failure rates. It is generally known that less than 10% of proposed innovations get to the market and less than 10% of new products succeed in the marketplace. Also, non-MNC industrial firms face severe difficulties in innovating due to lack of resources, limitations in understanding the customer needs, lack of result-oriented (R&D personnel, problems related to leadership, internal management systems, excessive rules, bureaucracy, unwillingness to change a winning formula, resistance to change, short term focus and so on. Industry and practitioners have also been found to seriously misjudge the future. For example, in 1899 the Commissioner of US Patents said that everything that can be invented has been invented, in 1943 Thomas Watson forecasted a world market for about five computers, in 1977 the founder of Digital Equipment Corporation Ken Olsen said no one needed to have a personal computer at home, even in 1981 Bill Gates said that 640K would be enough memory for anyone. Such notions, perceptions and limitations among the practitioners underline the need of vision that may be flowing from the academic intelligentsia as well as the low cost research leading to innovations and inventions. Thus, it can be said that the Premier Technical Academic Institutions (PTAIs) have an important role in promoting innovations and generating Intellectual Property (IP) in terms of patents. This is possible with the improvement in research facilities to the faculty of PTAIs through excellence in management of these institutions.

'Research funds availability from private corporate sector', 'Procurement efficiency' and 'Technical manpower support'. Contrary to this, the gaps between importance and availability of 'Research funds availability from internal sources' and 'Research funds availability from government sources' are the lowest across all the subject fields.

The empirically identified gaps between the importance and availability of some basic research facilities or RFFs can be bridged through well crafted management interventions so as to achieve research excellence in the PTAIs. These interventions are: (A) a combination of (a) building flexible & non-bureaucratic organization, (b) administration's role being that of facilitator and (c) creation of organizational culture conducive to promotion of S&T research, innovations and inventions as these interventions would lead to 'administrative system's adaptability and receptiveness' needed for research excellence; the support technical staff should be appointed with adequate incentives and terms and conditions that would enable 'promptness of HR support', 'equipment and material procurement efficiency'and 'improvement in technical manpower support'; (B) development of administrative systems that would save faculty-time from time-wasting activities such as chasing 'official papers' in the administration for seeking permissions about academic or research related or individual's official matters; (C) provision of all required general facilities and other perquisites to the faculty so that they have no interest in taking up academic-administrative responsibilities which are usually associated with added perquisites attracting the faculty towards administrative positions; the extreme position in this respect would be that faculty should feel happier without administrative responsibilities and thus it would enhance availability of time for research by the S&T personnel; (D) development of innovation performance measures and introduction of unparallel rewards for innovations that would create a strong desire to innovate and patent these inventions that would have high commercial worth and leading to transfer of technology (ToT) and rich dividends from ToT would incentivize faculty to further the S&T research excellence in PTAIs; (E) research funds should be made available from internally and the government should be liberal in funding R&D proposals; better funding would lead to better laboratory facilities; if the research is commercially worthy the corporate funding for R&D would automatically flow to the PTAIs due to their emergence as major source of low cost innovations; **(F)** encouragement of collaborative & cross-functional working and research. In addition, long gestation period research should also be encouraged along with low gestation period research. Breakthrough inventions and innovations may take time and thus instant results should not be expected. Negative oriented thinkers and those who lack confidence in innovating faculty should be kept away from the management of the PTAIs. Thus, the managers of these institutions should study the innovative management models of Stanford University and MIT and develop an adapted model suitable to local environment and culture.

Conclusion

The liberalization and globalization have made the world more competitive. This has necessitated low cost R&D which can be sourced from the Premier Technical Academic Institutions which have a track record of excellent faculty and young brilliant students. The best exploitation of the pool of such available talent is possible if the research facilities and other Research Facilitating Factors are made available in the PTAIs at par with their importance to achieve excellence in R&D. The empirical findings of a study in Indian PTAIs have revealed the gap in the importance and availability of the RFFs. The needed management system interventions can be adopted and applied in these institutions so that low cost inventions and innovations of high commercial worth may come out form the PTAIs in different countries. This model would support the industry for deriving competitive advantage in this era of globalizatio

TABLE 1: FIELD-WISE ANALYSIS OF IMPORTANCE AND AVAILABILITY OF RESEARCH FACILITIES (MEAN RESPONSES ON A 5-POINT SCALE)

Research Facilitating Factors (RFFs)	FIELDS									
	BIO (N=30)		CHEM(N=56)		CIVIL(N=50)		EEE (N=38)		MECH(N=73)	
	Impor-tance	Availa-bility	Impor-tance	Availa-bility	Impor-tance	Availa-bility	Impor-tance	Availa-bility	Impor-tance	Availa-bility
Lab facilities	4.40	3.30	4.46	3.32	4.44	3.24	4.50	3.37	4.54	3.26
Promptness of HR support	4.45	3.17	4.18	3.20	4.47	2.94	4.53	3.16	4.45	2.73
Administrative receptiveness	4.20	3.47	4.38	3.43	4.22	3.48	4.45	3.50	4.36	3.27
Admin System Adaptability	4.30	3.37	4.39	3.29	4.20	3.44	4.45	3.37	4.45	3.22
Availability of time for research	4.13	3.73	4.14	3.46	4.54	3.64	4.24	3.37	4.45	3.69
Research funds availability (Int)	3.47	3.10	3.82	3.46	3.60	3.52	3.76	3.47	3.74	3.30
Research funds availability (Govt)	4.57	4.07	4.55	3.80	4.44	3.90	4.29	3.76	4.32	3.64
Research funds availability (Pvt)	3.73	2.23	3.77	1.98	3.50	2.18	3.68	2.32	3.45	2.05
Procurement Efficiency	4.45	2.90	4.18	2.98	4.47	3.02	4.53	3.11	4.45	2.84
Technical Manpower Support	4.57	3.13	4.55	2.86	4.44	2.64	4.29	2.84	4.32	2.62

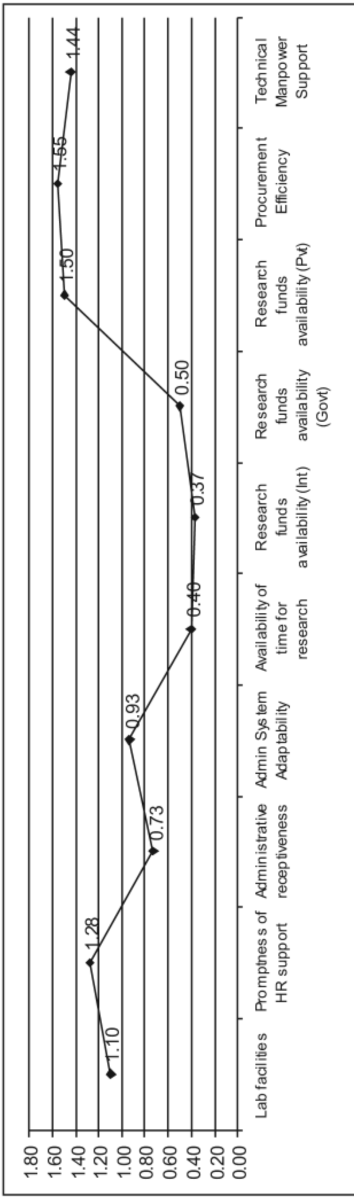

Exhibit 1: Difference Between Importance & Availability of RFFs (Biotechnology)

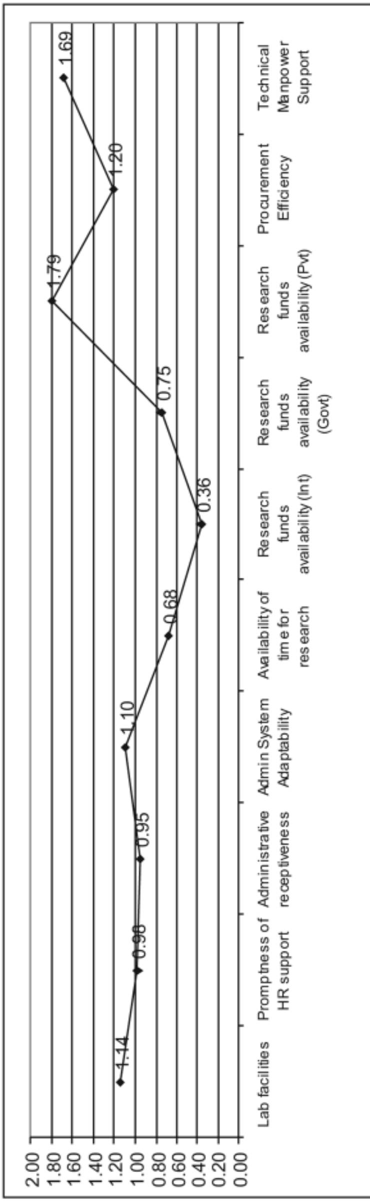

Exhibit 2: Difference Between Importance & Availability of RFFs (Chemical)

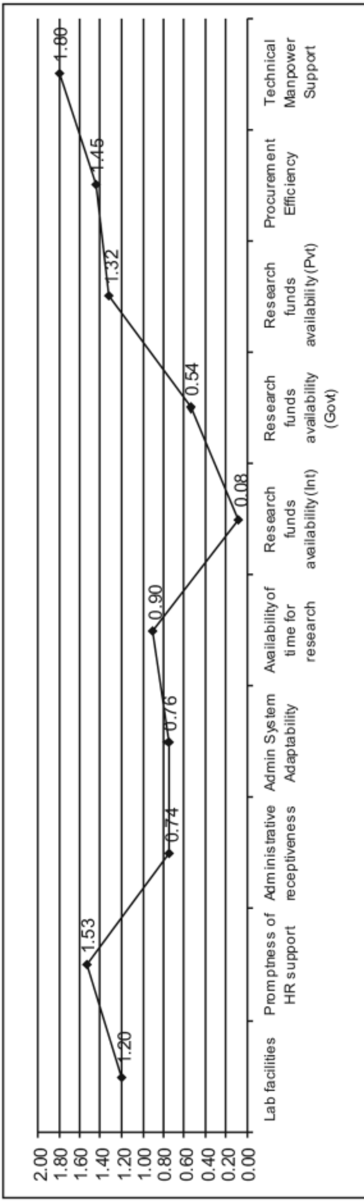

Exhibit 3: Difference Between Importance & Availability of RFFs (Civil)

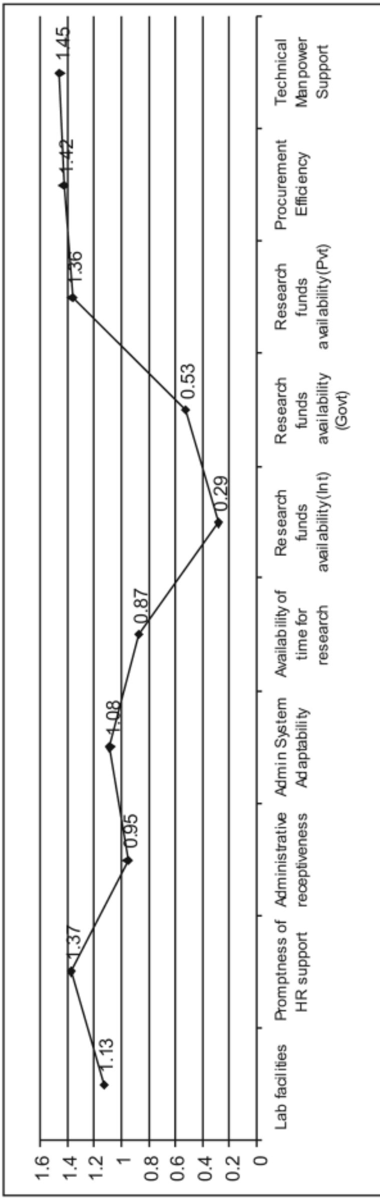

Exhibit 4: Difference Between Importance & Availability of RFFs (Electrical)

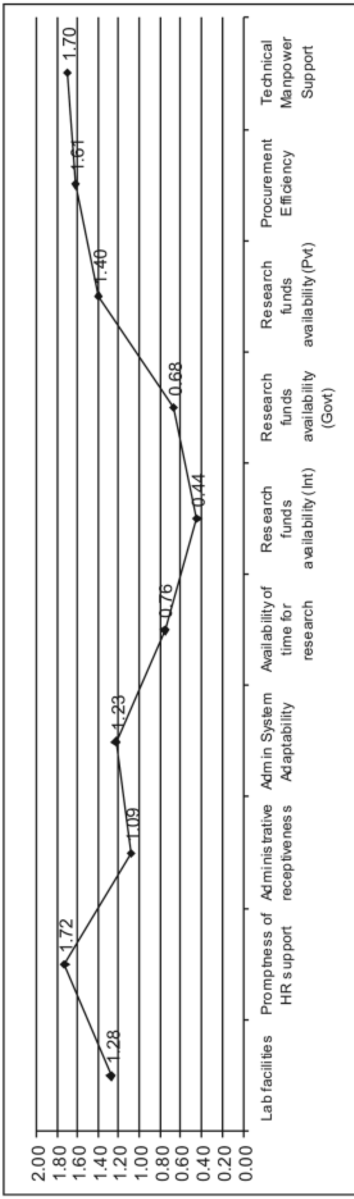

Exhibit 5: Difference Between Importance & Availability of RFFs (Mechanical)

Vinish Kathuria

Industry-Science/University Linkages — what lessons India can learn from developed countries?

Abstract:

Despite putting efforts by developing countries to grow fast and leapfrog, the results may not be to their likings. This is because their 'science policies' often misses the obvious link to grow i.e., the Industry-university linkages. Under this backdrop, the present paper had following two objectives: a) to find out the factors affecting university-industry linkages; and b) to look into different initiatives that would facilitate in reducing the industry-university gap. The paper finds that the gap between the two is due to their distinctive nature and style of functioning. University being a non-profit organisation, research is a part-time open activity aimed at enhancement of fundamental knowledge with valuation through publications, whereas, industry has a profit motive with closed and full time research linked to knowledge exploitation and patent generation. One key factor faciltiating reduction of gap between industry and university in several developed countries is the evolution of universities in these countries from the traditional 'storehouse of knowledge' to 'knowledge factories' to 'knowledge hub'. The paper suggests several initiatives from the industry that can facilitate reduction of gap. The paper argues that there does not exist a single and unique model of univesity-industry interaction. Depending upon the industry organization, networking and culture, distinct university-industry relationship might materialize as exempliefied in the case of Silicon Valley and Boston respectively. The paper concludes with the suggestion that the interaction should leverage the existing technology base of the area, the way Yamacraw Inititative did in Georgia by focussing on broadband technology research. The paper has important policy implications for university as well as for industry. The university should seek industry projects for their students as well as approach industry for long term joint-projects. This would enable university to do more closed type research more responsive to societal needs, whereas, industry should interact more with academia so as — a) to suggest changes in curricula as per their needs; and b) to carry-out research in areas which requires use of fundamental knowledge.

Introduction

Despite aspirations of developing countries to leapfrog, their 'science policies' often misses the obvious link i.e., the Industry-university linkages. The neglect looks all the more appalling given the fact that industry is the single most direct beneficiary of University's engineering programs. On an average, over 90% of graduates are employed by the industry, government or private utilities (Zaky and El-Faham, 1998). Ample evidence exist in developed countries reflecting the direct and indirect role of the university in furthering the growth process. Jaffe (1989) has shown that university R&D positively impacts industry R&D and patents. Audretsch and Feldman (1996) have shown that of the three factors influencing clustering of innovative activity, knowledge spillovers from university is one of the important ones. Similarly, Zucker and Darby (1997)[1] demonstrated that biotechnology firms seek to locate near 'star scientists' at universities to facilitate knowledge transfer to their R&D units. This dependence on university and then the direct role of industry in the growth of a nation warrants strengthening of university-industry ties, especially in developing countries contexts.

In the Indian context, barring few exceptions like Indian Institute of Technologies (IITs), or private research institutes (such as Sriram Institute, Delhi) most of the research in universities has no link with the needs of the industry. A number of reasons can be cited for this. Some of the important ones are: a) lack of funds; b) faculty members lacking any industrial experience; c) choice of research topics based mainly on the interest of supervisor; d) publication-oriented research to have quick promotion; e) aged research labs and equipments, which has made the research more of 'virtual' in nature (Zaky and El-Faham, 1998).

The outcome of all these is either there is a complete mismatch between industry's needs and academic research or sometimes industry is unaware of the research. There is no denial to the fact that universities and research centres also lack skills to market their products. Some of these gaps can easily be bridged if there is a proper interface between industry and academics.

Incidentally, this gap is not specific to India or developing countries. Most developed countries had this gap in not too distant past. However, these countries realized that if this gap is not bridged, the end-result would be detrimental to the growth. As a result, the

[1] As referred in Youtie and Shapira (2008).

past 2–3 decades has witnessed the US, followed by UK and other OECD countries embarking on an action plan to reduce this gap. The present paper looks into how some of these developed countries reduced the gap and are there any lessons that can be learnt by India?

The paper thus has following two objectives: a) to find out the factors affecting university-industry linkages; and b) to look into different initiatives that would facilitate in reducing the industry-university gap.

The remaining paper is organized into five sections. Next section (Section 2) gives the current state of R&D in India and what percentage of total R&D is of industry oriented. Section 3 highlights the importance of coupling of industry, science/university and government as warranted by business in new era. This is followed by what are the main causes of the gap between industry and university in Section 4. In Section 5 we discuss how to reduce the gap between industry and university. The section also gives an illustration of one successful initiative in the developed world that has strengthened the industry-university tie — Yamacraw Initiative. The paper concludes in section 6.

Current status of R&D

Historically, science and technology (S&T) has remained the single most important contributor to the growth of all the developed countries irrespective of the level from where they started. For example, England and France which industrialised first had a growth rate of 1.2–1.4%. Capitalising on the innovations of these countries and instituting their own S&T base, the latecomers like Germany, Denmark, Switzerland, USA etc. grew at a higher rate i.e., 1.6–1.8%. The trend has continued as Japan, Norway and Sweden had much higher growth rate than their predecessors. The role of S&T in fostering the growth has been further reinforced in recent past as the newly industrialized countries like Taiwan, Singapore and Korea have grown at a rate of 7–8% (Kathuria, 2000).

The emphasis on S&T starts simply with raising the investments in S&T. This is followed by focussing on sectors, which have largest potential or spillovers on growth and development. Some of the sectors that have wide impact on growth in the present industrial structure are software, communications, pharmaceutical and biotechnology Given the high level of capabilities of some Indian firms in these sectors, such as Infosys, Midas Communication, Natco Pharma, Ranbaxy, Shantha Biotechnics etc.,[2] any increase in research investment in these sectors is surely going to facilitate firms in these sectors compete globally. Another important pillar of the S&T led growth is realising the true potential of industry-university/science linkage. The importance of this linkage stems from the fact that science without industry (technology) will not lead to wealth creation or improve the quality of life, nor will industry without continuous research.

The current status of R&D in India is somewhat dismal. The two most important indicators reflecting the state of R&D are: (1) the per capita R&D investments (or R&D to GDP ratio); and (2) the per capita pool of scientists. So far the investments in S&T have been highly inadequate. Against the global annual expenditure on R&D of US$ 500–600 billion, India spends merely $2.5 billion (i.e., less than half a per cent), which is slightly over what Merck, a US-based pharmaceutical firm spent ($2.1 billion) in 1999 (Mishra, 2003). Compared to this the US Federal outlay on S&T in 2002 was $85 billion (≈15% of global expenditure). The objective of raising the investment in S&T to up to 2 per cent of GDP by 2007 as articulated in 'New Science Policy' though was laudable, but has become laughable as any other moving goal. This is because even in 2008, we have not touched 1% of GDP. From an all-time low R&D intensity of 0.71% in 1995–96, the increase to 0.87% in 1999–00 though raised a glimmer of hope, but thereafter falling below 0.8% in 2003–04 has raised an alarm. The decline looks all the more daunting in this era of globalization where knolwedge economy is the key to growth.

Figure 1 gives the trend in R&D expenditure at constant prices and the ratio of R&D expenditure to GDP. Though in absolute terms the R&D expenditure has shown an increasing trend with a CAGR of over 7% over 23 years period,[3] the R&D expenditure as

[2] Firms like Midas Communication, Natco Pharma and Shantha Biotechnics have already been awarded by the Department of Science and Technology (DST) in the year 2003 for outstanding in-house R&D achievements.

[3] Annual growth rate during 23 year period (i.e., between 1980–81 and 2003–04) is computed as $[(Y_t/Y_o)^{1/22}-1]*100$, where Y_t and Y_o are the terminal and initial values of R&D.

percentage of GDP has hovered around 0.8% the whole of 1990s. The CAGR since the year 1991, when India initiated liberalization process is however even less i.e., around 5.8%. A low R&D to GDP ratio is a cause for concern for the growth and catch-up, as it is much below the international recognized norm of 2%.

Researchers and Technicians in R&D

The Department of Science and Technology (DST) has been collecting information on the personnel employed in the R&D institutions and in-house R&D units of public and private sectors since 1973. The personnel employed in R&D units are either engaged in R&D work or extend technical support for R&D (termed as auxiliary personnel) or provide administrative support for research activities. This implies that the first two categories are mostly S&T qualified with former as the main researchers and the latter as the technicians. Figure 2 gives the distribution of personnel in R&D activities for 1998 and 2000.

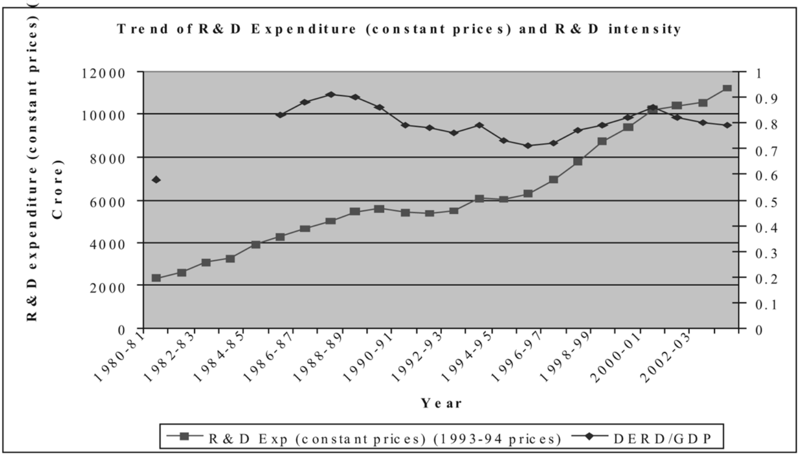

Figure 1: Trend in R&D expenditure and R&D to GDP ratio — 1980–81 to 2003–04

Data Source: R&D Statistics 2000–01, 2004–05

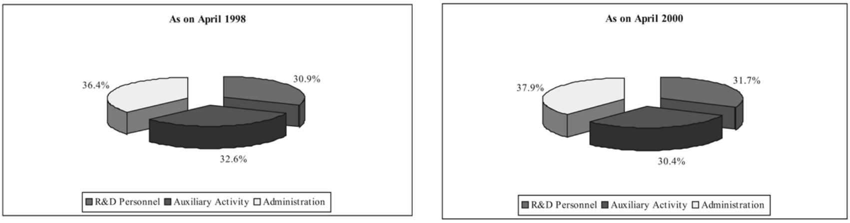

Figure 2: Researchers and Technicians in R&D Activities — 1998 and 2000
Data Source: R&D Statistics 1996–97, 2000–01, 2004–05

From the figure, one gets to know that researchers and technicians form over 60% of the total workforce in different R&D labs and their share has not changed much over the period. Employer-wise details as given in Table 1 indicates that in industrial sector, R&D personnel form half of the employees, whereas in institutional sector, it is the administrative staff that fills the most posts. The distribution is nearly same for both the years respectively. Interestingly, the focus in industrial sector is to have more researchers and less of other two categories, whereas in institutions most posts are filled with Administrative staff. This however, has implication for patents generated, products commercialized etc. (Kathuria, 2008).

TABLE 1: PERCENTAGE DISTRIBUTION OF PERSONNEL BY TYPE OF EMPLOYER

		As on April 1998		As on April 2000	
		Institutional	Industrial	Institutional	Industrial
1	R&D Personnel	25	50	24	65
2	Auxiliary Activity	33	31	33	19
3	Administration	42	19	43	16
	TOTAL	100	100	100	100

Source: DST (2002, 2006)

Private vs. Public Effort in R&D

Figure 3 gives the sector-wise R&D expenditure for two years — 1998–99 and 2002–03 respectively. From the figure, there does not emerge any trend over the period. However, the following points emerge. Central government including the public sector industry account for over 67% of total R&D expenditure in these two years. The private sector which was accounting for 21.6% of national R&D expenditure in 1998–99 has suffered decline in share to 20.5% in 2002–03. If one considers industrial sector as a whole comprising both public and private sector, the share of industrial sector in the total national R&D expenditure has decreased consistently over the past 6 year period. The share has decreased from 28.1% in 1997–98 to 26.6% in 1998–99 to 24.8% in 2002–03 (DST, 2002; 2006).

The above disussion thus indicates another disturbing aspect of R&D expenditure in India — the skewness against industrial sector. The share of industrial sector in the national R&D expenditure in developed countries is over 50%, whereas in India as shown by the data, it is hardly 25%. A sizeable share is by the institutional sector comprising of centre, state and academic sector.

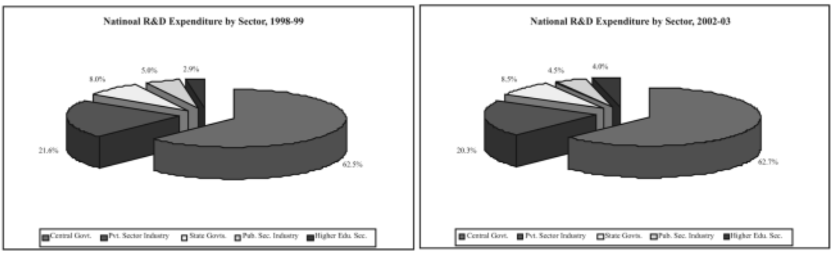

Figure 3: National R&D expenditure by sector — 2000–01 and 2004–05
Data Source: R&D statistics 2000–01 and 2004–05.

Another characteristic of R&D institutions, militating against R&D capabilities in India is the outnumbering of technical manpower by the support staff. A 1999 *World Development Report* indicates that against an average 151 research scientists and engineers for every million population in India over the 15 year period from 1981 to 1995, the three largest spender on S&T — the US, Japan and Germany — have on an average, 3,805 research scientists and engineers. The comparative figures for China and South Korea are 537 (i.e., nearly 4 times) and 2636 (i.e., nearly 17 times) respectively (World Bank, 1999).

All these shortcomings pertaining to R&D investment can be overcome if returns to R&D investment increases. This can be ensured only if R&D in India becomes close-ended i.e., should have more linkages to the end-user. This can be done if the untapped potential of industry-university linkage is harnessed.

Business in New era — Needs coupling of university, government and industry

The recent past has witnessed a sea-change in the ways business is being conducted. As a consequence any S&T strategy must involve all the three legs of the tripod — the academia (universities), the government and industry. As of now, because of mutual exclusiveness of their interests, all three actors are moving like a three-headed hydra. Government interest in research is mainly of strategic or directed type, e.g., defense requirements, public health, environmental issues, etc. Industry's interests are mainly applied in nature, whereas universities or academic institutes channelise their efforts and resources in fundamental and unidirected research. The creation of hybrid organizations acting as interface between university, industry and governmental segments — similar to the triple helix model of Etzkowtiz and Leydesdorff (2000) — can help in bridging the gap.

History is replete with examples, where academia through continuous interaction with the industry played a very pominent role in fostering the growth and competitiveness of the industry. The Silicon Valley is one such example where the Stanford University and University of California, Berkeley not only created the industry but also played a prominent role in its growth. Similarly, Route 128 corridor and Boston economy could flourish due to a key role of MIT and Harvard University.

The mutual exclusiveness in industry and university's orientation in developing countries is however very much reflected in Table 2, which gives the sources of technological innovation in Taiwan and India in the nineties. Row 1 gives the sources of innovation for Taiwan as part of a study understanding the 'Taiwan's National Systems of innovation'. However row 2 gives the sources of improvement of design by Indian CNC lathe producing firms[4] as found in a primary survey by Kathuria (1999).

[4] CNC lathe segment is one of the most dynamic segments of machine tool industry, where the design becomes obsolete every 2–3 years. The relevance of machine tool industry is evident from the fact that due to its widespread linkages, less than 2% industry output has a latitude to affect the remaining 98% of the industrial output (Kathuria, 1999).

TABLE 2: RELATIVE IMPORTANCE OF SOURCES OF TECHNOLOGICAL INNOVATION — TAIWAN AND INDIA*

	Internal R&D	Competitors/ Foreign Companies	Customers	Other Industries / subcontractors	Suppliers	Research Institutes	Universities
Taiwan#	1.3 (1)	2.2 (2)	2.9 (3)	3.4 (4)	3.4 (4)	3.6 (6)	4.3 (7)
India$	1.38 (1)	2.1 (3)	1.92 (2)	2.85 (5)	2.42 (4)	3.52 (6)	3.92 (7)

Source: For Taiwan — adapted from Wu (2000) and for India — adapted from Kathuria (1999)

Notes: * — Figure in parenthesis are ranking of these seven sources of innovations; # — For Taiwan it is based on 7 point Likert scale with 1 — Extremely high important and 7 — Extremely Low Important; $ — For India it is based on 4 point scale of a sample of 13 CNC lathe producing firms with 1 — Very important and 4 — Not important.

As indicated from above table, in both the countries, universities lag far behind as sources of technological innovations. This implies that their contribution to the innovations (and hence growth) is very minimal and there is a need to bring the gap between industry needs and university research.

Atlan (1990) and Peters and Fusfeld (1982)[5] provide several reasons why university-industry cooperation is a win-win situation for both and ultimately to the growth of the country. From industry point of view, these are: a) access to manpower, including well-trained graduates and knowledgeable faculty; b) access to basic and applied research results from which new products and processes will evolve; c) solutions to specific problems or professional expertise, not usually found in an individual firm; d) access to university facilities, not available in the firm; e) assistance in continuing education and training; f) enhancing the company's image; and g) being good local citizens or fostering good community relations.

On the other hand, the reasons for universities to seek cooperation with industry are little different. Peters and Fusfeld (1982) have identified several reasons for this interaction: a) Industry pro-

[5] As referred in Wu (2000).

vides a new source of funding for university; b) Industrial money involves less "red tape" (but more urgency) than government money; c) Industry sponsored research provides student with exposure to real world research problems; d) Industry sponsored research provides university researchers a chance to work on an intellectually challenging research programs; and lastly, e) Some government funds are available for applied research, based upon a joint effort between university and industry.

Gap between Industry and University

As mentioned earlier, barring few exceptions like IITs, IISc or some private research institutes most of the research in universities has no link with the needs of the industry. Among the key reasons cited for this are: a) lack of funds; b) faculty without any industrial experience; c) choice of research topics based mainly on the interest of supervisor; d) publication-oriented research to get speedy promotion; e) research is part-time; and f) aged research labs and equipments. All these factors has made the research more of 'virtual' in nature, where computer simulation is actively pursued to generate the results (Zaky and El-Faham, 1998).

Part of the problem lies in interpreting the definition of Research & Development (R&D). R&D has rarely been considered a single word. Since the beginning of industrial revolution, the Research and Development have been considered as flip sides of the coin. The research has always implied 'pure' research aimed at finding out how nature works and was considered to be the monopoly of universities, whereas the development, entailed the improvement of existing technologies and was considered to be the domain of industries (Zaky and El-Faham, 1998).

Another reason cited is 'cultural-mismatch' between the two due to their distinctive style of functioning. Zaky and El-Faham (1998) give a number of factors hampering synergies between the two. Following table (Table 3) summarizes these:

TABLE 3: FACTORS HINDERING SYNERGIES BETWEEN UNIVERSITY AND INDUSTRIAL RESEARCH

	University/Academic style	Industry Style
Nature of organisation	Non-profit	Profit oriented
Research type	Open activity, valuation through publications	Closed type, valuation through patents or revenue with restriction on communication and publication.
Research Aim	Expansion of knowledge	Exploitation of knowledge in product/process form
Speed of research	No emphasis on urgency	Short-term goals with high pressure of time
Nature of Research	Undirected and Fundamental	Directed / strategic and applied / ad-hoc
Research activity	Mainly part-time	Full time

Source: Adapted from Zaky and El-Faham (1998)

The outcome of all these is either there is a complete mismatch between industry's needs and academic research or sometimes industry is unaware of the research. There is no denial to the fact that universities and research centres also lack skills to market their products. Some of these gaps can easily be bridged if there is a proper interface between industry and academics. The developed countries like US, UK, France etc. understood the dynamics of this gap and created many institutions / agencies leading to an effective interface. For instance, CNRS (French National Centre for Scientific Research) in France, SERC (Scientific and Engineering Research Council) in the UK and federal agencies in US like NASA, etc. have acted in the past and now also acting as an effective interface. A similar interface organisation in India can easily bring out the best of the available resources and investment. The functioning of this agency will be such that both the government and industry can submit their problems and research needs to it and then agency can choose the most suitable place where the research can be carried out — research centre or university, and if there are several, which one of them based on some predetermined criteria.

Incidentally, this gap is not specific to India or developing countries. Most developed countries had this gap in not too distant past. However, these countries realized that if this gap is not bridged, the end-result would be detrimental to the growth. As a result, the past 2–3 decades has witnessed the US, followed by UK and other OECD countries embarking on an action plan to reduce this gap. The next section delves into how the role of universities has changed in most developed countries.

How to reduce the gap between Industry and University

One key factor faciltiating reduction of gap between industry and university in several developed countries is the evolution of universities in these countries from the traditional 'storehouse of knowledge' to 'knowledge factories' to 'knowledge hub'. Table 4 gives how the nature and functioning of universities have emerged with changing economic context.

TABLE 4: EVOLUTION OF UNIVERSITY AND ITS MISSION IN DEVELOPED COUNTRIES

Type	Traditional	Present	Future / Evolving
Function	Storehouse of knowledge	Knowledge Factory	Knowledge Hub
Economic Context	Craft Production	Industries Mass production	Post-industrial age, knowledge driven
Nature of University	Clerical or Elitist	Supplier of inputs and outputs	Integrated instittuion
Functioning or fostering	Above Society	Technology developer	Promotes indegen-ous development — new capabilities

Source: Adapted from Shapira and Youtie (2008: 1190)

The earliest models of universities highlighted their roles as merely 'accumulators' of knowledge isolated from the rest of soci-ety. This is exemplified in medieval universities such as Oxford and

Cambridge, where students and scholars housed in residential college lived and learnt away from the public, leading at times to 'town v. gown' clashes (Brockliss, 2000).[6] With onset of industrialization, universities assumed a more active role and pursued scientific research based on rational inquiry and experimentation. Besides, they took up roles in conducting research and training in technical disciplines and in educating students to meet the needs of industry (Moery *et al.*, 2004).[7]

The decades immediately after World War II are a period in which industrial mass production was key industrial philosophy in the US and other industrialized economies (Piore and Sabel, 1984). The different features of mass production — linear organization, scale economies, and dedicated systems — have at least some analogies in the growth and orientation of universities in the mid-to-late twentieth century, particularly for high-enrollment campus institutions. In the words of Shapira and Youtie (2008) "knowledge factories developed inputs (e.g., students and research funding) into outputs (prospective employees and research papers) in batches, with set methods, raising comparisons with assembly-line production" (p. 1189).

In recent decades, a third model of university has emerged, where university serves as a 'knowledge hub' that aims to foster indigenous knowledge, new capabilities and innovation, especially within its region (Shapira and Youtie, 2004).[8] In this model, universities become even more deeply embedded in innovation systems, seeking to actively foster interactions and spillovers to link research with application and commercialization, and taking on roles of catalyzing and animating economic and social development (Shapira and Youtie, 2008). The name knowledge hub is because in this new incarnation of university, processes of the creation, acquisition, diffusion, and deployment of knowledge are at the core of these func-

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[6] As referred in Youtie and Shapira (2008: 1189).

[7] The development of universities and local technical institutions in the industrial cities of Britain and state land-grant universities and private technical institutes in the U.S. in the 19th and early 20th century specifically stressed the significance of practical subjects and the application of research. For an illustration, refer the charter of Massachusetts Institute of Technology by the Massachusetts legislature in 1861.

[8] It is to be noted that despite this new evolving role of modern university, its traditional responsibility of training students and conducting research to produce basic knowledge still remains the key area.

tions. The university, of course, always has been an institution of knowledge, but in this third mode, the institution seeks actively to use knowledge to promote indigenous development and new capabilities in its region and beyond.

Following initiatives from the industry will go a long way to reduce the gap between them and academia — a) carrying out an inventorisation of need i.e., what kind of human resources and skills it would need in future; b) providing support for student projects; c) sponsoring long-term research; d) holding periodic seminars in collaboration with universities; and e) sharing equipment and facilities with universities.

It is not that these initiatives are not happening in India, only thing is they are still at the surface. For example, the use of electronics in machine tools since early seventies has resulted in a new branch of engineering called 'mechatronics'. Some of the engineering colleges in India are already producing engineers in this field. Similarly, a recent spurt in demand of bio-informatics has led some of the universities like Anna University to offer this course. Still one can learn from the experiences of developed countries like Japan, USA, Sweden etc. For instance, Kochi University of Technology, Japan has set up special curriculams to cater to the need of merging engineering and business management. Likewise, the Chalmers University, Gothenburg (Sweden) receives nearly half of its funding from industry through different collaborative projects.

On the other hand, some initiatives are needed from the University side also. These include recognizing the fact that in today's scenario the needs of industry are totally different. Not only the person needed by the industry should have formal engineering skills, but also should have good communication skills and an understanding of how technology links up to economics and commercial world. A more rewarding initiative from the university would be inviting industry to participate in periodic reviewing of syllabi and course contents both at undergraduate and graduate levels. Creation of incubators to support spinoffs of scientific and technological research — could be another initiative to bridge the gap.[9]

[9] Advanced Technology Development Centre at Georgia Tech University, Atlanta or Society for Innovation and Entrepreneurship (SINE) in IIT Bombay are few such examples of active incubators.

Besides these, the lack of effecive communication deprives both parties of vital information regarding their respective priorities and capabilities. However, it is to be noted that most of these differences are not insurmountable. The recent trend of curtailing financial support to university and other research labs have made them pro-active in carrying out applied research. Many of the CSIR (Council of Scientific and Industrial Research) labs like NCL (National Chemical Laboratories), NEERI (National Environmental Engineering Research Institute), CCMB (Centre for Cellular and Molecular Biology) etc. are doing not only applied research having direct utility for the end-user but also the projects are funded and supported by the industry.

Once the ball starts rolling, the interactions will provide multiple benefits to both parties having multiplier effect on the growth. Besides obtaining financial support, universities can reap many benefits like making use of sophisticated and expensive industrial equipment and facilities; gaining a first hand industrial experience; identifying problems leading to sponsored research projects or consulting opportunities; and attracting students from industry for a continuing education or professional advancement program.

Thus, there exists a repertoire of programs that can be initiated to increase interaction between university and industry. The different programs currently undergoing in IIT Bombay illustrates this possibility. These include: Consultancy Projects; Industry Affiliate Programme; Industry Sponsored Projects; Sponsorships of Laboratories; Collaborative Research; Technology Transfers; Technology Business Incubation; Continuing Education Programmes (CEP); Industry Sponsored Student Fellowships / Projects; Industry Personnel as Adjunct Faculty; Summer Placement of Faculty; Faculty as Members of Boards of Directors; Industry representative in IIT's Board among others.

The following subsection discusses in brief two such industry-university interactions — one in a developed country setting — Yamacraw Initiative and another in a developing country setting — Campus Connect by Infosys.

Yamacraw Initiative[10]

[10] This subsection takes mainly from Youtie and Shapiro (2008).

Yamacraw initiative was launched by Georgia State as a 5-year project in 1999 with a consortia of 8 universities[11] aimed at combining the efforts of private enterprise, academia and state government to make Georgia a world leader in the design and commercialization of high-capacity broadband communications systems, devices, and system-on-a-chip technologies. The basic elements of the initiative included: (1) corporate membership in the Yamacraw design center; (2) an industry-relevant research program; (3) development of a large and growing pool of graduates in relevant degree programs, based on the recruitment of new university system faculty and state-of-the-art curriculum development; (4) an early-stage seed fund for investing in chip design startups; (5) a marketing program to build Georgia's high-tech image in the area; and (6) a new building to house the program.

The initiative was renamed as the Georgia Electronic Design Center, when a new governor was elected. Forty corporate and federal agency members and research partners work with the center and it conducts about $10 million in research a year. The educational curriculum component, which resulted in more than 400 students receiving specialized training in the area a year, has been absorbed by the universities that were part of the original Yamacraw Initiative. An assessment of the program in 2002 found that Georgia Tech was the prominent producer of research in this field. A study by Shapira *et al.* (2003) raised concern about the potential limitation of employment growth in the area as the initiative would have dominance of university research and lack of significant corporate research. These concerns were largely unfounded as two companies — Pirelli and Samsung — set up embedded laboratories in the facility in 2005. Figure 4 giving the increased industry membership over a 4 year period, also refutes the concern.

[11] The universities involved are Georgia Tech, Southern Polytechnic State University, Georgia State University, University of Georgia, Kennesaw State University, Armstrong Atlantic State University, Georgia Southern University and Savannah State University.

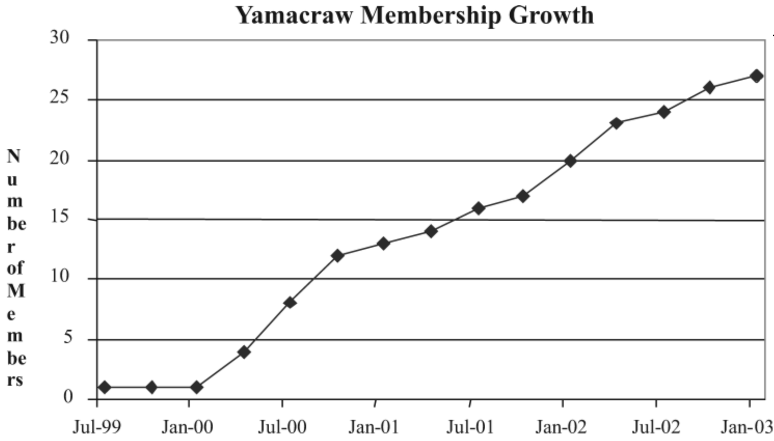

Figure 4: Yamacraw Membership Growth
Source: *www.cs.armstrong.edu/greenlaw/presentations/yamacraw_initiative_overview.ppt* accessed April 2009.

By establishing networks between researchers, established firms, and startups, the Yamacraw Initiative focused attention to collaborative research and commercialization opportunities in broadband and mixed signal (analog and digital) communications that might previously have been overlooked if they were in separate centers and departments. An underlying goal of the initiative has also been to foster innovative economic development through the creation of firms in these fields that engage in tacit knowledge exchanges with the university.

In a nutshell, Yamacraw sought to create a learning region of firms in the targeted communications sector in the metropolitan Atlanta area. There are some early signs of success, through startups, the increased membership of firms, and the formation of university–industry alliances, although it is acknowledged that this is a long-term transformational goal that will take more time to come to fruition (Youtie and Shapiro, 2008).

Campus Connect

In July 2004, Infosys Technologies launched an industry-academia partnership initiative — Campus Connect. The aim of the program is to deepen industry-academia relationship and create a strong foundation for the emerging knowledge economy in India.

Through an initial investment of Rs. 100 million, the program focuses on aligning needs of engineering colleges, the faculty and students with that of industry, thus preparing industry-ready professionals.

Some of the key components of the program are: a) Seminar and faculty workshops in colleges; b) working closely with educational bodies to facilitate alignment of college curriculam with that of industry requirements; c) Publishing Infosys courseware on the web; d) Sabbatical for Professors to pursue research interests with Infosys and lastly, e) Project work for students.

The program so far has been fairly successful. By 2008, the program had already entered into partnership with 490 colleges with over 500 batches of students covered and an over 1000 faculty were enabled. A key aspect of the program is increase in placement of the students. The survey shows that nearly 26–40% of non-IT students got placement due to Campus Connect. However the percentage was little low in case of IT students (11–40%).[12]

Concluding remarks

India is on a threshold of becoming developed country and will be in the elite group by 2020. The repeated proclamation though has raised expectations, however increasingly it will be difficult to sell. This is because there hardly exists any blue-print of how this uphill task of raising per capita income from approximately US $400 to US$ 2000 can be achieved without distorting and worsening the equity aspect within a short span of 16 years. Even if a blue-print exists, it has never been articulated openly.

Despite aspirations of developing countries to leapfrog to developed country status, their 'science policies' often misses a most obvious link i.e., the Industry-university linkages. The neglect looks all the more appalling given the fact that industry is the single most direct beneficiary of University's engineering programs. On an average, more than 90% of graduates are employed by the industry, government or private utilities. This dependence and the direct role of industry in the growth of a nation warrants strengthening of ties with universities. Any increase in S&T outlay only implies that the country is in 'investment-driven' stage and to move to

[12] Source: http://info.worldbank.org/etools/docs/library/244641/IndRavindra Infosys.pdf accessed in April 2009.

'innovation-driven' stage, it has to forge links between industry and science. The relevance of these links are even greater in the present era of globalization, where only competitive firms are going to rule the roost.

The overwhelming rate of advances in both science and technology has not only resulted in research becoming more detailed and specialized but also more expensive. To some, it has led to 'pulverization' of research i.e., knowing more and more about less and less. However, when science becomes useful for practical purposes it metamorphosis to technology and then warrants development. Thus, it becomes imperative that scientific research and technological development coalesce to achieve the aspirations of high growth, wealth creation and improvement in quality of life. This is possible if industry and university forge an alliance.

This paper looked into the factors militating against the industry-university linkages and what all initiatives can be taken to forge and strengthen the linkages. The paper argues that the way of thinking of the two has to be changed. Some key initiatives by industry that can bridge this cultural-mismatch include a) carrying out an inventorisation of skills need; b) sponsoring student projects; c) providing support for long-term research; d) holding periodic seminars jointly with universities; and e) sharing equipment and facilities with them.

In this era of globalization, there does not exist a single and unique model of univesity-industry interaction. Depending upon the industry organization, networking and culture, distinct university-industry relationship might materialize as exempliefied in the case of Silicon Valley and Boston respectively (Saxenian, 1996). The interaction however should leverage the existing technology base of the area, the way Yamacraw Inititative did in Georgia by focussing on broadband technology research. The Yamacraw initiative also suggests that interaction can have a wider horizon with a network of universities in an area interacting closely with large number of industries.

The paper has important policy implications for university as well as for industry. The university should seek industry projects for their students as well as approach industry for long term joint-projects. This would enable university to do more closed type research, which would be more responsive to societal needs. On the other hand, industry should interact more with academia for two key reasons — a) to suggest changes in curricula as per their needs; and b) to carry-out research in areas which requires use of fundamental knowledge. All these initiatives would then go a long way in causing a turnaround to declining R&D intensity in the country.

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Elena Ivanova

Changes in the Fields of S&T Research in St. Petersburg

Universities are one of the core elements of national innovations systems in most countries worldwide. In addition to universities, S&T research in Russia is performed by government institutes, mainly the Russian Academy of Sciences (RAS), and research organisations within the business sector. The problem in Russia is to assess the contribution of universities and RAS institutes in developing basic scientific research in different fields of science, including the issue of scientific staff reproduction.

The aim of this paper is to study the changes in research fields and to reveal the main challenges in developing S&T research in St. Petersburg.

St. Petersburg occupies the top rank in Russia for the number of active researchers per 10,000 population; $1/10^{th}$ of all Russian researchers work in St. Petersburg. Research in all fields of S&T is conducted in St. Petersburg.

To contribute to understanding about this problem, the author has collected information on all research grants given by the Russian Foundation for Basic Research (RFBR) for the years 1993–2007, which were received by researchers in St. Petersburg. Analysing the collected information made it possible to consider the scientific specialisation of universities and RAS institutes. As well, the author used government data for Russia as a whole and for St. Petersburg in her research [1].

In the Soviet period, organisations which engaged in scientific research and development (R&D) were conditionally integrated within three sectors: academic, higher education and industry-sector science. In modern statistical collections, Russia's scientific and technical organisations are classified in four sectors: government, business, higher-education and private non-profit. As a matter of fact, these sectors retain the basic structural features of the scientific complex that took shape in the Soviet period. The government sector include RAS institutes, including the Russian Academy of Medical Sciences (RAMS), the Russian Academy of Agricultural Sciences (RAAS), and research institutions run by regional and local authorities. The higher education sector include research institutes and design institutes subordinated to universities and other higher educational institutions. The business sector integrate industry research institutes, design and technology organisations, scientific divisions run by industrial enterprises, pilot bases. The private non-profit sector include private organisations not aimed at deriving profit.

In terms of numbers of staff engaged in R&D today, the business sector, like industry-sector science in the Soviet period, remains the largest.

In 1992–2008, the government sector share grew in Russia, while the higher-education and business sector share fell. This is accounted for by the fact that the number of staff in the public sector diminished more slowly than in other sectors, as structural changes took place against the background reduction of the total number of people in the scientific sphere. In 1989–2008, the total number of staff engaged in R&D decreased an astonishing 2.5 times.

The reduction of staff at industry research and design institutes was the greatest compared to other sectors. Some institutes were closed, some of them took status as state scientific centres, while others became private or combined their form of ownership.

Science in higher educational establishments also suffered in the early 1990s, when many research institutes at universities were closed. At the same time, all state higher educational institutions in St. Petersburg were preserved and now paying increasingly more attention to scientific research. In addition to state higher educational institutions, over 40 non-governmental educational establishments were opened in the city.

The numbers of scientific researches in the government sector decreased less considerably. It became possible to preserve in St. Petersburg all scientific organisations of the RAS, the RAMS and the RAAS.

In 1993, the RFBR was set up, followed by some other research foundations. Researchers soon joined the new science funding mechanism through a grant competition system. The share of RFBR grants for St. Petersburg scientists was considerably higher than their share in the number of scientists in Russia: it averages about 13% of the grants per annum.

Most of the grants received by St. Petersburg scientists are allocated to academic institutes (RAS). Taking the aggregate of all research grants of the RFBR received by St. Petersburg scientists in 1993–2008, 54.8% were given to scientists working in RAS institutes, 31.2% of the grants were allocated to researchers of higher educational establishments and 14% of the grants awarded to scientists working within organisations of the business sector.

The largest number of research grants in 1993–2008 was received by big academic establishments in St. Petersburg: the Ioffe Physico-Technical Institute and the B.P. Konstantinov St. Petersburg Nuclear Physics Institute. A considerable number of grants were allocated to biological institutions: the Komarov Botanical Institute and Zoological Institute, the I.P. Pavlov Institute of Physiology, the Institute of Cytology and the I.M. Sechenov Institute of Evolutionary Physiology and Biochemistry.

In the fields of “Mathematics, computer science, mechanics,” 57% of the projects are carried out by scientists at higher educational establishments. Further, among university projects, about 70% are projects by scientists at St. Petersburg State University, and another 15% by scientists at St. Petersburg State Polytechnical University, St. Petersburg Academy of Aircraft Instrumentation and the Baltic State Technical University.

In the area of “Chemistry,” 60% of the grants were received by university scientists and 70% of these grants were allocated for projects at St. Petersburg State University, with 15% awarded to scientists at the St. Petersburg State Institute of Technologies.

The only field where research projects by business institutes were significantly important (36% of grants) was the section «Earth Sciences».

Grants received by scientists at RAS institutes, shown against all other St. Petersburg grants, are highest in “Physics, astronomy” (67%) and in “Biology, medicine” (69%). The share of grants by St. Petersburg scientists as compared to the total number of grants awarded by the RFBR, received by Russian scientists in the area of “Physics, astronomy” was about 16% and about 18% in “Biology, medicine.”

The shares of St. Petersburg projects in “Physics, astronomy”, “Biology, medicine” exceeded the shares of these branches in all

RFBR grants at large. In this period, grants to the above-mentioned fields of scientific research accounted for 63% of all grants received in St. Petersburg and 47% of all research grants of the RFBR. That is, one may assert that these fields represent the specific character of St. Petersburg science. Most of the grants received by St. Petersburg scientists of RAS institutes have been registered in these particular areas. This evidences that academic-sector scientists are very active, taking a leading role in the scientific fields most rapidly developing now in St. Petersburg.

The losses in Russian science in recent years include reduction of the number of researchers in all sectors of S&T, especially higher-education and business. But the structure of basic research fields was saved. Scientific staff reproduction is now openly questioned for the future of main basic research fields.

Starting from the mid-1990s, significant growth in students has occurred at higher educational institutions in Russia. The total number of students grew from 2.6 million in 1993/1994 academic year up to 7.5 million in 2007/2008; that is, almost 3-fold increase.

In St. Petersburg, the growing number of students was not as impressive as in the whole of Russia. The total number of students at higher educational institutions in the 1990/1991 academic year amounted to 247,000 and in 2007/2008 to 450,000, an 80% increase. The expressive growth started from the late 1990s, after the falling number of students at the beginning of 1990s; in the 1995/1996 academic year the total number of students was only 218,000 thousand. The number of new graduates started growing in 2000/2001, reaching 48,000 and achieved the figure of 73,000 in the 2007/2008 academic year.

The number of postgraduate students in Russia from 1992 to 2008 grew 2.4 times: from 52,000 in 1992 to 148,000 in 2008. The growth in the number of postgraduate students started from the mid-1990s, which is similar to the dynamics of increase in the number of students provided for by the expansion of postgraduate courses at higher schools. The share of postgraduate students at scientific research institutes has fallen. In 1992, 443 Russian higher educational establishments provided training for postgraduate students, while in 2008 there were 717 universities. The number of scientific research institutes engaged in training postgraduate students in the same years in Russia decreased from 853 to 811, while the number of postgraduate students at research institutes increased from 15,168 to 17,397.

The number of postgraduate students in St. Petersburg in the last 12 years doubled: in 1995, 1673 postgraduates completed their programme, while in 2007, 3485 completed it. Our calculations show that the number of postgraduate students in economic and legal specialities grew most rapidly. In particular, the number of postgraduate students in economics in St. Petersburg in 2007 was 886 compared to 161 in 1995. The number of postgraduate students on technical specialities grew as well: 481 in 1995 compared to 812 in 2007. In these years the number of postgraduate students of medical specialities doubled, making 267 persons in 2007. The number of postgraduate students in jurisprudence grew sevenfold, with the number of graduates 218 in 2007. The number of postgraduate students in pedagogical sciences increased more than twofold: in 2007, 162 persons completed their postgraduate course. The number of postgraduate students in physics and mathematics fell somewhat as well: in 2007 there were 142 graduates compared to 189 in 1995.

From 1995 to 2007, the share of postgraduate students specializing in technical sciences fell: in 1995 it was 29% and in 2007, 23%. The share of postgraduate students in physics and mathematics dropped considerably (from 11 to 4%), the same as with biology (from 5 to 4%). The most growth was observed in share of postgraduate economics (from 9.6 to 24%) and law (from 1.9 to 5.1%).

The number of successful theses defences in St. Petersburg grew from 1,616 in 1995 to 2,193 in 2007. In 1995, 408 theses were defended at RAS institutes compared to 385 in 2007, while the figures for universities in the same years rose from 1,208 and 1,808. This means that St. Petersburg higher educational establishments noticeably stirred up the activity of their academic councils, i.e. which host and adjudicate the defence presentations. Among organisations engaged in training postgraduate students, the number of higher educational establishments increased as well.

The data shows that higher educational establishments have increased their importance in training postgraduate students in Russia at large and also in St. Petersburg. At the same time, the number of people engaged in R&D at universities has declined in recent years. From 1991 to 2007, there has been a yearly drop in the number of staff engaged in R&D in the system of higher education.

Let us compare the specialisation of postgraduate students by scientific fields against the structure of scientific research made in St. Petersburg. Most researchers in Petersburg represented technical sciences in 2007 (69%); those specialising in mathematics amounted to 2%; physics, astronomy, 6%; chemistry, pharmaceutical chemistry, 4%; biology, psychophysiology, 4%; medical sciences, 3%; and Earth sciences, 4%.

Young scientists specializing in the field of technical sciences are obviously not sufficient to replace those working there presently. The number of doctoral candidates in this branch is well below the required figure. Under current conditions, when biology has become one of the main "active-innovation" sciences, the number of postgraduate students in biological specialities is obviously not sufficient.

The number of researchers in Russia below 29 years of age was 12% in 1994; 10% in 1998; and 13.5% in 2002, while the number of researchers aged 30 to 49 during the same period was respectively 60.8; 52.2 and 37.7%. After 2003, the share of researchers below 29 years of age began slowly to increase; in 2006 it was 17%.

In St. Petersburg, the scientific sector is "ageing" more rapidly than in the rest of the country. The average age of researchers working in the sphere of higher education in St. Petersburg is nevertheless below that in RAS institutes.

A comparison of tendencies in the development of S&T shows the situation in the country has changed essentially with that at the beginning of the 1990s. The number of students and postgraduate students has grown, while the scientific sector has shrunk. This means that, on the one hand, the possibility of finding a job in S&T organisations is lower for the increasingly fewer number of students. On the other hand, even these jobs that exist are less attractive so as to ensure regular renewal of scientific staff.

Certainly, the situations in various regions differ. In St. Petersburg, the growth in students is below the overall level in Russia, while the number of postgraduate students is growing at approximately the same rate. At the same time, the shrinkage of those engaged in R&D in St. Petersburg happened at a greater scale. Therefore, the imbalance in science and education in St. Petersburg is more apparent than in other regions.

The Russian government endeavors to expand research carried out at universities in Russia and in St. Petersburg. This will make it possible to involve more students and postgraduates in its implementation. For this purpose, ties are being established between the universities and the institutes of the Russian Academy of Sciences. New forms of integration of science and education have appeared. One such relational form is the building of new universities for training postgraduate students. Teachers there are scientists from RAS institutes and the postgraduates work in the laboratories of these institutes in basic research fields. From 1999, such universities have functioned in St. Petersburg. The St. Petersburg scientific-educational physics and technology complex under the RAS has been functioning for several years already, including a grammar school, university and scientific research laboratories.

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INNOVATION SYSTEMS AND THE IMPACT OF IT UNDER GLOBALIZATION

Parthasarathi Banerjee

Innovation under globalization as inter-institutional contests for revaluing and redistributing assets

Introduction:

A simple robust definition of innovation is that it brings about redistribution of assets and income. Most discussions on innovation overlook this core defining element, which was germinal even in early Schumpeter's definition and whose explanatory unit was a business enterprise. The later Schumpeter on business cycles admitted the periodic transformative shift caused by both technical change and innovation.

The definition proposed here offers three distinctive features: (1) assets more than income suffers a shift, in other words, subsequent to innovation the valuation of assets change and the periodicity of cycles should change; (2) innovation shifts in assets reflect changes in expectations as well as changes in the composition of group(s) expecting such changes and also changes in herd behaviors (sustained by ideologies); and (3) for generic innovations, the shift occurs in institutions in which enterprise is a participant, in other words, innovation with impact shifts the dominance across contesting institutions.

In order to apprehend innovation we might examine shifts in assets and their values and shifts in expectations as well as in consumption. The unit of explanation would be institutions in the theatre of contests among institutions. Both expectation and consumption reflect certain sets of practices. Hence our explanation of innovation refers to shifts in sets of practices as well. Innovation helps redistribution of ownership, in particular assets-in-future. Changes in income (and hence, profit) could even be considered as a derivative of changes in definitions of assets. The enterprise or entrepreneur as agents of innovation is secondary to the agency of contesting institutions. Joint or coordinated expectations of several enterprises bring about innovative shifts.

Global institutions of assets, valuations, expectations, practices and consumptions engage in contests for major innovations. Both global and domestic systemic changes in asset valuations or consumption valuations result from such global contests. We thus tacitly assume two features: (a) degree of globalization is defined by the extent domestic systemic modes of valuation conform to global modes of valuation; and (b) the complete domain of institutions need not necessarily experience growth.

This essay introspects on redistributive inter-institutional contests, which we call innovation and examines some aspects of innovation contests in the area of biomedicine. We look into several features of innovation contests in the domestic systemic biomedical arena.

Institutions are stronger in the context of contest when they are global. Inter-institutional contests often thus render a domestic or local institution into being part of a global institution. The transformation of domestic systems relating to institutions into global systems changes the formation as well as agenda-process of institutions. Globalisation challenges local weak institutions and brings them into the fold of global institutions. With a shift into the global fold the rules and agendas of local institutional contests change. Subsequent to changes in rules, local institutions that do not migrate inter-nationally get engaged in contests of new dimensions, with new agendas. Globalisation causes this transformation. The following is a story of transformation in which innovation undertakes the role of being a change agency.

Contest in the field of biomedicine:

Generating knowledge, capability and capacity in the biomedical area confronts a complex milieu. This milieu is defined by the notion and practice of health (and then consumption of health solutions). In short, the structures and institutions of the biomedical market depend upon three major types of set-up relating to drugs, medical devices and physicians. Most often, capability in developing drugs has been considered as the only indicator. This leaves aside two other facts: (1) contests between physicians, medical devices and drugs in order to control outcomes, and also (2) that physicians themselves and medical devices are very important actors.

Resources are distributed over several markets, however, that in turn are governed by distinct and different sets of rules. There are multiple institutions that compete for access to greater resources and their distribution. Organizations of business corporations, including that of public R&D, unfortunately receive resources that they cannot gather based-upon their internal strategic governance. Resources are generated by institutions and allocated as well as controlled through contests between institutions. Resources then flow past one institution to be available for another. The circuit of governance is much larger and goes beyond the inside of business firms or public R&D organizations to the outside, where a firm/ organization competes for negotiating power.

Innovation involves shaping asset-outcomes in multiple institutions. Institutional contests in the case of biomedicine, for example, are innovative both for rendering more valuable assets under their own control while devaluing assets under the control of contesting institutions. This appears strange. Innovation studies particularly in relation to biomedicine often remain delimited by specific sectors or by a specific firm. Several scholars trace the roots of differential capability to the difference in networking between academia and industry. Biomedical innovation offers special circumstances that invite involvement by multiple institutions. Simply put, biomedical innovation is the outcome of contests between institutions. Innovation is the key instrument in arranging contests. Innovation refers to only those changes that attract or command greater or more voting. Regulators and legislators or judges and bureaucrats oversee voting. Regulators have little or no role in typically Schumpeterian innovation, but they have the most important role in the context of institutional contests.

Contests and the shape of knowledge outcomes:

Contests between drugs, medical devices and physicians take place through sets of institutionalised practices/rules. These are: clinical observational and interactive practices undertaken by physicians; theory-driven and theory-building open and not-for-profit knowledge practices of a university; and closed-door, for-profit, organized science-research often controlled by pharmaceutical firms. There are finer subdivisions within these sets. Medical devices research in practice shares the same institutions with the drug firms, yet in market these are fiercely competing for devices and to define different sets of practices for patients. Institutions of medical devices map the human body differently from mapping done by drug firms. We can overlook this in this paper, however, since the Indian biomedical system has almost no capability in medical devices and up to this date device-intensity in medical settings is far lower than in advanced countries. In short, we can call the first institution a clinic or hospital, the second a university, and the third organized research. Clinical institutions have features unique from other modes of practice and other streams of knowledge.

Universities offer contrasts. Disciplines of knowledge undergird practices in university. Disciplinary groups and sharing practices as well as a substantial part of accumulated knowledge taking place within the boundaries of disciplines have spawned turfs. Organized research is instrumental and goal oriented and, when undertaken by business firms, great secrecy is necessarily maintained. Public R&D organizations often reside in the interface between universities and organized research.

'Institutional contests for domination' refers to the power to: define agendas to influence and shape practices; decide definitions of what constitutes an asset or to disjoint assets beyond integration within institutional practices; disallow accumulation; weaken reproduction of a field of practice; achieve through innovations; force re-ordering of fields, practices, assets and their accumulation; and induce flows of funds and/or other resources to an institution.

Governance of innovation for institutional shifts:

Contests between institutions of knowledge-based practices and development of products are arranged through innovations. Does governance of institutional contests imply that innovations too are to be governed? On the surface this appears incredible. Innovators' profits by definition must follow an unpredicted and ungoverned path. An innovator must challenge the existing order of sunk-in investments and create opportunities for his or her novel mode of investment. This belief appears to hold true for most innovative changes happening in small niches. However, when an innovation challenges a large amount of sunk-in investments by several agents and the innovation mode is too far from existing modes of production and consumption, and when in particular, as Banerjee (2004 & 2007) has argued, the innovator does not arrange for mutual expectations, then the singularity of innovation causes failure. Innovations, it seems, depend on mutual concurrence; lone serendipitous imagination no longer bears fruit.

Concurrence and mutuality between several innovations by multiple agents latched onto a future expected envelope of a series of complementing products make innovation happen. We observe this rather often in software design and to a limited extent in biomedicine. At a primitive level, we observe the emergence of groups contesting with each other through standards (Benoliel, 2004; Teece & Sherry, 2003) or through rules (Kaplow, 1992). Opportunistic manipulations of standards (Besen & Farrell, 1994) have led many scholars to argue for restricting further the standards while favoring framing rules. Standards demand that, in lieu of organized competition on singular products and between identifiable agents, organization favors competition between multiple unidentifiable agents on a series of products or services. Agreement on standards requires concurrence between firms or public R&D organizations. A step ahead in this direction is rules-based competition since rules are framed both in concurrence between parties and through governance by agents with arbitrational power. Jain (2002) warns us that exhibiting homogenization or harmonization of rules across countries creates a contestable global market. Severalties of rules would therefore hasten innovations. In order to derive strategic advantage a country or an institution must strive, therefore, to sustain markets based on severalties of rules. Governance of innovation is a reality. In fact, in rudimentary forms modularization of products or technologies brings in elements of governance in the leading of innovations.

Contests between institutions made possible through contests between innovations happening in respective institutions can therefore be governed. In other words, governance of institutional contests implies governance of innovations and vice versa. Our unit of analysis for innovation in biomedicine, for example, or in machine tools, cannot simply be a firm for pharmaceutical or medical devices. Several actors, in complementing or competing with each other, contribute to a grand piece of innovation. Coombs, Harvey and Tether (2001) have described this as a 'distributed innovation process.' If we follow them, we identify multiple agents contributing to innovations. However, we are not informed how and why these agents began complementing each other. Governance outside of the institutional milieu of innovators designed to influence and shape contests between institutions might help promote distributed innovation. To put it simply, the appearance of research collaborations between discrete disciplines happens easily as soon as there is a mega-science project. The only other mode through which collaborations can emerge remains within disciplines as failing pieces of scientific queries that cannot be resolved from within the disciplinary knowledge. The latter can explain only a few cases of emerging collaborations while the former immediately can establish governed emerging collaborations. Governance and arrangement of innovations appears to hold the key. If that is so, our unit of analysis must also include governance beyond multiple distributed actors.

From Coase (1990) we learn that increases in transaction costs demand solutions through governance. Williamson (1981) extended the argument to show the emergence of multiple forms of governance in the substitution of markets. Emergence of governance or authority assumes the prior existence of markets as well as a limit to authority, such that the sphere of governance remains limited within an institution. So we can have authority over firm organization, over inter-firm organization or over an emerging institution. Forcing contractual obligations is cheapest for the first and costliest for the last. Our puzzle begins prior to this; we may observe that assets in knowledge and human skills belong to different disciplines and specializations that do not undertake market transactions. A plausible response could be to explain the absence of transactions in terms of the high transaction cost. However, since science has historically grown through sharing certain ‘commons,’ the existence of which should nullify prevalence of high transaction costs, we cannot claim that transactions do not take place. We know for certain that transactions based on contracts or prices remain few and far between. Unformed prices did not allow for the emergence of markets while transactions took place rather regularly. The other related issue is about the domain of authority. An authority substituting for a market by an organization or a rule-based institution can claim its domain not beyond what the market encompasses. For example, an authority in pharmaceutical firms cannot lay claim to the practices of physicians and hence to physicians' assets. In other words, Williamson's meaning of 'authority' remains limited to the market domain that the authority substitutes.

Our puzzle is first about non-market transactions and assets whose prices did not form properly. Secondly, it is about the larger domain where assets never undertake transactions. About the first aspect, we observe that several structures such as specializations or disciplines shape the values of assets, but only within an institution. About the second aspect, in domains between contesting institutions there are no inter-institutional transactions and they are not dominated by any single authority. A physician in clinical practice grows an asset that has value and can be priced within limits only according to clinical institutional practices. However, a pharmaceutical firm by way of bringing out a new drug can affect both the value and practices of physicians. This authority of a firm and its allied organizations for example, does not exercise contracts or prices to achieve influencing practices and asset-values. The domain of authority derived from transaction cost minimization cannot explain the power to influence states of affairs in other contesting institutions.

We can take stock of the highlights from above: Contesting institutions employ innovations. Arranging contests between institutions implies arranging innovations within an institution. These innovations are distributed processes. Governance necessarily arranges for distributed processes to accomplish innovation. There is, however, something strange in this governance that differs from recognizable authority within firms. This governance cuts across contesting institutions or rules over contesting institutions and innovations that are encouraged by this authority undermine some institutions while elevating others. Innovation appears as an instrument deciding the fate of contests between institutions; governance over innovation processes ensures governance over contesting institutions.

Innovation implies an expectation on the future. And since the future expected good must prove complementary to a relevant set of future goods, innovation implies joint expectations. Banerjee (2004) explored joint innovation in the context of inter-firm actions and suggested that winning firms employs strategies according to mutual expectations. Strategies about innovation are then strategies about influencing the expectations of others. Once we expand upon this suggestion to observe the contested terrain between institutions, we see how through innovation strategies institutions desire to win influence over the practices of other contesting institutions. No single agent within a winning institution can muster enough resources to carry through such a gigantic strategy. There comes the need for governance, in negotiation with agreements between institutional agents and governance on future paths of innovations, such as a mega program on genomics or a space mission. Initially mopped up finance from governance soon generates enough skill assets and ideas/products/experiments that then initially attract through venture funds and later through IPOs the further release of funds and intangible brands.

Together, all of this causes a shift (away from contesting institutions) in terms of credibility, consequently resulting in a lower inflow of manpower assets (since now asset values in losing institutions have decreased) and finally in the lower value in the stock exchanges and in other markets. Soon or later the winning institution will receive assets from losing institutions. Values of assets are thus reset. This resetting happens through mega innovations. We define this occurrence as the result of a macro strategy.

Individual agents, however, had already sunk in investments in the form of relationship building or developing skill-sets, including accumulating several tangibles. This investment past confronts the present as well as the future. An individual resorts to maneuvering within a small world in order to simply stay ‘practical’. These maneuvers define the micro strategy. No knee jerk reaction or accommodation characterizes micro moves. A person makes a small bet, holds back certain powers while outwardly conceding to the demands from winning institutions. Such a person initiates, along with a large multitude of losers, a process that checks to various degrees the diffusion of winning institution’s templates. The micro strategies of losers are for the practical ends of surviving.

In a narrower sense this is a holdup. However, holdups arrest the speed of diffusing templates. Contrarily, the swelling pool of newly skilled manpower checks holdups. The chemist checks genomics, which having swelled up by large entrants arrests the power of the chemistry profession. The quantity of manpower in genomics is therefore decisive. A quantity policy therefore is crucial. A country with a large number of youth can join future institutions with greater ease than a mature country suffering from arresting holdups. US immigration policy testifies excellently to leveraging the quantity aspect of newly skilled manpower.

Three broad types of organized innovation

We can observe three broad types of innovation-based intervention, which inter alias point out the character of emergent authorities. The USA and the advanced countries of Europe testify to the first type in which organizing mega science projects appears to be the key. In the second type, we observe distributed innovation processes undertaken by multiple clubs. This type coexists in a few advanced countries. In the last type, characterized by distributed but highly enriched knowledge practices (such as clinical investigation by physicians), uncodified practices often hold the key to innovation. The third type appears to be most dominant.

Galambos (1970) has charted out the emergence to dominance of the 'big' in US. His observations vary with what Chandler (1990) found most important and possibly essential to the development of contemporary productive capabilities. Galambos (1983) in another variation on this theme showed how largeness, including the formation of large professional societies in US, has also excluded technological and innovative options not conducive to further growth in the 'big'. He lamented the formation of deep 'fault lines' while institutions and organizations in the US increased specialization, centralization of authority along with development of elaborate hierarchical structure for coordination and control, and increased systematization of both funding and selected development of technologies. This awesome power grew hand in hand with political support and formation of an extensive regulatory apparatus as well as formation of funding agencies in public (as NIH) or in private (as the Rockefeller Foundation). Research funding that was unavailable from private firms before Second World War commenced flowing in since the formation of the NIH after the 1930 Act. Funding was conceived as the most important incentive and the instrument to control research and development of drugs, however, funding in

USA till recently has continued from three sources: the government, the industry and the private foundations. Field et al (2003) report on current attempts to increase concerted focus to the somewhat uncoordinated funding by these bodies. Ziner (2001) maps out the R&D scenario end of the millennium. Brown (1979) observed years back that private firm could exercise great degree of control over not only the funding by foundations but also more importantly the funding from government. Instrumentality of funding and the authority and corporate culture (Kreps, 1990) of organized research in the firm shaped the outcome of developmental efforts and research (much before the Bayh-Dole Act) not only within the firm but also far more widely in the universities and in the hospitals. Several powerful exclusionary mechanisms in particular journal publication, appointments and rewards, membership in select bodies as well as in professional societies, and most importantly the threat of de-recognition or social exclusion influenced to the point of determining the outcome of events.

Evolutionary methods and the theory of incentives as employed by the economists overlooked the extremely important aspect of exclusion. In the evolution of a biological species an identified food (or its chain) never excludes other foods as garbage. In the organization or in the market what we observe in contrast, as incentives and 'selection', is in exclusion of the other. Indian philosopher Matilal observed "The general belief that reality presents only positive facts and no denial or negation can be shown to amount to some triviality of the form of 'things are what they are'. ... to say what a thing is not is itself a way of saying what it is" (1968: 88). Categorical affirmatives are only one amongst several types of descriptions. An institution with the intent to build upon only one set of positive categorical affirmatives therefore denies, negates all other possible states of affairs of that institution.

Medical profession in US thus excluded other practices, and as Noble and Brown (1977) observed it was 'by design' to grow to satisfy corporate ends. Kohler (1976, 1978) observed in the evolution of a discipline how exclusionary selections were exercised by foundations, by the select professionals and the mechanisms of communications within the discipline being groomed up. The field related chemistry practices through continual exclusionary pressures selected the professionals, their languages and the medium of communication such as acceptable experiments and reliable research, and through several similar authorizations the discipline and its men the biochemistry, for example evolved. Possibly more important was the development of drug regulation as the quasi-standard and the protections afforded by patents. Large drug firms more because of regulations and patent protections became risk-shy and security seeking. Jenkins (1975) observed emergence of oligopolistic accommodation as the ultimate outcome subsequent to a new shattering technological change that appeared from outside the business. Our contention takes us a step further. Business through positive exclusionary incentives designed or influenced the future arrival of technologies in negotiation with regulators, government, fund providers and professional bodies along with its medium of communication. Threats that could come from unknown technologies had been tamed and shaped to advantages beforehand through the institutional arrangements and through containing contesting institutions. This whole canvas has surely accommodated specific interests of multiple parties such as regulator, researcher, business, big finance, renters and the government, a picture drawn by Wilson (1980) yet all these parties, a point not emphasized by Wilson, conformed to a singular institution. Other institutions and their parties had to accommodate and capitulate to the really big organized science undertaking.

Big science flaunted large innovations. A map of such large scale science in biomedical (Nass & Stillman, 2003) characterizes three objectives of creation of large-scale: products, developing large-scale infrastructure such as databases and bioinformatics tools and, addressing focused systemic goals though large problems. It outlines several departures from small individual-proposed research paradigm. These departures are: requirement of long-range strategic planning, longer time frame and higher total cost, more complex management structure, multi-investigator and multi-organizational project/task teams, and similar others. An example of such initiative is genomics, which offers the potential of a series of products, new and higher level of coordination between government, academic research, private research, regulator and above all a coordination across the globe. This also ensures emergence of new professionals and consequently genomics forces the physicians, the academic researchers including the device manufacturers to adapt to new practices while necessarily excluding previous practices. The exclusionary force as in the case of genomics came from rather ironically the practice of open science. Opening up of gene sequences by drug firms such as Merck forced the adoption of genetic research by a rather large number. Cascade of information can shift dramatically the power-balance in the market for innovation, and several public strategies therefore cunningly employed the public sphere for subversive ends to undermining asset-bases of contesting institutions. Switching over to new assets formation, which the market of assets evidently had signaled as Bull Run, initiated the transformation within the institution of organized research.

Much in contrast is the state of affair with the institution of distributed innovation. This institution has taken several forms; the academic research in order to build up credibility of advances over previous research, makes citation to prior knowledge essential; the experimenter enlarges upon a previous experiment based upon the disclosed data, and similar others. In contrast, devices, surgery, drugs and medical practices commingled in the institution of distributed practices to generate over time a complete service or product. The former mode of commingling typically took place in the academic milieu while the latter mode spread out through the diffusion of certain therapeutic techniques or through new modes of provisioning of a medical care, such as knee replacement surgery.

Academic processes of distributed innovations remained structured differently in different countries. University as institution and as organization differed between countries and often also within a country. Cutting across organizations of university, massive professionalization followed especially in the US resulting in enhanced control of professional societies, discussion groups, journals, appointments and rewards, and ultimately in the setting of research agenda. Two major modes of competitions between disciplines and within discipline set the dynamics through which apprentice students made decisions as to which discipline and within discipline which research agenda to pursue. The chemist attempted treating cancer through her expertise and now the genomics specialist threatens her privileges. In a country where professional societies amassed enough power, as in USA, negotiations between competing disciplines appeared crucial to the future success of innovations. This is very similar to investment in software where US large firms had sunk in a lot in the legacy software and for them to switch over to the contemporary software proved prohibitively expensive. The large drug firms have built up chemical fortress and it had been very difficult for these firms to negotiate with biotechnology start-ups. Several routes to drug discovery such as organic chemistry, biochemistry and genetics continued simultaneously.

Accommodation that was evident till about early 80's swung sharply in favor of the genetics and allied routes subsequent to political and regulatory changes in the US and other advanced European countries. In consequence distributed innovations that were visible till about mid-eighties gave in to the currently dominant paradigm. This transition has sometimes been captured in terms of four alternative logics of attachment between the firms' namely accumulative advantage, homophily, herd behavior and multiconnectivity. Such networking Robinson and Stuart (2000) argued happened because in the absence of structure of a discipline as also in the absence of a market for information an individual could use network connections to get at relevant information. Herd behavior reduces search cost while ensuring that value of skill asset the person possessed did not fall. In fact accumulation supports this trapped up value. Multiconnectivity contrarily widens the horizon of search and once undertaken through the network ensures that opportunism could be kept at bay. The fluid state of affair in both losing and winning fields including disciplines increases incomplete contract and individuals remain in search for assets with potentially larger future value while sticking to homophily-based group knowledge assets. This search, we argue, is undertaken with twin objectives of risk reduction to current knowledge holding and locating assets with higher expected value in future.

Information on future since it travels through the network and not through established stock exchanges of journals or rating agents such as reviewers or peers, takes long time to diffuse or sometimes fell to reach the critical mass of followers required to make a proposed asset a certainly-valuable asset in future. Unlike an established field a new emergent field exhibits heightened activities in the attachment logic. Right at this stage if the governance initiated large programs get started, autonomy of search behaviors would be destroyed and the field in lieu of emerging might stabilize in the middle of development. Aoki's (2000) Silicon Valley model of governance takes care of this problem by providing clues as to how the governing agents could act as information purveyor while between them competing for assets or incubated ideas with higher expected value. A typical research-leader often acts similar to a venture-capital manager.

These models suffered then from two major debilities: firstly, expected value of assets and formation of mutual expectations as part of information transactions behaviors were neglected; secondly, opportunities for betting on micro strategies were overlooked. Formation of asset value in future depends largely on complementarities of assets in future and on quantities of asset belonging to a single definition. For both, however, as Aoki pointed out, a wholesaler of ideas as a possible governance mechanism would be necessary. Left to the network's quasi-market the free hand of market would be unable to canalize enough assets to an asset-definition, and since currently these asset-definitions are competitive these definitions would remain separate and unable to form into complementarities in future without the mentoring by governance.

Aoki's model provides scope to an agent in undertaking micro strategy. The losers in the game undertake mostly micro strategies. A better too in the new field undertakes micro strategy. A departure from this model seems important in our context because our betters cannot divulge their theories in complete while communicating a suggestive information, and incentives of external market too are hazy currently for the betters. Micro strategy appears to be solution. Such a strategist divulges in complete the past sunk-in knowledge assets, releases only partially information on current investment in knowledge and does not disclose beyond making suggestive yet deceptive information on future investments in knowledge. A micro strategist should often undermine her representation to others on the future value of contesting assets. She desires to restrain others from valuing correctly or expecting correctly. She would like to harvest maximum from her past sunk-in knowledge assets.

Such a micro strategist when in the practice field, enjoys most the power of arbitrating between several alternative goods or services in order to provide a bundled service or product. The scope of arbitration depends on the power. A micro strategist physician remains bound to the fashion of treatment powered by the intangibles enjoyed by a drug firm for example. Precisely because a physician enjoys limited arbitrational power the drug firms in all countries have increased employment of medical representatives or direct marketing when allowed. The prescription behavior, the surgical or clinical bundling behavior and the overall therapeutic value of treatment is the most contested domain where the micro strategist physician appears to be losing fast her ground. Decidedly then micro strategies could be subversive. Diffusion of new branded drugs can be influenced only limitedly through direct consumer marketing or otherwise through employing media. Diffusion of new techniques and devices ultimately must compromise with the micro strategies. However, deployment of micro strategies depends on the extent of point encounter between the physician and the patient. The more such encounters are structured as in a for-profit hospital or managed care/ specialty centers — the less physician's micro strategy makes sense.

The clinical institution has been decidedly practice based. The institution of distributed innovation processes exhibits several modes of social strategizing including maneuvering in professions, in research, in appointing someone and such others. The doctor however, is challenged face to face by the patient. The sciences of a doctor are greatly different from the theory-driven sciences in university. The doctor knows that her patient has the body as history and that the future states of her patient's body would be path dependent arrivals of her current treatments. Establishing causal relations would prove nearly impossible. However, if the steps and medicines and tests that were followed get recorded, the doctor loses much of this intimacy of practice on patient's body. Evidence based medicine is an example on limiting the practice by a doctor. In USA the Agency for Healthcare Research and Quality (AHRQ) was created to support evidence based research. Several others including the surveillance on physician in US by the networks of managed care or the academic health centers and definitely by the insurance third parties delimit the practice.

Equally important has been the transformation of medical investigation from field based to increasingly more theory driven academic research. Major universities and teaching hospitals including non-teaching hospitals have confronted the practice-dominated reasoning and methods of a doctor with structural solutions borrowed in general from the practice of manufacturing corporations. Inter-disciplinary inquiries between the doctor at the bedside and chemist or biologist in the laboratory either failed or when succeeded the power decided the score. The situation has worsened with clinical trials since in particular its randomization and multi-location, and with industry sponsorship of expensive research in the areas of genomic and phenotypic inquiries. Several doctors resented the increasing influence while others favoring argued that without fund progress of knowledge would be curtailed. There have been numerous evidences, however, as reported from a survey of 108 medical colleges of USA that only very few agreements between industry and medical researchers adequately protected investigator independence (Schulman, et al, 2002), or allowed investigators access to all the data in a multicenter trial and only 40% researchers had control over publication of their findings. In Canada Bristol Myers Squibb and Astra Zeneca suppressed research findings that were not in their interest.

Orienting the physician to formal research necessarily required that the data be completely disclosed and the experiment can be verified. Data disclosure as soon as the privacy of relations with doctors is made public must raise ethical concerns, apart from raising concerns relating to bioterrorism. In fact transforming doctor's practice into the believed and traditional science demands verification. Few journals in clinical medicine and life sciences for example, ask for depositing data or for sharing materials (for example a voucher specimen of a genetic result) as a policy. A further risk comes from personalization of genomic medicine. Moreover, a DNA sequence patent provides the patentee with the power to control how the physician and her patients use the patented sequence. Myriad Genetics, the patent holder of BRCA1 and BRCA2 genes requires the patient and doctor to send for test the sample only to their office for tests to be done by a method determined by Myriad, for example. This and other modes of genomification of medicine have increased both the specter of dread and social genetic policing in a Foucauldian manner. Practice can enjoy a niche, however. The editors of the Canadian Medical Association Journal commented, "As they strive to understand, diagnose, counsel, encourage or dissuade, physicians will need practical and just-in-time information to help their patients translate new knowledge into personal interpretations of hope and of risk. And, while genetic testing becomes ever more refined, physicians will need to maintain their clinical acumen: genetic tests, like all test, have imperfect sensitivity and specificity and are not exempt from biological variation and laboratory and clerical error" (2003: 949). The area seems ripe for increased clinical practice.

States of affairs in India — 1

The above account referred most to societies with deep control and larger structures. Using innovation to influence and otherwise decide the outcome of contests between institutions seemed feasible in those contexts. Does Indian experience corroborate similar contests, and could Indian governance employ innovation as an instrument for subversion of a few for the win by another institution!

Mega science never took off in India. Ironically large projects such as the space program or the atomic energy program remained since their beginning departmental feats largely. The spillovers from the programs are countably few and direct partnerships established by these programs with other public and private bodies including universities and engineering institutions are perhaps lower than expected. At a much smaller level, twice the Indian science initiated nation wide grouping, once on a national plan and only outcome of that effort was charging up a bit the domestic chemical technology capability, in which India today is at par in a handful of areas though with major global sites of capabilities. The other similar initiative was about undertaking national missions in a few areas including on telecommunications. Both these were mission-type and these were not conceived or managed as mega projects. The result initially was as in telecommunications very assuring. However, rather soon weak political will saw that the missions died. The space and atomic energy programs, in contrast, managed large projects and delivered goods developed jointly by multiple labs/ agencies. However, neither the national missions nor the space/ atomic energy programs aspired to create novel and shaking mega innovations.

Professionals from the space and atomic energy, however, over these long periods steered several other public research organizations as directors or a few universities as respective vice chancellors. Some members of Indian Administrative Service and allied services too acted as vice chancellors, however, much unlike the French counterpart the Indian administrator from defense or government appeared shy in grooming these stand-alone S&T establishments through forging linkages between them. Nevertheless research collaborations or forging of strategic research ties or framing and conducting a number of research projects in multi locations were undertaken sparsely and sporadically; although single strategic initiative of mega innovation nearly never happened.

The CSIR initiated NMITLI (New millennium India technology leadership initiative) partnered by several laboratories of the CSIR, a few universities and a few business firms, or similar initiatives by others such as the DBT — are amongst a few of the relatively large multi-party multi-location projects that remained targeted to producing only one good/ product. Results from this program are yet to appear, however, my field interviews indicated that moral hazards and opportunistic micro strategies by participants underscore the somewhat indifferent aspirations. The provision of funding, whose size is pitiably small, remains under executive management. Partnering laboratories, for example, have been continuing with their previous management styles and structures. Few only joint publications between the CSIR or the DBT labs, and the partnering university and firm have appeared till some time back. Often such relatively large projects had insufficient understanding of strategic merits of joint undertaking and of strategic patenting.

Poverty of strategic ideas and relatively poor skills to steer a research organization appear to have suffocated umpteen number of grassroots and distributed small-projects based initiatives. If distributed geography has to be blamed for lack of strategic fit, one must notice that even in concentrated geography with dense national strategic interests such as at Hyderabad and Bangalore with presence of several organizations belonging to space and atomic energy, other public R&D and universities as well as engineering and medical institutes — could rarely go beyond the forging of simple personal ties between research professionals up to strategic joint research.

Research collaborations governed by large-scale research never perhaps came up in these otherwise dense knowledge geographies. Therefore Stanford and the emergence of Silicon Valley wherefrom cannot be compared to what you have in Bangalore today.

Funding science and technology development has always been small, less than one percent of GDP and that too widely dispersed amongst several competing claims. Agencies for funding too are many. Ministries have their small research budgets earmarked for own research organizations, and then there are councils such as the ICMR or the CSIR, commissions such as in Atomic Energy, and departments such as the DBT or the DST, and finally the UGC and the AICTE for the education. Much of this continued as modifications upon the colonial administrative structures and the colonial legacy of monitoring and audit even while most of the undertaking grew post independence. The socialist pacifist ideology shared much with the ideology of development and together they curtailed or constrained the potential of strategic funding and initiatives. Funding for atomic energy and space are under direct heads and are not covered under the plethora of departments and councils mentioned above. Extramural funding plays a significant role. As a result research in genetics for example, can get funding from DBT, DST, CSIR, ICAR, ICMR, DoS, DAE, UGC, AICTE and other central and even state ministries!

Precisely because of this and also because most agencies do not provide data break-ups we do not know how much funding a specific area such as genomics or biochemistry or biology received. No wonder an applicant for funding as well the fund-manager do not know what similar or identical research funding have been made. Fund based management has not played key role. Funds, when deployed for R&D, are almost always managed by departmental executives. Low quantity, inter funding-agency conflicts, inter-personal conflicts and definite absence of coordination render outcome of funding disjoint, discrete and piecemeal lacking minimal strategic sense. Private research is pitiably small. Foundation based funding is not known. State governments provide a puny fraction of total research funding and that too, however, mostly get spent on social sectors. Data on recurring and non-recurring in other words non-plan and plan respectively are unavailable for break-ups under types of R&D,

for example. In all likelihood capital spending on research has gone down or remained stagnant over the years. Capital spending moreover and rather often has been on land and buildings, and then on imported machineries. Spills over from capital spending have therefore been zero perhaps. It has also been easier for the local governance mechanism to reallocate cash flows within an organization or across organizations universities and special (major) institutions. Cash flow control much similar to managing a business firm rendered most research projects vulnerable to whims fancies of executives and no wonder many projects failed to get completed, or some areas of research suddenly discovered their sources of funding dried up.

Ironically statements on corporatizing the public research appeared synchronously with the general ideological stance on deregulation. The political feelings and mental imageries built up a picture of science self fuelled. Strangely this was the time that advanced countries in Europe and the USA took to most stringent property rights including intensification of regulation along with increasing the public contribution to R&D. Talk on self fuelled CSIR, for example (Banerjee & Roy, 1999), proved a disaster no sooner than it took off. More importantly, this failing process of turning CSIR and later the ICAR and recently the ICMR, had unwanted consequences for the internal processes of research within the laboratories. Scientists who had taken individual initiatives in getting industry-linked research funding often later had to face legislative ire and public audit questioned their wisdom or the putative lack of accountability. Morale broke down in recent times in most of these organizations.

Several public laboratories especially those under social sector ministries whose number surpasses thousands are currently passing through a fluid state not knowing unambiguously their respective charters and visions , and many of these labs are under-capitalized while for a handful cash flow earned through petty services have swelled up enormously. The public space never grew up on science-practice. Most major institutes or research universities maintained scant respect for the local minor institutes or universities. Universities have been challenged as elsewhere through budget cuts, freezing of appointments, and permissions withheld to open new departments or research initiatives. Universities are under siege (Banerjee, 2004a). Failed dialogues, failed exchanges and collaborations, and failures in the diffusion of better pedagogy and better course materials including text books from the major to the minor universities ruptured the germinal of public space in science. Technology making and engineering in particular have never been undertaken by most major research organizations. Institution of bridge organizations that would undertake upscaling, adaptive research, or detailed designing including prototyping or pilot-scaling and similar others remained amiss — in fact R&D organizations with social sector ministries and those under public-private governance were to take up such bridging. Consequently technologies from the CSIR failed to take off not having acquired the wings of engineering, or germinal technologies from IIT's failed to grow up into products ready for transplantation. Course materials from the IISc or the TIFR could not diffuse to minor organizations even within the same city. This surely helped maintain the brand of major organizations amid poverty of minor organizations.

Weak state authority with poor reach, fractured polity with deep fissures and inability of any particular science community to enforce own agenda reminds us of the Gramscian Caesarian crisis. Multiple S&T communities and very large number of research/ teaching organizations suffering from the crisis of stalemate and from the absence of dominant suzerain spins into a state of affairs with twin features: the first indicates increasing executive dominance over research and the second indicates increasing small worldliness of research groups or organizations. Negotiation and accommodation by the small organization have been so pervasive that today possibly all organizations in the country are fractured and compromised from within.

Organizational laws failed to evolve in tandem with the demand of science research. Decrees of the ministries originally designed for accounting and auditing of clerical work rule internal accountability in public science establishments and such rules act by default often as the measures of performance. The latter indeed has proved extremely crucial. Organizational learning within laboratories, for example, would presume prior operationalisation of measures of performance conducive to both the strategies of organization and that of an individual as well as a research group. Ironically, performances are measured and promotions are awarded on publications in 'international' journal. The country brings out, however, a few if any global journals. Reputation is generated through small worldly maneuvers or through micro strategies of the professional from a university or from R&D lab. Local peerage or local gatekeeping as well as local grooming of potential inductees while suffering from small worldliness vouches the global ideology of open and public and large or mega sciences.

Unfortunately low quantity of personnel within a research/ teaching community preserves status quo. An individual or a research group necessarily follows as a laggard the global fashion and rather often as micro-strategy switches affiliations or research-interests, and ultimately become increasingly dependent on domestic peers with good access to finance and to the global peerage for securing 'proper' reference and entry-visa to international networks. This process lost touch with local neighborhood milieu especially of practice, and above all did not find long term commitment to organization as rewarding. No wonder local journals or discussion groups or research networks died or never grew. Professional societies, such as the domestic-oriented The Institution of Engineers or the Chemical Society or the Mathematical Society through rivalry and lost senses of direction were rendered voiceless.

Funding alone even if it were large, would have failed to recover. A Caesarian crisis has a flip side, however. An opportunist can easily sneak in under covers of ideology and quickly harvest cash flow, fund allocations and appointments and all this could happen as in a drama, by overnight. This then informs us that long commitments have been few and far between. Accommodation ensured that universities and research organizations were never closed down, however, opportunistic sneaking in ensured that funds and appointments were cut off to the contestant institutions and they became marginalized. Only a handful of major organizations and only select professionals enjoy voice in India. This handful organizations and within these organization a few alone receive funds more than demanded. They are the peers in India appointing, doling funds, endorsing research and awards and above all they are the windows to sciences and scientists in USA or Europe. These peers in fact enjoy more power than what their counterparts enjoy in USA, for example.

There have been no wage differences between professionals in fashionable and upcoming areas on the one hand and those belonging to the considered-dead skills. Wage signals have been infructuous in shaping skill-mobility across current asset holders. A typical researcher or professor does not enjoy licensing fees or consultancy fees in general albeit there are exceptions. Current asset holders enjoy lifetime employment and cannot switch over jobs because there is no mobility across organizations. For the youth signals have been different though. A fashionable skill has the expected reward. The skill holder can get into the global circuit. As a result students flock to those research guides who enjoy enough foreign networking or at least who enjoys the power to remain on appointment boards. Signals of this kind are proverbially local. Few students from a distant district would know of this networked-professor but regionality and other affiliations-based network sends across signals to students in distant areas. Generation of assets-in-future suffers from the inability to broadcast signals. A credible broadcast is the brand that an organization enjoys by virtue of being able to dispatch contingents of graduates to USA or to coveted jobs as also by virtue of being in the media for close political linkages. Such intangibles of the major organizations and not its contribution to research and discovery decide the Arrovian filtering of youth in making asset-in-future.

States of affairs in India — 2

Large science never took off the ground. However, aspirations on large science reallocated current resources and future commitments. Universities suffered most (Tilak, 2003). Marginalized, practice in universities got reduced to a handful including networking based on local affiliations, parroting to students skills of lost value and as a challenged species to keep reproducing only. The asset fields, however, did not get reproduced. Local networking fails to reproduce in the long run. Overall fields demised.

Old professional societies died in this process. A few such as in biochemistry sprang up. Professional societies command little public space and enjoy little peerage or monitoring authority. A few informal clubs instead of the large professional societies filled in part of this void in the public space of science. One such quasi-society has been The Guha Research Conference (GRC) that as an elite grouping survived for a comparatively longer period. The GRC came up in 1960 as an initiative of three young scholars while working in USA who dissatisfied with old mode of functioning of the Society of Biological Chemists of India wished to develop the field of biochemistry, fathered in India by B.C.Guha and in whose name the GRC was launched. The last meeting of GRC that took place in 2004 recorded that the members were hopeful that the GRC would continue to survive. Number of members in 2002 was 115, which has increased little over the years. In 1982 GRC had 68 members of who 20 delivered talks at the annual meet of 1982, for example. Membership was through election and is terminated if the member fails to be present three years in succession. During first five formative years from 1960-65 there were 33 professionals from major institutes, to name the AIIMS, CMC Vellore, NCL, IISc., Cancer Institute Bombay, IICB, BHU, JU, BARC, ITRC, TIFR and organizations came to be known later as NII, and CCMB.

Pushpa Bhargava the pioneer of GRC and founder of CCMB recorded as long-range objectives: "To provide a network of close, personal contacts — considered to be specially important in a large country such as ours — amongst active research workers in biochemistry and related areas in modern biology. ... To improve the quality of research work in newly emerging areas in biology by providing a close internal scrutiny within the group ... to establish a tradition in the country ... to set up a tradition of free, frank and objective criticism of scientific work" (GRC, 1982: 3). Years later in 2002 D.P.Burma, one amongst the founders, reminisced and probed the following three questions "Has GRC changed a lot? If not, should it not change for the better? Is it an exclusive club? Is its continuation justified? If not, is there any alternative?" (Burma, 2002: 13) Bhargava knew from his days in the US how personal contacts mattered. In a time when knowledge-asset markets are in a flux, information appears reliably and at lower cost through network. However, network has other dimensions. Affiliation to the group acts as the token ensuring easier access to prizes of several sorts. Since even within the GRC, research followed at a lag what had been initiated already in US, the Indian members had to face little uncertainty about the value of future assets. The risk of securing future values could be minimized through associating with the GRC and this alone appears to have delimited the initial aspirations of the founder members.

Over the years Burma recalled, "It is heartening to record that we have amongst us chemists, physicists, biologists, immunologists, cell biologist, reproductive biologists, molecular biologists, and what not. It has thus broken the barriers between various disciplines of science" (Burma, 2002: 9). Not strangely all this divisions of assets pre-existed in the USA, for example. Sivaramakrishnan of Cancer Institute, Madras recalled, "a wide range of subjects has been covered from pure biophysics at one end through biochemistry, molecular biology and pure biology to sociobiology at the other end. Side by side with in-depth fundamental research, ... a lot of work on the crucial problems confronting our country is being carried out .. for example, population control ... through .. active immunization ... passive immunization ... antibody ... (then) leprosy, the scourge of India, ... cancer, the baffling ... amoebiasis, and the horribly disfiguring leucoderma ... members of the GRC are ... out to solve the problems of the nation" (GRC, 1985: 67). The ideology of serving national goals and supporting the poor-lot directed several minds, and the challenge unfortunately never taken up strategically by many together as a large program; contrarily at individual discretion a few research papers trickled.

GRC has been exclusive. Sivaramakrishnan recalled discussions in the GRC about IISc of Bangalore alone having about a quarter of memberships (20 at that time). Few professionals were from university. Only Delhi, Jadavpur, Banaras Hindu, Madurai Kamraj, Jawaharlal Nehru, Poona, Hyderabad (Central), Osmania, Calcutta universities and for once GND University had their academics in some of the meetings. All this universities are from large cities and many receive disproportionately larger funds. In short only major universities had some representations in meetings dominated most by the IISc, followed by a few major organizations of public research, such as Bose Institute, TIFR, BARC, ITRC, CCMB, NII, and a few others. Few members were ever from industry. This handful represented Ciba-Geigy, Hindusthan Lever, Alembic, and United Breweries. Funds to organize meetings, however, came not from the private firms contrarily several funding agencies of the government and a few of private dealers of laboratory instrumentation provided for the meetings' organizational costs. Most medical colleges excepting AIIMS, CMC, University College of Medical Sciences Delhi, Kasturba Medical College, Jawaharlal Nehru Medical College, VP Chest Delhi, Sher-I-Kashmir Institute remained absent from meetings. A strange outcome, however, should be noticed. Possibly only two institutes of organized research sprang up from within clinical research practice and these were the IICB and Centre for Biochemicals, incidentally both came up to belong to the CSIR. Like many other professional associations the GRC too never evolved into the churning pot of large projects or strategic alliances including even a forum to guide, mentor and grow up large number of apprentices from small and non-metro organizations.

The distance from 'mundane' clinical practices increased over the years to a level that threatens separation of research practice from clinical practice even within the top few elite research hospitals. Joint undertaking of research, joint authorship of research or joint guidance of students or extensive citations to other members of the GRC appeared not to emerge from four decades of annual meets. On the top of this, local journals continued to lose relevance and most members coveted publishing in high impact factor journals from USA or advanced countries from Europe. Joint authorship including collaborative research between medical and non-medical had been rare. Outcome from GRC was not the direct signals that large projects and directed funding or thriving networks bringing out reputed journals and such others can establish. Contrarily a small group that established brand in being with the GRC sent indirectly signals across — that minor organizations were to generate students as future asset-holders in areas that GRC members represented. GRC members continued with privately proposed individual research. Exceptions came up, however. CCMB and NII — two organizations were established by the GRC members. Nevertheless, organized research as a program failed to get established. Both CCMB and NII remained organizations. A plethora of assets each with sub-critical quantity of researchers and students therefore evolved once again testifying to the old political pragmatism of accommodation of varieties. Several similar but smaller gatherings emerged having received the original inspirations from UK or USA.

Clinical practice remained distanced. Ordinary university academic practice of reproduction too remained distant. Updating of curricula and pedagogy as distinct markers of the influences that setting agenda by the elites could achieve too failed miserably. Asset pools of the old and the contemporary types set in practices reactively, which distanced the pools further. The institution of distributed innovation processes experienced possibly the worst fate. Indian science lost touch with device making since independence of India. Device brings in several practices and their outputs together. Use of instruments contrarily focuses back on the interior of a discipline. Experimentation becomes the key generator of knowledge. Indian researchers remained users of imported devices, which further restricted their respective practices closely within disciplines. Meets such as the GRC never touched upon setting experiments together or on the procedural aspects of work within laboratories. Formation of novel knowledge assets through networks such as the GRC or through local collaborations and similar feats of bundling knowledge cues developed through bundling of experimental and investigative practices of apparently distant fields — failed to take off.

This failure indicates the failure of the market for knowledge assets in identifying solitary signals of such novel bundling that happens naturally and necessarily in any human socialized activities, such as research investigation. Typically a venture capitalist achieves doing this. In academia journals, peer groups, research networks, funding agencies and ultimately when the solitary asset is expected to have higher asset or strategic value in future patenting or minimally copyrights serve this specific purpose of identifying authorship with novelty of asset. Indeed a market can continue to exist only if it can solicit and recognize such assets with future values. Indian market for knowledge assets therefore fails to exist. As a corollary it is not important to seek copyright or patenting covers. Indian market does not value such assets. Ironically the value of research publication has been reduced to impact factor of the journal in which the paper got published and sometimes the citation counts of papers. Impact factor has the disrepute that this indicates the brand, the marketing and distribution efficiencies of the journal and above all several other social powers that the authors of papers enjoy; together these parameters affect citation and therefore the impact factor. No less important is the fact that most researchers do not have access to such journals as can publish solitary assets or assets in the fringe of a discipline. The global stock exchanges of journals and the rating agencies of peers and reviewers follow yardsticks eminently suited to local business of generation of papers, powers and funds as well as other market worthy items. An Indian asset holder is only distantly or otherwise often not related to those signals. Asset formation therefore follows the known organizational path, and assets that are generated belong to those classes for which the global market offers a rent at the most but surely no innovator's profit.

A potential roadmap: in conclusion

Recalling that markets are moving away from drug as product while appreciating the emerging importance of practice and methods as well as of individualized facts and data we could suggest a biomedical innovation strategy based upon services in lieu of products. Such a strategy offers several important advances that India can have. In order to appreciate the merit of this proposal we must recall that India is potentially sitting on such a strategy. In drug as product Indian institution of organized research including the drug firms necessarily would remain laggard. Indian institution of organized research is not in a position to shape and dominate practices of contesting institutions through innovations brought out by large-scale research. Globally drug as product is on a lost field and generics does not offer more than bank rate of interests. Contrarily large number of physicians at the field practice remaining largely unorganized on a billion of diverse genetic population in the domestic market alone and this practice of doctor could be a great resource. Gaps in resources can be identified easily. For example, most doctors and hospitals are unequipped and untrained to go ahead in differentiation as well as perfection of genetic methods. Nevertheless the current out of pocket spending pattern of patients appear to suggest that practice enjoys a premium. Enriching practice would reap higher premia.

An issue of far more strategic importance comes along a strategic adoption of healthcare as service. Genetic methods have arrived in US and in other advanced countries as the outcome of large-scale research and through the dominating institution of organized research. Innovation has been used as the instrument of domination. India cannot match this. On the contrary Indian political and voting systems can rather easily adjust to a reversal of domination. This reversal of domination envisages agenda setting, fund allocation and resources generation through bottom-up approach. The bottom of the physician's practice can then dominate other contesting institutions. The lever of domination is innovations from the diverse and distributed research-practice of the physicians. Because of this reversed-domination research on new biology including in genetics sets agenda on individuation, on methods and on individual-oriented data as well as medicine and genetic-devices. In fact the research agenda of new biology is eminently suitable towards such individuation.

The bonus that India has in this reversal is the weakness of Indian institution and its voting system now become its strength. Conversely, switching costs for the institutions in advanced countries with history of large-scale corporate bodies and organized research become phenomenally high. Grassroots practice and grassroots methods are unavailable in those countries, and the current stranglehold on the market by large corporations is unlikely to allow blossoming of very diverse mimetic of Silicon Valley across spatial practice-regions. Possibly this is the great weakness of large organization. Domination switching costs a lot. Indian states of affairs do not face the switching costs much. Domination in India has been effective more through global signals that global organized research sent across.

Corresponding to the alliances between global organized research and domestic organizations and research programs, the reversed domination scenario looks for inter-country alliances between doctors in the field. Grassroots linkages across individual doctors are feasible now with contemporary networking technologies. Databases grow up from there dominated by physicians' practice. Such a scenario then drives databases bottom-up and the bioinformatics that these databases would employ be qualitatively different from bioinformatics currently being proposed. This reversal is called domination because doctor's practice and methods including methods of genetic inquiries would now guide the downstream research in academia and research laboratories.

Practice and method become the sources of innovation in this scenario. Practicing doctors therefore drive the innovation in biomedical. Facts and data from practice and method of individuals generate enough differentiated problems for the researchers and academics. Indian knowledge asset market, which is diverse and highly differentiated spawns further differentiation. Severalties of assets, we must not forget Adam Smith's maxim, are the sources of innovation and growth. This reversal of institutional domination in league with services strategy to healthcare necessarily demands support from the voting mechanism. Voting to recall appears in the new scenario more 'for the people' and hence reversed domination can secure better political support. This strategy surely takes a global dimension since from the beginning it is based on linkages between doctors in several domestic fields. Indian biomedical innovation appears to have great potential in this direction of developing healthcare as services.

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Irina Eliseeva

Benchmarking Russian Science and Technology Productivity

Science and innovation constitutes the base for world progress. According to the consequences of transformation period and non-effective management during the Soviet time, Russian position among the countries is not responses to potential ability of the country. Annual Human Development Report of UNDP includes the main indicators for the international comparison (Table 1).

TABLE 1. RESEARCH AND DEVELOPMENT INDICATORS*

Country	Patents per 1 mln population	Royalty and licences payments, USD per 1 person	R&D expenditures percent to GDP	R&D employees per 1 mln Population
Japan	852	96.3	3.1	5085
USA	302	167.2	2.7	4526
Rep.	633	27.8	2.5	2979
Korea	317	261.8	4.3	5171
Sweden	274	51.7	2.5	3229
Germany	105	1.2	1.2	3415
Russia				

*Human Development Report, UNDP 2005, pp.284-285, 296-297

The number of R&D organizations in Russia declines on 22 percent for 1992–2005, the number of employees in R&D became less on 47 percent for the same time.The financial policy was not favourable: R&D in percent to expenditures of Federal burget was equal to 1.60% (1996) and 2.19 % (2005). Nevertheless we have to conclude the dynamic is a very positive. The main source of finance for science is the Federal burget: its share in the expenditure of science was equal to 60.8% in 2005. The state sector of science is covered 73.8% scientific organizations of Russia, which are accumulated 86.3% material recourses of Russian science. The influence of the state sector on science increases and provides a new innovation process and integration forms: integration of science and education, re-enforcing the relationship between science and the economy, the transferring and introducing knowledge and technology to production. The problem of science and technology becomes more and more important in the policy of Russian Federation.

TABLE 2. NUMBER OF ADVANCED TECHNOLOGIES DEVELOPED IN RUSSIA

Year	Total	including	
		New for country	New in principle
1997	**996**	**830**	**90**
2000	**688**	**569**	**72**
2001	**637**	**543**	**44**
2002	**727**	606	70
2003	821	582	56
2004	676	569	52
2005	637	538	60
2006	735	642	52

Source : Russia in 2007. Stat.abstract. Moscow, 2007

The main innovations are adopted; only 8–9 % of new technologies are new in principal (see Table 2). Of course, innovation depends on financing support from the State (Table 3).

TABLE 3. DOMESTIC EXPENDITURES ON R&D IN FIXED PRICES (1989=100)

Year		
		Percent of GDP
1995		0.85
1997		1.04
2000		1.05
2001		1.18
2003		1.28
2004		1.15
2005		1.07

The figures in Table 3 are not stable; they deviate, but the tendency is positive in general. The shares of expenditures on the science and technologies in the total expenditures of Federal budget in present time exceed 2%. In strategic program 2020 the expected level of this indicator will be equal to 3.5%.

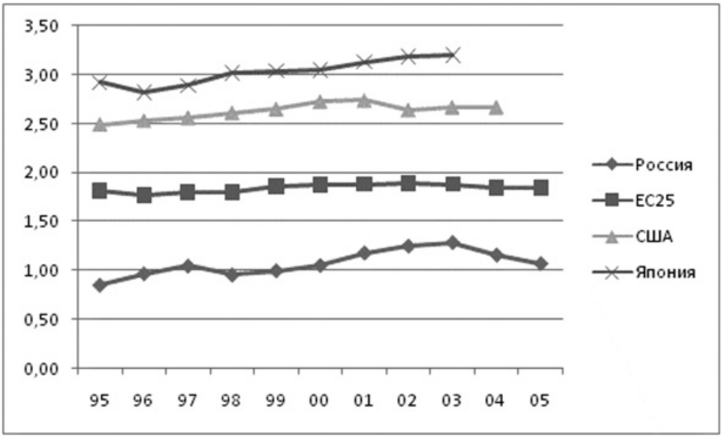

Fig. 1 Domestic R&D expenditures for several countries.
Fig.1. Domestic R&D expenditures, percent of GDP
Axis x — time (years), Axis y — percent of GDP,
Russia — blue line, EU-25 — red line, USA — green line, Japan — violet line.

We can see the big differences between Russia and developed countries.

Nowadays a new stage of reforming of the state sector of R&D is going on. The targets of reform include the finding and supporting of effective scientific organizations, individual financial support of those researchers who have the best results of their scientific activity.

However, the project of reforming of the state sector of science was developed and introduced by Government — "from the top", without takinig into account the opinion of the scientists.The part of reform is the shortening of the employees in R&D sector (- 7% from the number of scientific staff per each stage of reform of Russian Academy of science. Total we came through three stages of reform). More than half of the leaders of scientifical institutes (52.6%)

estimate the results of reform as negative, especially pissimistic estimations belong to the leaders of the fundamental reasearch. They are not sure in the state support for the modernization of the experimental base.First of all this opinion reflects the thinking of the directors of the RAS institutes.

However the integration process of Russia into a world science is going on. More than 70% researchers have scientific publications in the western peer reviewed scientific journals during the two last years.

The modern position of scientific organizations are very defferent: there is a small part of active and very progressive organizations, there is another part — outsiders, but the biggest part of the scientific organizations are adopted to the new conditions and try to find their segment in the Russian and in the world science. They use a various ways for cooperation with Western and Eastern colleagues and research institutes, as individual as institutional contacts.

One way for communication between Russian and Western scientists is the Euroscience local section in Russia which is located in St. Petersburg. This section was founded three years ago. In December 2007, an international scientific conference in St. Petersburg was arranged by the Local section. The conference was devoted to the process of integrating Russian science into world science. The participants discussed their experiences of cooperating with Western colleagues, specific approaches to research projects, and the development of new educational programs. Representatives from Euroscience and the COST foundation presented their wondering papers. Scholars from Kazahstan, Moldova, Ukraine, Canada, France and Belgium demonstrated that scientists from different countries have a common language. International cooperation in sciences and humanities is a benchmark for Russian scholars and it provides new stimulus for development.

The problem of innovation and attracting young scientific personnel to scientific organizations to help create new technologies is not specific only for Russia. It is a real situation nowadays around the world. According to European statistics, in 2010 the EU will reach a deficit of about 700 thousand researchers, i.e. the so-called knowledge-workers.

The scientific community discusses the problem of ways and mechanisms for attracting young people into the scientific sector.

Of special meaning for Russian scientists and students consists of their personal scientific contacts with colleagues from abroad. In order to attract skilled staff leaders to the EU, it followed the prototype of the American green card with an EU blue card. This affords special permission to scientific jobs and for part-time leave among specialists.

One of the main factors for young scientists is the wage and salary in the S&T sector; now the wage in this sector is equal to 144% of the average wage in 2007. The number of young scientists has thus increased from the year to year (Table 4).

TABLE 4. THE NUMBER OF THE SPECIALISTS IN RUSSIA (PER CENT OF THE TOTAL NUMBER OF RESEARCHERS)

Age	Less than 40		40–60		60 and older	
Year	2001	2007	2001	2007	2001	2007
Specialists — total	26	30	53	47	21	23
With scientific degree						
Doctor of sciences	2	2	42	41	56	57
Candidate of sciences	15	19	54	48	31	33

Source: Statistics, 2008, N 18, p. 76.

According to Table 4, the share of specialists aged less than 40 have increased significatly, but at the same time the share aged 60 and older have kept their position: more than 1/5 of specialists are at the age of official pension (55 years for women and 60 years for men). Young scientists are successful in that more than half of them have their first scientific degree (there are two levels of scientific degree in Russia: the first one is Candidate of Science, the second one is Doctor of Science). In general the ratio between the numbers who have the first and second degree is equal to 3:1. Of course this proportion depends on the field: the number of Doctors of Science is higher in economics or law than in mathematics or physics. On average, Doctors of Science are 10 years older than Candidates of Science.

It is well known that innovations are divided into two groups:

goods and commodities,
processes
The first kind of innovations belongs to industry (e.g. manufacturing). Table 5 consists of data about the location of industry innovations in Russia Federation.

TABLE 5. RANKING OF RUSSIA'S REGIONS BASED ON THE LEVEL OF INDUSTRY INNOVATION DEVELOPMENT

Region	Level of industry innovation development	Share of innovation production		Share of innovation production produced by innovation-active enterprises in the total industrial production, %
		in the total industrial production, %	in the total industrial production of innovation-active enterprises, %	
Chelyabinsk Region	1	17,8	23,9	67
Nizhniy Novgorod Region	2	16,7	21,5	78
Bryansk Region	3	15,3	17,6	87
Vologda Region	4	11	14,3	81
Dagestan Republic	5	9,5	11,7	1
Kaluga Region	6	9,4	34,4	27
Irkutsk Region	7	9,1	20,5	44
Murmansk Region	8	8,5	18,2	47
Novgorod Region	9	7,8	18,2	43
Moscow	10	7,7	16,4	47
Tatarstan Republic	11	7,7	12	64
Tver Region	12	7,3	27,5	27
Arkhangelsk Region	13	7,2	21,4	34
Tyumen Region	14	7,1	9,4	75
Ulyanovsk Region	15	6,9	13,5	51
Lipetsk Region	16	6,8	68,3	10
Belgorod Region	17	6,5	9,2	71
Orlov Region	18	6,5	15,7	41
Samara Region	19	6,4	7,8	82
Yaroslavl Region	20	6,2	14,3	43

Source: Comparative analysis of scientific-technical and innovation development of Russia's regions. *Information-analytical bulletin*, Centre of Research and Science Statistics, Moscow, 2007, № 5, p. 39.

Table 5 includes data from about 20 regions of Russia (there are 84 total regions). There is a big gap between the first group of leaders (positions 1–4) and other regions. The main regions are located in Central Russia, but there are also industrial regions in Ural and Siberia (e.g. Chelyabinsk region, Irkutsk region and Tyumen region). St.Petersburg lost the position of being the industrial centre, but keeps its position as the centre of science and education. Nevertheless, St. Petersburg has a good perspective for innovation in machine-building, energy production (e.g. turbines), shipbuilding and other branches.

Russia's task for now is to overcome the non-unity of the regions, to open up new fields for innovations (e.g. nano-technologies) and create progressive, competitive development.

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Sujit Bhattacharya,
Kashmiri Lal

Innovation Activity in the Indian Software Industry

Abstract:
The present study primarily investigated whether there has been a tangible shift in the activities of the Indian software firms towards higher end of the value chain and factors that helped the firms to make transitions. The objectives were examined by broad examination of thirty nine software firms and deeper investigation based on case study of three firms derived from the above selected firms. It was found that firms are active in different areas/subareas of software industry including the embedded software segment. The firms obtained various types of quality certifications but these certifications were mainly restricted to process standards. Acquisitions and joint ventures were exposing firms to new knowledge, new hardware and software platforms. It has also helped the firms to move into niche areas and enter new markets. Linkages between firms and with academia were also important factors in firm's enhancement. From the case study it was possible to discern how the firms are developing capabilities. The three firms show that they have evolved over a period of time, moving from simple to complex operations mainly through incremental innovations. The study shows that among the thirty nine firms, a few firms have significantly moved up the value chain. Nevertheless, it is important as it shows that a few of them have broken away from the mould and achieved success.

Introduction

Impressive growth in the Indian economy in the last few years, experiencing an average growth rate of 8% has been primarily attributed to the strong growth in India's service sector. The service sector is now accounting for 61.8% of India's real GDP, 39% in overall exports and 81% of FDI share (Mani 2008). The software services in particular are acting as the main driver behind the service sector growth, which is experiencing a phenomenal compound annual growth rate (CAGR) of about 50% since 1991.The service driven software export has jumped from $1.76 billion in 1998 to $23.6 billion in 2006; in the total export basket software constituted only 1.9% in 1994–95 that shot up to 18% in 2002–03. This sector has also significantly contributed to employment generation at a comparatively lower capital investment with minimal government support and intervention.

The business model of majority of Indian software firms is mainly confined to the vertical integration "at lower end of the value chain" with major MNCs. Influential writings (see for example D Costa, 2003, Kattuman and Iyer, 2001) points to the low end manpower intensive services provided by majority of the firms. Arora (2001) observed that although the software sector is human capital intensive, the Indian software industry does not require exceptional skills beyond academic training at the first-degree level. Analysis of NASSCOM (1999–2000) points out that large numbers of firm are offering the same kind of services and competing with each other on the basis of cost-price advantage. The above observations support the internationalisation argument of Bhagwati (1984):

"[the] trend in innovations in services can be described in terms of splintering of goods from services, and internationalisation of services. Progressive part of the old services would be incorporated in a material product, leaving behind a reduced and unprogressive service. The latter part is the one that bears high transaction cost and internationalised. Both innovations and internationalisation are the intended actions of the mainly top multinational of the world, developing countries are at the bottom of this process".

The above viewpoint of innovation in services is being increasingly challenged by the changing industry trends particularly in the high technology sectors. ICT sector is a typical case in point. The rapid paces of technological change, growing complexity, technological convergence are intrinsic factors motivating this change. This new trend is leading to 'globalization of innovation' (Krishna & Sujit, 2007). *Globalisation of innovation relates to various components of knowledge production and innovation chain which are not hierarchical but are horizontally connected networks and geographically dispersed across various actors, agencies and regulated by institutions at different levels and locations.* Innovation networks are increasingly being used in ICT for client tailored innovation services- to design custom chips and supply chain software algorithms. This brings in a new class of services 'product engineering services'. New technological developments such as ASIC chip[1] are facilitating

1 ASIC chips (Application specific integrated circuits) can be programmed for a specific application (for example a device for a sound card/video card), without having the chip manufactured in large quantities.

this process. Thus in this new scenario, firms will not simply source low-cost talent but invention services (R&D services) in one country and transformation services (manufacturing services) in another country and build products for a global economy. Radjou (Forester Research, 2006) increasingly see the role of India and China in this type of configuration with US firms; India expected to do the invention service and China the transformation service. Chesbrough (2003) has termed this as 'open innovation' model, a new paradigm of innovation where firms will not carry the baton of innovation all by itself. As Ernest (2005:72) observes, even big firms like IBM are in no position to 'mobilise all the diverse resources, capabilities and bodies of knowledge internally'.

Pradosh and Hazra (2002) have used the widely acknowledged software development process the Waterfall model proposed by Royce in 1972 to understand the software market. The Waterfall model proposes a strict order that is followed in software development: moving from concept, through design, implementation, testing, and installation, troubleshooting to the last phase of testing and maintenance. In this model, the complexity of the task, the innovation involved also follows this order, moving from highest to insignificant at the last stage. They posit that later stages which are non-creative routine segments are the visible part of the market. The other phases constitute the inaccessible high investment/high risk and high skill activities, are part of firm's growth strategy and are developed in house.

We argue that the new concepts 'open innovation', 'globalisation of innovation' that have emerged due to new competitive demands, radical technology shifts have forced firms to open out the creative routines involving even their competitive partners. *The outsourcing model is no longer restricted to non-creative routines*. These new developments auger well for country like India that can participate in at the creative level, part of horizontal linked network that will increasingly help it to move up the value chain in the process.

In the last few years there are indications of this type of shifts with some Indian software firms undertaking higher investment in R&D, and creating the other essential requirements that are prerequisites of research based firms. The linkages with international firms have also expanded in breadth and scope and in some cases have translated into higher order vertical linkages. Leading firms such as Infosys, TCS, and WIPRO are involved in 'product engineering services', protocol standards, participating in international innovation chains. A good example where Indian firm is a crucial player in the globally dispersed networked innovation is Infosys participation in Automotive Open Systems Architecture — Autosar. It is network of major global automobile manufacturers involved in R&D and standardization of software for auto electronics innovation. Firms such as Toyota, Bosch, BMW, Volkswagen, Siemens, Ford, DaimlerChrysler and Continental Teves are partners in this global network (Krishna and Sujit, 2007). A handful of small companies such as Sasken, ittiam, i-flex and others are trying to break the mould of IT services and develop their own patents and license to others (The Economist, 2005).

Source of the changing perception are however still primarily observed from media reports, business magazines, and anecdotal accounts. Changing shift can be discerned under three broad domains namely (a) Indian firms undertaking complex tasks (Kash *et al.* 2004) (b) creating global footprints through opening up international subsidiaries, merger and acquisitions and in the process increasing its knowledge base and competency (c) foreign firms establishing research centers that are internationally independent laboratories involved in developing novel products/processes. This includes firms in the software segment.

Research Questions

Drawing lessons from the above literature review, a cross-section of Indian software firms were examined to see whether there has been a tangible shift towards higher end of the value chain, major factors that helped the firms in this context, whether research partnerships are being established, to what extent software firms are involved in research and innovation activities, are they participating in global innovation chains and the outcomes of these involvements.

Innovation is defined in broad sense borrowing from UK 'Community Innovation Survey'. Innovation is defined as occurring when a new or significantly improved manufactured product, or service product, is introduced to the market (product innovation), or when a new or significantly improved production, or delivery method, is used commercially (process innovation), and when changes in knowledge or skills, routines, competence, equipment, or engineering practices are required to develop or make the new product, or to introduce the new process. Thus, we also do not count as product innovation, changes which are purely aesthetic (such as changes in colour or decoration), or which simply involve product differentiation (that is minor design or presentation changes which differentiate the product while leaving it technically unchanged in construction or performance). The implementation of a quality standard is not innovation unless it is directly related to the introduction of technologically new, or significantly improved, products or processes.

Thus within the above context we tried to capture ‘product innovation’, ‘process innovation’, ‘longer term innovation activities’ (to develop or implement technological change not directly aimed at imminent new products or processes), and ‘wider innovation’ (Changes in advanced management techniques; changes in organisational structures; and changes in marketing strategies)

Methodology

To address the objective of this study, two approaches were undertaken. First, involved a broad analysis of a sample of software firms; case study of a few software firms was undertaken in the second part.

The population consisted of all public limited firms that had made investment in R&D at-least within the last three years. Public limited firms were chosen as the study depended to a large extent on capturing information from secondary sources. As per government regulations, public limited firms have to divulge detailed information of their financial expenditure including expenditure in R&D and are also obliged to spell out details of their activities. The listing details of these firms (red herring prospectus) also provide rich insights of their activities. We postulate that firms that do not make investment in R&D are not in a strict sense involved in research and innovation and this guided our consideration of choosing only firms that had invested in R&D.

The population consisted of 70 software firms that had undertaken R&D investment over a five year time period: from 2000 to 2005. There was lot of missing gaps in the latter years in terms of firms providing detailed financial data to the company affairs and thus it was not possible to correctly estimate how many firms had undertaken R&D expenditure. Multiple approaches were undertaken to capture the data. Firms were asked to send two page fact sheets on their profile, main products, major activities, R&D expenditure, technology absorption/adoption, benefits acquired through R&D, products developed etc. Missing response and other details were supplemented through accessing company web-sites, database of newspaper clippings, annual reports, Red hearing prospectus (stock exchange listing), etc. Commercial databases such as Prowess (CMIE), Capitaline, IBID were extensively used. From the above population, detailed information could be collected for 39 firms. This was the sample used for this study. The sample included large firms as well as medium and small firms. This was a good representative of the population. Financial statistics was collected from 1990–91 to 2004–05. The research and innovation activities were uncovered to the latest as possible.

The second part of the research covered case study of three firms: Cranes Software, HCL Technologies, and Sasken Communication Technologies. The three firms were identified from sample study i.e. from the 39 firms examined. These firms had evolved over a period of time and have created niche capabilities by adopting various strategies; were now operating in the value added software segment. 'HCL technologies' is one of the representative firms of the industry and the other two were small companies. In depth examination of these firms helped in understanding how firms (large and small) develop competency and also allowed deeper introspection into the innovation process. The case study approach is ideal for detailed examination as it helps to understand a phenomenon when it is difficult to separate the phenomenon and the content (Yin, 1989). Case study allows collection of data from multiple sources and the interpretations of the findings are based on evolving linkages between observed data.

Findings
Broad characteristics of the sample:

TABLE 1: BROAD STATISTICS OF THE 39 SOFTWARE FIRMS

Year	Sales	R&D	R&D as %age of Sales	Exports	Imports
1990-91—1994-95	2,640.02	17.75	0.67	698.02	570.08
1995-96—2000-01	14,329.25	816.19	5.69	6,245.64	3,321.67
2000-01—2004-05	55,309.19	542.38	0.98	45,183.28	20,377.81
1990-91—2004-05	**72,278.46**	**1,376.32**	**1.90**	**52,126.94**	**24,269.56**

All figures in Rs Crores

Significant increase in sales, exports, and imports can be observed in the later periods indicating growth in this sector. The sharp negative change in R&D intensity in comparison to 1995–2001 implies that firms R&D investment is not commensurate in the same proportion with the increase in sales.

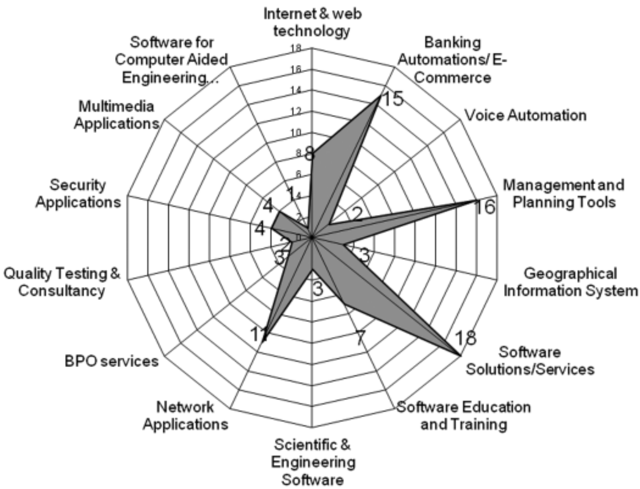

Figure 1 highlights the main areas of operation of the selected 39 firms.

Firms exhibited a diverse range of activities with many having positioned themselves in multiple application oriented areas. Many firms had shifted their focus onto software as its core area of operations in view of the changing scenario in the sector and decline in margins in the hardware segment. At the lower end of the value chain we find a number of firms involved in distribution activities. They are mainly having re-seller agreements to sell products of major software firms. Firms such as those providing network products require some level of expertise as they have to configure the network for the clients. Another firm NIIT has created a brand value through its education and training. Some firms have evolved from providing simple service oriented operations to developing their own in-house service products. A few firms were involved in more complex operations such as embedded software development, voice automation, etc.

Out of 39 firms, 19 firms had obtained quality certifications. These standards have been obtained from India and also from foreign countries. Majority of the standards obtained were ISO or ISO type standards (TickIT, BS799). ISO are set of quality management standards; all ISO standards are process standards (not product standards). Three firms, Satyam, Tata Elxi, and Zenser have obtained level 5 CMM (Capability Maturity Model). This is a highly regarded standard for software development process, level 5 being the highest level. Specific certifications have also been obtained. For example, Bathania has obtained 'National Software Testing Laboratory' certification for voice automation products, Flexotronics and Tata Elsxi obtained certification for 'information security management system' (ISMS certification). It is important to observe that firms when they are moving into specific domains are also trying to obtain quality standards of that domain. Infosys involved in developing applications in the aerospace sector had obtained AS 9000 which is 'Aerospace Basic Quality System Standard'. Similarly, a firm involved in health sector has obtained OHSAS 1800, standard for occupational health and safety management system. The above statistics indicate that firms have paid attention to 'quality certifications'. These are more or less a pre-requisite for a firm to enter a regulated market or serve international clients. The majority of the firms are well equipped in this regard. It is however, difficult to judge whether this has contributed to the research and innovation activity.

Acquisitions and joint ventures have also helped firms to move into new areas. For example 'Goldstone technologies ltd.' alliance with Forte has helped it to foray into 'enterprise application'. Differentiated profile is observed within each application areas where a number of firms are visible. For example in e-commerce application firms focus on its different segments: procurement, customer relationship management (CRM), payment gateway services, etc. *A firm moving into a new area signals a transition is taking place*. It is an indication that firms are developing new competence and is willing to take the risk in operating in a new area (a major factor for innovation).

How Firms are developing domain knowledge and creating core competency:

Firms in this study set have adopted various approaches to develop their competency.

Acquisitions, joint ventures and memorandum of understanding are exposing firms to new knowledge domains and state of art hardware and software platforms.

Investigation of the different M&A show that firms have used this as an instrument to externally acquire capabilities developed by their "partners". These acquisitions have contributed to the innovation activities of the firms. Some of the examples drawn from the sample are important in this context. Aftek Infosys Ltd has signed an agreement to acquire a significant stake in V-Soft Inc of the US. The company has also acquired Arexera, a telecom company in Germany. It has signed a memorandum of understanding (MoU) with 3G Tel of the UK to set up Aftek 3G Tel and will be involved in wireless and mobile and focus on 3G and other emerging technologies. Goldstone technologies ltd (GT) has acquired StayTop Systems Inc of the US (provider of Oracle consulting services), and Bancmate Banking Software from Natural Technologies. With this, GT holds the product rights and patents of the bilingual banking software. Goldstone alliance with Forte is helping it to develop niche capability in enterprise application integration.

Acquisitions also have a strong element of convergence. For example Bathina Medical Information Services Limited (BMISL) merged with BTIL (Bathina Technologies(India) Ltd (BTIL) BMISL has expertise and intellectual property in medical information-based information systems while BTIL is a leader in voice automation technology and product development. This new configuration would allow voice automation features to be incorporated in medical information.

Creating separate/specialized divisions

Some firms have tried to separate its R&D division from its other services. For example, Danlaw Technologies India Limited (DTIL) has two divisions, engineering & information technology. The engineering division is concentrating on development of software services and products for the automotive sector through embedded software development. The other division is involved in routine offshore software services.

Linkages

Linkages could be distinguished under service/distribution tie-ups and R&D collaboration. In some cases they are leading to creation of institutionalised entity through joint venture. Distribution tie-ups are evolving leading to firm getting sole distribution rights, re-seller rights for a number of countries. R&D linkages are important in the context of our examination. R&D linkages were visible not only among firms but also with academic institutions and research organization. Interpersonal linkages have evolved in some cases such as making him/her as board of director, consultant, etc. This type of configuration allows tacit knowledge to be exchanged. Linkages are evolving from loose coupling to more formal linkages i.e. knowledge links are getting further institutionalised. Some of the R&D linkages that led to tangible outcomes are illustrated below.

Creation of new entity

Joint ventures and other collaborative linkages were leading to the creation of new entities. The MEMS (Micro-Electro-Mechanical Systems) design and test laboratory was set up by Cranes software in association with the 'Centre for Sponsored Schemes and Projects' of Indian Institute of Science (IISc), Bangalore. It focuses research on nanotechnology and continuously evaluates the commercial potential of the research. 'NEC HCL System Technologies Ltd' was created through joint venture between HCL technologies ltd and NEC Corporation (Japan). This entity is undertaking R&D in network and security, embedded software, hardware design, high performance computing and mobile technology.

Arm's length linkages (transactions)

Cranes software has provided financial support to Indian Institute of Science (IISc)/ Industry collaboration, i.e. "ESOUBE Communication Solutions Pvt. Ltd." which is involved in designing and developing Proprietary IPRs and Products in the areas of Voice over IP (VoIP), Speech/Audio and Wireless Communication.

Learning

Firms show addition of new services, further enrichment in their existing services, developing service products, etc over a period of time. They are entering into new domains. It shows that the firms are 'learning-by-doing' and 'learning by using'. Learning's are facilitated by the interactions the firms have with other actors. Rosenberg and others have highlighted the importance of learning in the context of innovation undertaken by a firm. For example Danlaw Technologies by gaining experience in 'web based technology' has been able to move into animation and multimedia. The case study latter enumerates the learning experience of three firms.

Type of knowledge/innovation being created

Delivery capabilities: Service innovations have mainly concentrated on creating new delivery methods to serve their clients. This includes portals that allow easy access to a range of services.

Development of embedded software is a high investment, high risk and high skill venture. Embedded software is increasingly part of sophisticated machines; these machines become useless without the control provided by the software. From textile machinery to consumer goods, automobiles, airplanes we find embedded software playing the key role. India's insignificant presence in embedded software segment has been a matter of intense discussion. Five firms in the study set were involved in embedded software domain. Firms have developed capabilities in embedded software in the area of network monitoring and access. One of the firms, HCL has made significant technology leap by co-developing a control chip for Boeing 787.

Firms are involved in developing customized software in different sectors. Banking and medical (mainly hospital) are sectors where a number of firms are involved. Some have developed products that specifically cater to this sector. Finnacle, the core banking software solution of Infosys is a good example. This is a proprietary product respected in the banking sector and used as automation solution in different countries.

Firms are developing reusable bits of software or processes that it can draw to serve its clients better. The intention is to build up IP library, to reuse components and frameworks across projects and thereby increase quality and productivity. This knowledge is being strategically used by the firms. However, only a few firms are involved in patenting. Plausibly their contractual obligations with clients are preventing them from taking proprietary protection. The innovations are created mainly to satisfy the needs of their clients i.e. more efficient services, new delivery methods etc.

Further Insights into the R&D and Innovation activity: Case Study

As the analysis of the sample set illustrates, a few firms had significant involvement in R&D and have capitalized on it. Among them is Infosys, a firm that has created a global delivery model — framework for globally dispersed project management and multi-location execution of R&D and services for innovation. It has rich clientele from different sectors such as aerospace, banking, telecommunications. It participates in global network, one of them involving different players in the automobile segment. Another firm in the study set was NIIT that has created global footprints through its education and training. On the other hand we also found a handful of small firms that are developing their business by investing in R&D. They have evolved from small entities to firms that have developed core capabilities. Three firms stand out in this sample. These firms are Cranes, Sasken, and HCL technologies. Closer examination was undertaken to gain insights of their evolution, and processes that helped them to develop capabilities.

Cranes Software International Limited

Cranes Software International Limited (formerly known as Eider Commercial Ltd), was co-founded by Mr. Asif Khader and Mr. Mukarram in 1991 in Bangalore. Cranes has created a unique business model driven by multi-industry applications of mathematics, statistics, data visualization and related analytical techniques. It has played a major role in the usage of software based scientific and engineering tools in India, creating a market for these types of products. The company has also developed capabilities in microelectronics and computer-added-engineering. The development of the company from a software distribution[2] company to the present stages involved significant transitions.

Initially when it was a software distribution company it strengthened its position from a normal distributor to sole distributor of reputed software. Reseller arrangement[3] with Texas Instruments (TI) for Digital Signal Processing (DSP) tools was an important tie-up in these initial periods. As latter sections highlights, the M&A and linkages helped the firm to evolve as a specialised company addressing three differentiated technology categories: (i) Mathematical Modelling and Simulation tools; (ii) Embedded Software and Controls; and (iii) Business Modelling and Simulation solutions. According to revenues centric groups, Cranes's activities can be divided into two groups viz. engineering and analytic. In engineering, automotive is a major revenue generator, while lately it has forayed into aviations and aerospace. Some of the products developed for engineering sector are: suite of CAE design, embedded engineering, control system design and testing, and finite elements. For analytic, the focus of the company is on pharmaceutical, environment sciences, social sciences, telecom, and BFSI (Banking & Financial Service Institutions). To address the retail credit, it created a risk analysis product *Predica* in 2008. The two approaches (M&A and Linkages with academia) that helped the firm to develop to the present status are enumerated below.

Merger and Acquisition

Merger and acquisitions were done with the intention to strengthen its existing product lines and enter new domains. It helped in the transition of the company from a mere distributor to one encompassing expertise and niche software based products/services in engineering and analytic domains. The firm made two significant acquisitions in 2000. It acquired U.S.-based AISN Software's range of visualization software products e.g. TableCurve 2D, Table Curve 3D, Autosignal and PeakFit. In the same year, Cranes Software

[2] Early 1990s, Cranes started with distribution of MATLAB-technical computing software that has now base of 5 lakh technical users spread across 100 countries.

[3] This alliance has evolved into more creative engagement. Products such as MathWorks and Tektronics for the global wireless industry were developed thorough the collaborative work of these two firms (Annual Report, 2003-04).

acquired from SPSS their highly acclaimed statistical software SYSTAT, which brought with it a global base of over 64,000 licensed users. These acquisitions transformed Cranes from software distributer to a company having its own line of products. Moreover, it was the sole owner of the monopoly rights, intellectual property and the know-how of each of the products. Thus this proprietary domain knowledge provided the firm possibility of exploiting it further.

The firm has continually upgraded the SYSTAT software by bringing new rich features; upgraded its platform from FORTRAN to C and incorporated several new features such as Markov Chain Monte Carlo (MCMC) techniques and quality analysis. This helped the firm to target specific user groups. Additionally, it created Japanese and Korean language versions of this software (Annual Reports, 2003–04 and 2007–08).This gave the company a strong leverage to penetrate the user base in two lucrative markets of Japan and Korea.

The previous acquisitions was strengthened in 2004, when Cranes acquired the marketing, licensing and development rights for the Sigma product line from SPSS Inc., including the flagship SigmaPlot® offering, SigmaStat® statistical analysis package, and SigmaScan® image analysis software. These statistical packages were highly complementary to Cranes current portfolio in terms of cross-selling potential within existing users and addressable markets. The acquisition included 100,000 customers largely in the pharmaceutical and biotechnology marketplace, personnel, fixed assets and all related intellectual property. Users included Merck, Eli Lilly, Pfizer and NASA, each of which had over a thousand desktop installations. Acquiring the development rights and intellectual property helped in developing its domain knowledge. This also allowed it to further upgrade on this software product- helping it to address its clients better and create potential customers.

In 2005, Cranes made another significant transition by acquiring the Indian arm of Engineering Mechanics Research Corporation (EMRC). *This acquisition added a new domain new business line different from the statistical tool product namely* services *based on Computer Aided Engineering (CAE)*. It positioned itself more firmly in 2008 in targeting its CAE capabilities in automotive sector. This was facilitated by acquiring 'Engineering Technology Associates Inc.' (US firm), and Tilak Auto Tech (Indian firm). The firm developed capabilities to design embedded control systems for the automotive sector particularly in the areas of auto safety, vibration, and noise testing products. Lately, the firm has also addressed the aerospace and industrial instrumentation using the same tools/ knowledge it has acquired.

The company has also diversified into e-banking, mobile solutions by making a number of acquisitions of small foreign and Indian firms from 2007 onwards.

Linkages with academia

Cranes developed strong relationships with one of the premier universities in the country, the Indian Institute of Science (IISc) which has been instrumental in its entering the area of wireless and wireline networks, and 'micro-electro mechanical systems' (MEMS). In association with IISc, it created CranesSci MEMS[4] design and test laboratory in 2004. The Lab has started working on cutting edge research in MEMS and nanotechnology that has wide applications[5] in textile designing, farming technique, etc. IISc and Cranes will jointly own the intellectual property for technologies and products developed by the Lab.

The company has acquired microelectronics knowledge through this association. It has helped it to understand the embedded software and control systems and develop solutions for automotive sector (where acquisitions also played an important role), and industrial control and measurement systems applicable to various industries. Microelectronics knowledge also helped the firm to develop real time operating system on SIC33209 32-bit processor. This chip is low power processor and is thus useful for hand held devices such

[4] MEMS integrate mechanical components and their control electronic circuits on the same chip. These mechanical components have sizes ranging from one thousandth of a millimeter (micro-meter) to a millionth (nanometer). MEMS is expected to provide next technological leap as it provides the possibility of creating complete system on a chip (Annual Report, 2003-04).

[5] The firm is involved in designing textiles using nanostructuring that has hydrophobic qualities i.e. less absorber of detergent and water. It is doing research in developing nanotechnology based energy efficient sensors and actuators, with automatic monitors for computation that can help farmers to find the optimal requirement of moisture content at different sections of the land. (see for example Interview of Dr. Rudra Pratap Singh, Chairman Board of Directors, Cranes, March 2006 available on www.itmagz.com)

as mobile, palm tops etc. Designing a new operating system for this chip can improve the utility of this chip.

The firm strongly associates itself with IISc's industrial interaction initiative through its incubator programme termed as 'Society for Innovation & Development'. A spin-off firm 'ESOUBE Communication Solutions Pvt. Ltd' was created through this association. This firm is involved in designing and developing proprietary products in the areas of voice over IP (VoIP), speech/audio and wireless communication. ESQUBE has developed a proprietary voice dialler application, speech recognition algorithms and audio coder (TARANG), which is an alternative to MP3. The company is carrying out research to build WiMAX base station and the WiMAX customer premises equipment. *In 2008, Cranes acquired this spin-off entity.*

The company's association with TI and IBM led to the setting up Cranes Varsity in 1998 to provide post-professional technical training in niche domains such as DSP, Real Time Embedded Systems (RTES) and mathematical modeling for the academic and corporate sectors. The intention behind starting this entity i.e. Cranes Varsity was to create a usage and demand for scientific and engineering tools.

Interactions with academia also played a role in attracting eminent academicians Dr. Rudra Pratap (nanotechnology) and latter Dr. Manju Bansal (computational biologists) on Cranes's Board of Directors.

Overall position of the firm

Over the years Cranes has reduced dependency by increasing proprietary product portfolio. The company earned almost 82% revenues by selling proprietary product in 2007–08 FY (see Table 2).

TABLE2: BUSINESS WISE REVENUES
(RS. MILLIONS)

Sector/activities	2005–06	2006–07	2007–8
Proprietary products	1661	2252	3247
Product alliances	390	491	607
Training and services	57	94	98
Total	2108	2837	3952

Source: Annual Report, 2007–08.

HCL Technologies Ltd

HCL Technologies (HCLT) is a part of the HCL enterprise, the country's oldest hardware firm. HCL enterprise was conceived in 1976 by the group of former employees of DCM Limited headed by its founder director Shiv Nadar. The company got opportunity when IBM walked out of India on the foreign equity issues. HCLT could target the emerging domestic market by lunching it first commercial PC in 1978. It was difficult for the group to tap international market through hardware operation. Diversification to software resulted in the creation of a separate entity in 1991, HCL technologies. The company started its US business in 1994 and its Europe and Asia Pacific business in 1998. The software operation of HCL enterprises grew enormously in the late 1990s to dominate its overall business—the ratio of hardware to software has consistently declined from 83:17 in early 1990s to 38:62 in 1997–98 to further 23:77 in 2000–01. HCL Technologies has been instrumental in this change.

HCLT has pursued growth through organic as well as inorganic route; each complements the other. The firm operates in two segments: one is the traditional mode in which majority of the Indian software firms are present i.e. service operations (outsourcing type/ BPO operations) and the other is its activities in the embedded software. In both the areas, it has extensively used M&A and joint venture as strategy for entering/consolidating in new areas and new markets; latter sections dwell on this issue.

Like other Indian software companies, it used the outsourcing route/BPO operations to start its activities. In its software service role, it continuously expanded its activities in terms of new clients and entering new sectors. M&A (or obtaining substantial stakes in companies), and Joint Venture helped the firm in fulfilling this objective. One can observe this process from 1996 with the target firms being Indian as well as foreign firms. Its strategy was to enter a new market or new area of activity through any of the above routes and then consolidate further following the same strategy. Two important instances can be observed that was very useful for the firm. The joint venture with Perot Systems Inc. (US) in 2003 led to the creation of the new entity 'HCL Perot System'; it helped the firm to become a leading outsourcing and systems integration company with major clients in the banking, energy, healthcare, insurance, and manufacturing and telecommunications industries. Acquisition of the UK-based Axon Group for J441 million ($658 million) in 2008 helped it to enter the SAP market (estimated to provide $26 billion market opportunity).

The important transition of the company was its efforts over the years starting from late 1990's to develop domain expertise in aerospace- safety and mission critical real time avionics systems involving both airborne avionics systems and ground-based systems. HCLT focused on developing embedded software in the above specific areas. HCLT enhanced its engineering knowledge by its association with NEC Corporation (Japan). In 2005, NEC and HCLT came together in a joint venture to set up a new facility, 'NEC HCL System Technologies Ltd' to provide high-end offshore-led software engineering solutions in network and security, embedded software, hardware design, research and development, high performance computing and mobile technology.

The domain knowledge expertise it developed in aerospace helped HCLT to forge partnership with Airbus for co-development of an embedded chip for communication with ground control. Successful development of this chip led to its implementation in the Airbus A380. The same chip will also be used in Boeings 787 Dreamliner (formerly known as the 7E7). The company earns 6% revenues from this segment and it is likely to jump to 20–22% in future. Currently HCLT counts several global leaders[6] in aerospace amongst its key customers, to whom it provides services in hardware, embedded software, CAD/CAE and application development.

HCLT is also applying its embedded system capability that it has developed in diverse areas other then its core focus on aerospace sector. The company has filed a patent application in the Indian Patent Office on a GPS based navigational tool for finding potential fishing zone. It has created a chip that measures how much insulin is needed to be injected in a patient who requires external insulin intake. This chip can mitigate the difficulty in giving proper dos-

[6] HCLT is associated with 35 aerospace companies. For example HCLT has developed AIRBUS A340 flight warning system for AIRBUS France and for flight management system for Smith Aerospace, and Aerospace Systems and Equipment Company. (www.hcltech.com)

age, particularly for those patients who require injection of insulin through nervous system.

The firm was able to enter the area of software based applications in 'mathematical modeling and statistical applications' by collaborating with Saila Systems Inc. (Japan). The partnership resulted in the development of a statistical analysis tool (Panax Finder), useful for the pharmaceutical companies in the drug discovery process. It is a user friendly tool, more efficient and cost saving in terms of manpower involvement and in finding the desired candidate molecules. The software utilises 3D quantitative structure activity relationship (QSAR) to guide the chemical synthesis.

Sasken Communication Technologies Ltd.

Sasken was conceived by Mr. Rajiv Mody, who went to US for a job and returned to India in 1991 (subsequently Sasken shifted to Bangalore) after establishing this firm in a garage in Fremont, California in 1989. The company has evolved over the years to become a leading provider of telecommunications software services and solutions to network equipment manufacturers, mobile terminal vendors and semiconductor companies around the world. It delivers end-to-end solutions that enable richer content delivery on next generation networks by building on its accumulated technical expertise in wireless and broadband technologies, signal processing and IC design. The company's 'mobile software group' has successfully launched several data protocol stack products like GPRS (General Packet Radio Service), 3G.

The company, unlike majority of the companies in India, has built its business by investing in R&D. It spends more than 10% of its sales in R&D. It has a highly qualified manpower[7]. The company has reputed academicians[8] on the list of Directors. It has established over the years, R&D centers in different parts of the world: Bangalore, Pune, and Chennai (India); Kaustinen, Tampere, Oulu and Turku (Finland), and Monterrey (Mexico). Of the 3800 employees, 300 are deployed full time in R&D. The R&D centers

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[7] Of the 3611 Sasken employees in FY 07, 67% were graduate engineers, 22% were master of engineering, and 1% had doctorate degrees (Annual Report, 2006-07).

[8] Dr. Jhunjhunwala, a Professor at Dept. of Electrical Engineering at IIT, Chennai, and Prof. J. Ramachandrans, Professor of Business Policy at IIM, Bangalore are currently on the list of Directors of the company

are involved in joint research activities as well as work in specific niche areas.

The company has developed Symbian-a wireless handset operating system that is a leading operating system at present and is certified by Texas Instruments as an independent OMAP (Open Multimedia Application Platform) technology centre. OMAP family of semiconductor has been specifically designed for use in 3G wireless communication and application processing. The announcement of 3G policy by Government of India in August 2008 and subsequently launching the same in 2009 has brought new opportunities for a company like Sasken as there would be increasing demand of mobile value added services (VAS). India has one of the largest mobile phone populations with around 350 million phones in the country, out of which 5 million subscribers use 3G enabled phones. It has also developed High Speed Packet Access (HPSA), a collection of mobile telephone protocol, which will augment 3G technologies to a high bandwidth path straightaway. Camera enabled phones, polyphone ring tones, and multimedia services will further add up as value additions in the 3G technologies. In order to cut the packaging and silicon cost, Sasken developed single mixed signal chip that can replace multiple chip handling baseband, RF, memory, PLL etc.

Like the other two firms in the case study, M&A and linkages played a key role in the firm's evolution as a value added IT software firm. The section below highlights how these two approaches played a major role.

Mergers and Acquisitions

Sasken's business comes from wireless software products and services that includes software for mobile phones, and has clients such as Nokia, Motorola, Philips, Samsung and Vodafone among many others. The company was listed in 2005. In the same year it launched its wholly owned subsidiary, Sasken Network Engineering Ltd (SNEL). This subsidiary provides network planning, deployment, commissioning integration and network operations support to network equipment vendors and operators. SNEL was formed following Sasken's acquisition of Blue Broadband Technologies business in 2004. Sasken became software development partner for Philips Nexperia home and mobile products. It has joined the S60 product creation community for the Symbian smartphone operating system, which would enable it to add value to the S60 ecosystem.

Sasken enhanced its capabilities in wireless communications by adopting knowledge gained from further acquisitions. In 2006, Sasken acquired Botnia Hightech, Finland-based wireless research and development and testing services provider. Subsequently in 2007 it acquired Integrated Soft Tech Solutions Pvt. Ltd. (iSoft Tech), and Botania Hightech, Oy Finland. This was instrumental for the firm in establishing itself more firmly in the area of data network wireless LAN, hardware & mechanical design, RF design, and testing. *Deficiency of connectivity in software was solved by acquiring another foreign firm-Nokia'a Adaptation Software R&D, Germany in 2008.* Sasken's strategic entry in to the Western Countries, especially Nordic country like Finland proved fruitful, because Europe is the world's largest wireless communication market. Being the birth place of GSM[9], a 2G technology and presence of world's leading wireless vendors including Nokia, Ericsson, Alcatel, and Siemens in the region, Europe till date remains the single place, where single technology/protocol[10] existed. As a result of its foray into the Europe, Sasken was able to fit its own IP in over 4% of the phones shipped in 2005, and over 7% of phone shipped in 2006 across the world (Annual Report 2006–07).

The company shifted focus from software products for telecom to a product-and-service strategy by establishing an international development and support centre in Mexico. The centre will focus on embedded system software development. It has joined ARMs proved Design Centre Programme and will build solutions around the ARM processor using the technologies that it will gain access to through the programme.

Linkages

Sasken entered a new sector- the automotive sector in 2008 primarily through its association with TACO (A Japanese firm). A joint venture was formed, leading to the creation of a new entity

[9] Before the development and subsequent launch of 3G technology, GSM was the most preferred digital air interface standard (Lal & Rai, 2004).

[10] Developing countries like India is just an opposite case having adopted multiple technologies/protocols e.g. in addition to GSM, it has CDMA, WLL, and DECT technologies in the operation.

'TACO Sasken Automobile Electronic Pvt. Ltd.'; to create software solutions for automotive sector. It has created another joint venture with 'Connect M Technologies solution Pvt. Ltd.' in the area of network engineering services

Sasken has proprietary technologies in telecommunications and is aggressive in protecting it through patents, unlike other Indian firms. These intangibles are strength of this company. It has been granted 16 patents in the US, and has filed 13 and 18 patent applications respectively in the US and the Indian Patent Office. It has also filed patents in Europe and Japan. The firm has built up its patent portfolio from 2001 onwards. In patent terminology, the firm has thicket of patents in mainly two key ICT domains: power reduction, and network management. These patents address power efficiency reduction in micro-processors and mobile 3G system, congestion reduction in networks, and multimedia applications (picture retrieval, efficient transmission of multimedia content). Among the patent technology is the Optimized Multimedia Subsystem. It is considered to be best in its class globally, as evidenced by its deployment in commercially released mobile handsets by many tier-1 vendors. This product is in more than 50 models and over 50 million phones across networks in Australia, China, Europe, Hong Kong, Japan and Taiwan earning development and maintenance license fees as well royalties for company. The learning and challenges in developing the multimedia subsystem in mobile phones has effectively been used in development of the company's other products. The team is already engaged in enhancing the system to include new features such as mobile TV using DVB-H and Video over IP.

Discussion

The study tried to uncover whether there has been a tangible shift towards higher end of the value chain. The other prime objective was to investigate the factors that were instrumental for the firms in moving up the value chain. This also provided some insights into the process of innovation. However, we do not divorce our self from the fact that capturing the innovation process requires a deeper investigation and engagement (Pavit, 2003). The first objective was mainly addressed through the broad examination of 39 firms. Further, insights were obtained through the case study. The second objective was mainly revealed through the case studies.

The broad examination showed that firms were active in different segments of the software industry. The firms were also moving to address different sectors. Firms had also paid due attention to 'quality certifications'. These certifications were pre-requisite for firms to enter regulated markets or attract clients. By examining two aspects (a) how firms are developing domain knowledge and creating core competency, and (b) type of knowledge/innovation being created; it was possible to uncover factors that helped the firm to move up the value chain and reveal tangible outcomes. Through the case study, a more informed picture could be discerned.

Acquisitions and linkages were found to be the main contributing factors for firms to enter new areas, new markets increase their domain knowledge, gain knowledge in a new field, create novel products, etc. Strict differentiation in the extent of value addition was not possible. For example, among the eleven firms that are in network applications, there were some involved in the routine service oriented part whereas a few of them were creating applications that enhance the efficiency or deliver novel products based on network applications. To a large extent the value addition is more in the second case. Thus, we distinguished instances that showed a certain activity can be attributed to higher value added segment or were novel initiatives.

The case study provides some insights of how firms move up the value chain over a period of time. For the three firms investigated: HCL technologies, Sasken and Cranes; the role of acquisition, joint ventures, and linkages were again visible as the main drivers that helped them to move up the value chain say build up their domain knowledge and foray into new application areas. Each of the three firms had niche areas of operation; Sasken in telecommunications, HCL technologies in engineering solutions and Cranes in software based scientific and engineering tools. Each of these firms had integrated and built upon their acquired knowledge to deliver highly competitive products. For example, Sasken had designed embedded multimedia chip for mobile handsets. Cranes enhanced the functionality of its acquired statistical software SPSS, and created Japanese and Korean language version of this package. This incremental innovation helped the firm to penetrate the user base in Japan and Korea. HCL technologies learnt about engineering solutions through its joint venture with

NEC. It partnered with Airbus for designing an embedded chip for communication with ground control.

Conclusion

In the Indian software industry which is mainly service driven, inventiveness is monetized in work done for clients, not as an income source in its own right. Thus it is difficult to assess the innovativeness that is taking place. In other words, innovations are mainly in processes rather than in products. Keeping this problem in consideration, innovation was defined in a broader context so that it would be possible to capture innovation in its various facets: process innovations, incremental innovations, non-technological innovations which are generally neglected but play an equally important role as product innovation or radical innovations

The investigations show that some firms exhibited significant movement from simple to complex services, and created novel service processes/products. Firms had taken different paths to develop their expertise. The M&A and strategic technology alliances have mainly been used by the firms to absorb new technologies from their partners or to jointly develop new innovative capabilities. The findings are in conformity with (Kogut (1991), Auster (1992) findings that learning through alliances complements endogenous learning to create new competencies. Case study provide more details of how these strategies are useful but it is also true what (Hagedoorn and Schakenradd, 1994) says "the extent to which such strategies are successful is not always clear".

Linkages were varied and ranged from strong horizontal/ vertical linkages to loose couplings. Tangible outcomes through linkages could be discerned. There are also many causes of concerns. R&D investments were sporadic. Niche operations, services or products were few. Only a few firms have proprietary products. Every firm had shown commitment towards gaining international quality certification. They do realize that it would not be possible to attract high value clientele without attaining certifications. As we had clarified earlier, the implementation of quality standard is not innovation unless it has direct bearing on the products or processes. It was not possible to uncover this relationship.

The case study show how learning and incremental innovations have helped firms transition to complex technologies. All the three firms examined show that they have been receptive to new opportunities; taken actions to take advantage of new opportunities. Their interactions with foreign firms have evolved from low end vertical linkages towards horizontal linkages.

The study shows that a few firms have been able to address higher value in the software development process. They have used a different business model for growth, the mainstay of which is developing innovative capability. It would however, be premature to generalize this to the overall view of Indian software industry. Among the 700 to 800 public limited software firms, only a handful (approx 10%) have undertaken investment in R&D. The sample of 39 firms was selected from this population. The study is thus the reflection of a limited sample from the constrained population. The true population would constitute along with public limited firms, private firms that have undertaken R&D investment[11]. We have no proper estimate of private firms involved in R&D. But, on the hindsight it is possible to postulate that this number would not be very high to change significantly the observations and conclusions of this study.

Recent study estimates 277[12] foreign firms in ICT sector involved in R&D activity in India. It calls for a separate study to uncover nature of knowledge creation in these entities and how knowledge spillover is taking place. The central question in the context of the present study would be whether they have forged linkages with Indian firms and whether that has contributed to enhancing their research and innovation capabilities. We have been able to get some insights of interactions with foreign firms while investigating the linkages of the firms in this study.

The present study is limited and further detailed investigations are required to capture innovation in the Indian software industry and come to the conclusion of what extent innovation has taken place. Nevertheless, from this study, it is refreshing to observe some firms have tried to break away from the mould and achieve success.

[11] It is safe to assume that firms that have not undertaken R&D investment are not involved in the innovation activity.

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Lakhwinder Singh,
Baldev Singh

National Innovation System in the Era of Liberalization: Implications for Science and Technology Policy for Developing Economies

Abstract:

The national system of innovations in the recent phase of globalization has undergone dramatic structural transformation. Innovations entails organizational as well as changes in the rules of the game. The history of economic development of the developing and newly industrializing economies shows that national systems of innovation have evolved keeping in view the most pressing requirements of the national economic development. The knowledge generation and transmission are the two essential characteristics of national innovation system that connects the users and producers of knowledge and also allows institutional arrangements to functions as a feedback system. The institutional arrangements are being altered substantially to allow capital to move freely across national borders on the one side and strict trade related intellectual property rights on the other. How these arrangements have affected the national system of innovation both in the developed and developing countries during the recent liberalisation phase of economic development? In this chapter an attempt has been made to provide some plausible answers to this question. Input and output indicators have been used with a view to unravel the dramatic structural changes occurring both in the economic and innovation structure of the global economy. The internationalisation of R&D expenditure and its implications for revealed comparative advantage have been examined in order to understand the direction of change during the era of liberalisation. The suitable changes in the science and technology policy have been suggested to strengthen the national system of innovation for generating unique competitive advantage in the developing countries.

Introduction:

It is widely recognized that Knowledge is the most important source of economic development and change. Income differentials that exist across countries and over time have been essentially attributed to knowledge gaps. The industrially advanced countries continuously strive to push knowledge frontiers outward and consequently generate competitive advantage to forge ahead in economic activities. This process not only generates income gaps between the rich and the poor countries but also continuously adds to the gaps in capacity building in knowledge. The capacity to create knowledge that matter for economic development is mainly being developed within economic system and is called national system of innovations (NSI). The seminal contribution in this direction has done by Lundvall (1992) and Nelson (1993). The concept of NSI assumed significance and attracted attention of the large number of researchers and policy makers working in the areas of innovations and development economics both in the developed and developing economies after the publication of work by Lundvall and Nelson (Freeman, 1997; Mytelka and Smith, 2002; and Edquist and Hommen, 2006). The national systems of innovation that generates capacities to innovate new knowledge entails network of economic actors and institutions essentially coordinated by the Government. The NSI progressively generates dynamism in the productive economic activities, which usually culminates in developing and nurturing unique competitive advantage in economic activities and actors. The superior economic performance within the national economy encourages economic agents of production to expand operations at a global scale to further take advantage of home grown competitive advantages to exploit economies of scale of various kinds. The knowledge generation and transmission are the two essential characteristics of national innovation system that connects the users and producers of knowledge and also allows institutional arrangements to functions as a feedback system from top to bottom and vice versa. The channels and mechanisms that act as an agent of knowledge transmission both in the national economy and international economy are essentially common but differ in terms of costs. It is significant to note that national innovation system since its origin and evolution has strong learning linkage across national borders. The development in the institutional innovations in terms of transnational corporations that have contributed in rapid transmission and exploitation of knowledge across national borders and weakened their commitment to place of origin (Ruttan, 2001). According to Ruttan (2001), the national differences in terms of capacity to generate, transfer and absorb knowledge continue to remain a matter of prime importance. The rate and direction of knowledge development and change essentially remained very much rooted in the national resource and cultural endowments, capacity to made investment in education and research, and institutional structure and government support. In the real world situation, the proactive role of public policies are essential to protect and enhance the existing competitive advantages and also to reduce knowledge gap between the advanced and backward countries (World Bank, 1999).

The national economies have been growing in the interdependent world. Therefore, national innovation system is continuously being influenced by the changes occurring in other parts of the world. During the past two decades, the collaborative R&D in pre-competitive research has emerged as a key tool of knowledge generation policy at the national and supranational levels (Roediger-Schluga and Barber, 2006). The dramatic reduction of tariff barriers for international trade, direct foreign investment and cross border flows of finance capital have altered the rules of global management system. With the establishment of World Trade Organization (WTO), the transnational corporations have dramatically influenced the national innovation system and innovation outcomes. On the one hand, the WTO pushed forward the liberalization of trade and capital flows across national boundaries but tightened rules and regulations related to commercial use of intellectual property rights on the other hand (Commission on Intellectual Property Rights, 2002). Why were trade related intellectual property rights changed from public to private rights by the WTO precisely because of the rapid increase in the private sector initiative led R&D expenditure in the industrially advanced countries. The dramatic rise of proportion of private R&D in total R&D in the developed countries essentially reduced public sector R&D as a minor partner during the last quarter of the 20th century (Singh, 2004). Protection was provided by the WTO to the global players of generation of knowledge to reap economies of scale and reduce externalities so that further investment in knowledge can be increased. The monopoly rights in IPRs ensured by the WTO have been examined and put to rigorous tests by the leading experts and found that it may reduce global innovations but surely will not benefit to the less developed countries (Helpman, 1993; and Grossman and Lai, 2004). However, in this era of liberalization and globalization, the developing economies have substantially altered earlier institutional arrangements for national rules and regulations in favour of receiving higher investments both in productive economic activities and innovations. Some of the developing economies are receiving higher flows of investment and research and development flows from developed countries TNCs and others have lagged behind (Singh, 2009).

The fundamental aim of the chapter is to investigate global trends in terms of R&D inputs and output measures to establish that how liberalization era, started with the establishment of WTO, have affected the innovation system and economic structure of the developing economies. The evolution of internationalization of R&D and its impact on revealed technological advantage during the recent phase of liberalization is examined with a view to ascertain the process of homogenization or diversity in the national systems of innovation. Furthermore, the historical experience of policy making and role of international institutions and national governments during the liberalization era are examine to draw implications for the science and technology policy and innovative interventions that can generate national capabilities for strengthening national system of innovation in the developing countries.

The chapter is organized into six sections. Apart from introductory section one, the theoretical and empirical aspects of the debate on how will global innovations be affected in liberalized regime enacted by the WTO in section two? To ascertain impact of liberalization of innovation regime across countries, the indicators of innovations based on input-output measures have been presented in section three. Fourth section contains the discussion related to internationalization of R&D and revealed technological advantage. Fifth section investigates the role of international agencies to enact rules of the game in an open innovation system and the national governments in terms of enacting innovative interventions in the fast globalising world economy. Policy implications for science and technology development of other developing countries that emerge from the national system of innovations and fast development experience of the successful East Asian countries are presented in the concluding section.

National System of Innovation in Transition:

Innovations trigger economic growth and structural transformation is widely acclaimed and accepted fact in economic growth literature. Innovations entails organizational as well as changes in the rules of the game. Thus, transition in the national innovation system is the fundamental determinant of long-run economic growth and development. This is being reflected through the changes, which are occurring in the economic structure of an economy as well as in the structure of the innovation system. The history of economic development of the developing and newly industrializing economies shows that national systems of innovation have evolved keeping in view the most pressing requirements of the national economic development. The process of economic growth thus brings in economic transformation and non steady state economic growth. Technology has emerged as a distinct and key factor that determines changes in the long run economic growth and structure of the economy. It needs to be noted here that the innovations are of two types that is radical and incremental (Fagerberg and Verspagen, 2001). Radical innovations open up new opportunities and push the frontiers of knowledge, which dramatically alter the existing economic structure. Incremental innovations not only improve the practices of the existing technologies but are potent factor of diffusion of the radical innovation that engineer structural change in the economic system. However, imitation tends to erode differences in technological competencies across economic activities and over time that reduces differentials and gaps in economic activities. Therefore, radical and incremental innovations are a source of structural transformation and divergence in economic growth and imitation acts as an agent of reducing productivity gaps and initiates the process of convergence. Both the processes of innovations continuously remain in action and the combination of the two actually determines the economic transformation and convergence in the economic system (Fagerberg and Verspagen, 2001). Liberalization era has secured tight intellectual property rights and its implementation will reduce imitative and innovative adaptations. This may significantly affect the future emergence of innovation system in the less developed countries. According to Commission on Intellectual Property Rights (2002), there is an increasing concern that protection of IPRs under the influence of commercial pressures, which insufficiently circumscribed by consideration of public interest and are being extended with a purpose of protection the value of investment than to create or stimulate inventions. It was also apprehended that denying access to developing countries scientists to the protected data related to important diseases or new crops affects the developing countries. This implies that knowledge gaps will continue to rise that will also allows productivity gaps to further increase and cripple the process of productivity convergence.

Changing the structure of production and altering technological trajectories are among the most formidable policy challenge facing NSI, given that when uncertainty and risk are high, the danger that markets will under perform relative to public policy objectives is particularly great (Edquist and Hommen, 2006). However, Lundvall (1992) asserted that NSI would continue to pursue distinctive national trajectories, even under the homogenizing influence of globalization process. It is important to note here that developing countries have been under sustained pressure to increase the levels of intellectual property protection based on standards in developed countries. This harmonization process of IPRs protection has severe consequences for adverse distribution of income for developing countries. According to one estimate, the most developed countries would gain net benefits from WTO regime of IPRs and US alone will gain $ 19 billion annually but the developing countries will incur deficit from the IPRs related transactions (Commission on Intellectual Property Rights, 2002).

It is important to note here that the knowledge generation process in the national system of innovation has undergone a fundamental non-reversible structural change in the developed countries. It is the transition from fundamental research to applied one. This phenomenon has been described as a dual “crowding out”. Firms are now increasingly engaged in applied research and do not finance fundamental research either in house or in the institutions of higher learning is one form of crowding out. The other form of crowding out is the near absence of fundamental research from the public laboratories and the university research (Soete, 2006). During the period of liberalization, even in less developed countries the government support to the R&D institutions reduced substantially and asked these institutions to find financing while supplying innovation output to industry (Singh, 2004). Therefore, there was not only reduction of public support and financing to the public institutions, which were mainly contributing to global pool of fundamental knowledge, but orientation of these institutions was changed to applied research. This process set in especially under the WTO regime may reduce global pool of knowledge and hence has a capacity to reduce future scope of innovations because applied knowledge is highly dependent on drawing knowledge from the availability of the fundamental global pool of knowledge (Helpman, 1993; and Grossman and Lai, 2004).

The reduction of barriers on foreign capital in the post WTO regime has dramatically affected the rules and regulations that govern across border flows. The analysis of the Table 1 reveals that the number of countries increased from 43 in 1992 to 63 in 1995 who have introduced regulatory changes from 77 to 112 during the same period.

TABLE 1: GLOBAL TREND OF REGULATORY CHANGES RELATING TO INTERNATIONAL INVESTMENTS FROM 1992-2007

Items	1992	1995	2000	2005	2006	2007
Number of countries that introduced changes	43	63	70	92	91	58
Number of regulatory changes	77	112	150	203	177	98
More favorable changes	77	106	147	162	142	74
Less favorable changes	0	6	3	41	35	24

Source: UNCTAD (2008)

The number of countries and changes further increased at a fast rate from 1995 to 2000 and reached at a peak in 2005 when 92 countries introduced 203 changes in the regulations related to international investment. When we make a comparison with highly favourable and favourable, out of 203 regulatory changes 162 were highly favourable. Thereafter the changes introduced with regard to regulations continued and largely more favourable changes with regard to the operation of multinational companies across countries dominated (Table 1). It is significant to note that these changes may have profound effects on the national economies of the developing countries in general and national system of innovations of developing countries in particular. The first and foremost impact of these relaxations provided by the developing countries to attract foreign companies and investment can be ascertained in terms of changing structure of production of the developing countries. The production structure of developing economies substantially changed to follow the production structure observed in the developed countries (Table 2).

The changes occurring in the gross domestic product produced in the three sectors of the economies shows that the global economy generated 69 per cent of the income from the service sector of the economy. It is well known that agriculture sector has lost its importance as a prime sector of the global economy but the industrial sector also losing fast its importance in the production structure of the global economy. This process has been described as deindustrialisation. However, it is well known that the industrially advanced countries have recorded changes in the production structure and dramatically moved towards service oriented and more specifically knowledge generating economies.

TABLE 2: SECTORAL DISTRIBUTION OF GDP ACROSS ASIAN COUNTRIES 1990 AND 2005

Region/Country	Agriculture		Industry		Service	
	1990	2005	1990	2005	1990	2005
High Income Countries	3	2	32	26	65	72
Middle Income Countries	16	9	39	38	46	53
Low Income Countries	32	22	26	28	41	50
East Asia and Pacific	25	13	40	46	35	41
South Asia	31	19	27	27	43	54
Bangladesh	30	21	22	27	48	52
Nepal	52	40	16	23	32	37
India	31	21	28	27	41	52
China	27	13	42	46	31	41
Pakistan	26	22	25	25	49	53
Sri Lanka	26	18	26	27	48	55
Indonesia	19	15	39	44	42	41
Philippines	22	14	35	32	44	54
Thailand	13	10	37	44	50	46
Malaysia	15	10	42	50	43	40

South Korea	09	04	42	41	50	56
Hong Kong	-	-	25	11	74	89
Singapore	-	00	38	35	-	65
World	06	04	33	28	61	69

Source: World Bank (2006) World Development Indicators 2006, Washington, D.C.: The World Bank.

The developing countries were being characterized as predominantly production oriented. It is worth noting that the opening up of the developing economies has been substantially impacted in terms of changes in the production structure. The production structure of the developing countries turn to be predominantly service oriented with some exception of East Asian countries where industrial sector still generated larger proportion of gross domestic product. However, these economies in the post WTO regime are fast approaching to become predominantly service oriented. It needs to be mentioned here that most of the East Asian countries are following the standard pattern of structural change but most of the developing countries are prematurely becoming service sector oriented (Table 2).

These changes in the production structure of the developing countries can essentially be attributed to the international linkage of these economies. As the developing economies are becoming more open, they are fast becoming service oriented. This is how the developed countries and operation of international investment and trade has played an important role in changing the production structure of the developing countries. The rise of inter-linkage between the developed and developing countries has also substantially altered the emerging national system of innovations from national needs to international needs. It has been moving from more public oriented to private sector oriented and from fundamental to applied. Even the operation of multinational corporations in the developing countries have impacted on domestic firms not to incur in-house R&D expenditure rather depend for technological knowledge on these companies.

The world economy is passing through a worst form of recession triggered with financial meltdown in US and spread over to many developed and developing economies due to its devastating effects on the real productive sectors. According to Wade (2009), the

Anglo-American model of liberal capitalism has lost credibility compared with the French model based on national objectives and state-favoured industries and steering markets by the state seems to be the most acceptable norm. He further argued that state should support innovations in the areas of biotech, nanotech, new materials, new transport systems and healthcare. These activities not only will be helpful in the revival of growth process but will also save environment and facilitate lifetime education. This requires reversal of role of global institutions to bring in the agenda of social justice and equity considerations instead of pursuing the commercial interest of developed countries and that too of the commercial organizations. The developing countries must be allowed in enacting and framing Public policies in such a manner, which are suited to the stage of economic development and specific circumstances so that development must result in benefiting the developing countries to reduce technological and productivity gaps across countries and within countries across sectors or classes.

Structure and Trends in Global Innovations:

The recent phase of globalization has increased interdependence of countries and international flows of trade, technology and finance along with universally applicable IPRs may have substantially increased the openness of the national innovations systems. Therefore, it is instructive to understand the changes that have occurred during the last decade and a half in the national system of innovation in the global economy related to investment pattern in the national systems of innovation. This can be ascertained from the two types of indicators, that is, input and output indicators of innovations. One of the most important input measures that generate innovations is research and development expenditure, which is presented in Table 3. Research and development expenditure in the whole world, which is investment for generation of innovations, as per UNESCO estimates, was 409 billion dollars on purchasing power parity (PPP $) in the year 1990. countries were 811.64 billion PPP dollars, which was nearly 82 per cent (81.64 per cent) of the total global expenditure in the year 2005. This shows that there was a rise in the relative share of developed countries in the total global R&D nearly 3 percentage point within a half decade. Although the total expenditure of the developing countries has increased but the rate of rise was slow that has shifted the relative position of R&D expenditure in favour of developed countries.

An interesting finding worth mentioning here is that the relative share of global R&D expenditure of the North America was 38.16 per cent of the total global R&D in 1990, which marginally declined to 37.21 per cent in 1999-2000. The R&D of North America declined during the decade of 1990s less than one percentage point. But it marginally improved in the first half decade of the 21st century. The lead and dominance of this region in the global R&D expenditure continued during the period of analysis.

TABLE 3: STRUCTURE AND TRENDS OF GLOBAL RESEARCH AND DEVELOPMENT EXPENDITURE.

Region/Year	R&D expenditure (billion PPP$) 1990	R&D expenditure (billion PPP$) 1999/2000.	R&D expenditure (billion PPP $) 2005
World total	409.8 (100.00)	755.1 (100.00)	993.69 (100)
Developed Countries	367.9 (89.77)	596.7 (79.02)	811.64 (81.68)
Developing countries	42.0 (10.25)	158.4 (20.98)	182.05 (18.32)
North America	156.4 (38.16)	281.0 (37.21)	373.02 (37.54)

Source: UNESCO (2004 and 2008).

The share of developed countries research and development expenditure in the global economy was 89.77 per cent and developing countries were just contributing 10.25 per cent in the year 1990. According to the UNESCO estimates for the year 1999–2000, the total global research and development expenditure increased to 755.1 billion PPP dollars. The developed countries expended 597.7 billion PPP dollars, which was 79.02 per cent of the total global R&D expenditure. The developed countries relative share of global R&D expenditure declined from 89.77 per cent to 79.02 per cent during the period 1990 to 1999–2000. This was a decline of 10.75 percentage points, which is quite substantial during the decade of the 1990s. The rise of R&D expenditure in the newly industrializing countries of Asia on the one hand and decline of East European countries expenditure on the other was the major reason for this dramatic change during the decade of 1990s (Singh, 2007). The analysis of the Table 3 reveals that there was a rise of R&D expenditure in the global economy from 755.1 billion PPP dollars in 1999–2000 to 993.69 billion PPP dollars in 2005. The total R&D expenditure incurred by the developed countries was 811.64 billion PPP dollars, which was nearly 82 per cent (81.64 per cent) of the total global expenditure in the year 2005. This shows that there was a rise in the relative share of developed countries in the total global R&D nearly 3 percentage point within a half decade. Although the total expenditure of the developing countries has been increased but the rate of rise was slow that has shifted the relative position of R&D expenditure in favour of developing countries.

Innovative investment expenditure rise if accompanied with the rise in gross domestic product depicts a real rise in the investment in the knowledge generation activities. Therefore, R&D expenditure-gross domestic product (R&D-GDP) ratio represents innovation investment intensity. This indicator change over the period truly reflects the rise or fall of effort of a particular country in the knowledge generation activities. The R&D-GDP ratio for the period 1991 and 2006 and the sources of finance across OECD and BRICS countries for the year 2006 are presented in Table 4. It is important to note from the analysis of the table 4 that the OECD R&D-GDP ratio has increased slightly from 2.20 in 1991 to 2.26 in 2006. A substantial fall in the R&D-GDP intensity has been recorded in many OECD countries between the period 1991 and 2006. Most prominent among them are UK, Italy, Netherlands, Norway and France. There is also a marginal decline in this ratio for US. A dramatic decline of R&D-GDP ratio has been reported from the East European countries such as Poland, Hungary, Slovak Republic and Czech Republic. But in other OECD countries innovation investment intensities have increased substantially. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, Iceland, Ireland, New Zealand, Spain, Sweden and Switzerland. Two Asian countries, that is, Japan and South Korea are OECD member countries, where R&D-GDP

ratios have sharply increased (Table 4). Germany economy's R&D-GDP ratio has registered a marginal rise between the period 1991 and 2006. However, there are low innovation investment intensity OECD countries, that is, Greece, Portugal and Turkey, which have recorded an increase of R&D expenditure between the period 1991 and 2006. An interesting finding which comes out of the analysis of the structure and pattern of financing of research and development expenditure of the low R&D-GDP ratio OECD countries is that more than fifty per cent research and development expenditure has been done in these countries by the government. But in the high innovation investment intensive OECD countries, more than fifty per cent financing of R&D is being done by the industry. This ratio is 75.45 per cent for Korea, 77 per cent for Japan and 79.72 per cent for Luxembourg.

The business enterprise R&D expenditure shows that for the OECD as a whole nearly 90 per cent expenditure has been incurred by the industry (Table 4). However, there are wide variations across OECD countries so far as the business enterprise R&D expenditure proportion of government and industry is concerned.

TABLE 4: INNOVATION INTENSITY AND R&D FINANCING PATTERN ACROSS OECD AND BRICS COUNTRIES

Country	% of GDP		% Financed by 2006		% Financed by Business enterprise expenditure 2006	
	1991	2006	Govt.	Industry	Govt.	Industry
Australia	1.31	1.78	40.51	52.97	4.3	93.4
Austria	1.44	2.45	36.58	46.35	6.4	67.2
Belgium	1.62	1.83	24.65	59.68	6.5	82.5
Canada	1.60	1.94	32.68	47.97	2.7	81.6
Czech Republic	1.90	1.54	38.97	56.91	13.6	83.7
Denmark	1.61	2.43	27.58	59.53	2.4	86
Finland	2.02	3.45	25.11	66.56	3.7	89.9
France	2.33	2.11	38.39	52.24	10.1	80.8
Germany	2.47	2.53	28.38	67.57	4.5	92
Greece	0.36	0.57	46.82	31.06	5.6	85.7

Hungary	1.06	1	44.77	43.3	8.4	75.6
Iceland	1.18	2.78	40.5	48	2.8	84.9
Ireland	0.93	1.32	30.13	59.26	3.9	86.5
Italy	1.23	1.09	50.68	39.66	9.7	79.2
Japan	2.76	3.39	16.18	77.07	1	98.5
Korea	1.84	3.23	23.07	75.45	4.7	94.8
Luxembourg	-	1.47	16.61	79.72	5.2	91.7
Mexico	-	0.5	45.34	46.49	5.7	92.6
Netherlands	1.97	1.67	36.23	51.06	3.4	81.6
New Zealand	0.98	1.16	42.98	41.25	11.3	80.7
Norway	1.64	1.52	43.99	46.41	10.5	80.7
Poland	0.76	0.56	57.45	33.05	12.3	80.9
Portugal	0.57	0.83	55.2	36.27	4.2	91.4
Slovak Republic	2.13	0.49	55.56	34.96	20.8	68.2
Spain	0.81	1.2	42.49	47.07	14.4	79
Sweden	2.72	3.73	23.5	65.7	4.2	87.1
Switzerland	2.59	2.9	22.71	69.73	1.5	90.9
Turkey	0.53	0.76	48.63	46.05	8.7	90
UK	2.07	1.78	31.87	45.2	7.6	69.4
US	2.71	2.62	29.34	64.89	9.3	90.7
OECD TOTAL	2.20(1.87*)	2.26	29.46	62.71	6.8	89.6
Brazil	-	1.02	57.88	39.38	0.8	99.2
China	0.74	1.42	24.71	69.05	4.5	91.2
India	0.79	0.71	80.81	16.11	-	-
Russian Federation	1.43	1.08	61.1	28.8	52	35.7
South Africa	0.84	0.92	38.19	43.87	16.2	68.3

*Denotes EU-15
Source: OECD (2008).

But the analysis of the sources of business enterprise R&D expenditure clearly brings out the fact that it is largely done by industrial sector of the OECD economies and governments have been reduced to a junior partner that is why in these countries commercial interest are quite influential in so far as the domestic and international policy making related to protection of IPRs is concerned. It is widely held view that future engines of global economic growth are BRICS countries that is Brazil, Russia, India, China and South Africa. Among the BRICS countries, India is the lowest R&D expenditure incurring country in terms of her R&D-GDP ratio, which is 0.71 per cent in 2006. This ratio for South Africa was 0.92 per cent. Although, both the countries are spending less than one per cent of GDP, but the R&D-GDP ratio has marginally declined in the case of India whereas it increased substantially in the case of South Africa. For Russian Federation the R&D-GDP ratio has declined between the period 1991 and 2006 but remained more than one per cent. China has dramatically improved the innovation intensity investment and was below India's level at 1991 and not only surpassed India but has emerged as the highest R&D expending country among the BRICS countries. The R&D-GDP ratio has increased from 0.74 per cent in 1991 to 1.42 percent in 2006 (Table 4). There are two distinct pattern of source of finance of R&D expenditure that emerged from the analysis of the expenditure pattern of BRICS countries. One, the government is the major or dominant source in terms of financing R&D expenditure in three countries, that is, India, Russian Federation and Brazil. Two, the industry turns out to be the major source of finance of R&D in China and South Africa.

Apart from resource allocations for the development and creation of new knowledge, the researchers engaged in the conception or creation of new knowledge, development of new products and processes are the fundamental and the only dynamic factor input in the national innovation system. The researchers (scientist and engineers) are the professionals, which are working with the availability of investment resources in knowledge generation activities. Therefore, the human resources devoted for knowledge generation in a particular region/country are the most important indicator of the intensity of input measure. The researchers engaged in R&D activities across regions and countries are presented in Table 5. The total number of researchers engaged in the global economy was 5521.4 thousands in the year 2002. It comes out to be 894 per million inhabitants and per researcher R&D expenditure was incurred US $ 150.3 thousands. When one divides the researchers engaged in innovation activities across developed and developing economies, there was high degree of concentration of the researchers engaged in the developed economies. Out of the total researchers engaged in the innovation activities in the global economy, more than 70 per cent were working in knowledge generation and development of new products and processes activities in the developed countries. The developing economies have been engaging just 29 per cent of the total researchers engaged in the global economy. The intensity of researchers, that is, per million inhabitants number of researchers, was 3272.7 in the developed countries in the year 2002. However, this intensity was 374.3 researchers per million inhabitants in the developing countries, that is, more than 8 times low in the developing countries compared than that of the advanced countries. It is heartening to note that the less developed countries had engaged only 0.1 per cent of the global researchers engaged in the national innovation system and researchers' intensity was also very low, that is, 4.1 researcher per million inhabitants. These indicators provided ample evidence of the inequitable national innovation system emerging in the global economy. Continent wise distribution of researchers employed in the innovation activities clearly brings out the fact that Asia as a continent has emerged as the largest in terms of the proportion of the researchers engaged in the global economy. The share of researchers employed in Asia was 36.8 per cent of the global economy and emerged number one continent just ahead of Europe, which has engaged 33.4 per cent of the total researchers (Table 5).

So far as the proportion of researchers engaged in R&D activities are concerned, North America comes at number three in the global economy. According to the intensity indicator of researchers, the North America engaged 4279.5 researchers per million inhabitants. This is the highest number of researchers that provides the prime position, that is, number one rank in the global economy to North America continent. The Europe turns out to be number two in the global economy according to the intensity of researchers as an indicator of research intensity. The gap in terms of intensity of researchers between North American and Europe was very large. It is important to note that this gap is highest between North America and Asia, that is, four times.

TABLE 5: RESEARCHERS ENGAGED IN INNOVATIONS IN DEVELOPED AND DEVELOPING COUNTRIES.

Region/Year	Researchers (Thousands)	Per cent of World researchers	Researchers per million inhabitants	GERD per researcher (US $ thousands)
World total	5521.4	100.00	894.0	150.3
Developed Countries	3911.1	70.8	3272.7	165.1
Developing countries	1607.2	29.1	374.3	114.3
Less Developed countries	3.1	0.1	4.1	153.7
North America	1368.5	24.8	4279.5	224.5
Latin America & Caribbean	138.4	2.5	261.2	156.5
Africa	60.9	1.1	73.2	76.2
Asia	2034.0	36.8	554.6	128.5
Europe	1843.4	33.4	2318.8	122.7
Brazil	54.9	1.0	314.9	238.0
China	810.5	14.7	633.0	88.8
India	117.5	2.1	112.1	176.8
Russian Federation	491.9	8.9	3414.6	30.0
South Africa	8.7	0.2	192.0	357.6
UK	157.7	2.9	2661.9	184.2
USA	1261.2	22.8	4373.7	230.0

Source: UNESCO (2005a) UNESCO Science Report, UNESCO

Thus, Asia turns out to be number third in terms of intensity of researchers per million inhabitants which is still very low. Even the expenditure incurred per researcher is highest in North America followed with substantial gap in Europe and Asia. The intensity of researcher shows that Latin American and Caribbean countries were ranked number four and Africa turns out to be lowest ranked according to intensity and the proportion of researchers as an indicator of innovations among the five regions of the global economy.

Among the BRICS countries, China and Russian Federation were quite ahead according to intensity of researchers engaged in innovation activities. However, India, Brazil and South Africa are the three BRICS countries having very low intensity of researchers engaged in knowledge generation activities.

The resources incurred for innovations and capability building show results not only in terms of developing a system of innovations but also nurture economic agents of production to participate, learn to use and develop new knowledge and products. Therefore, there is a positive relationship between resources expended in new knowledge creation and innovation output, that is, contribution of a national economy in producing scientific and technical journal articles, patents, royalty payments received and internationally traded high-tech goods and services. The contribution of scientific and technical journal articles during the period 1995–2005 across the regions of global economy are presented in Table 6. During the period 1995–2005, the scientific and technical journal articles in the global economy increased from 436951 to 708086. The rate of growth of scientific and technical journal articles turns out to be 4.5 per cent per annum during the period of analysis. The high-income countries contributed 379529 scientific and technical journal articles in the year 1995 which turns out to be 86.86 per cent of the total number of scientific and technical journal articles of the global economy. There was a significant increase in the contribution of high income countries to the scientific and technical journal articles over time and published 578656 number of scientific and technical journal articles in 2005. The per annum rate of growth of scientific and technical journal articles of high-income countries was 6.21 per cent. This rise in the growth rate was higher than that of the rise of rate of growth of scientific and technical journal articles in the world as a whole. However, the global share of scientific and technical journal articles of high-income countries declined from 86.86 per cent to 81.72 per cent during the period 1995–2005. This decline was more than 5 percentage point. On the other hand low-income countries contribution in scientific and technical journal articles in absolute numbers have increased from 14646 to 16711 between the period 1995 and 2005 and the rate of growth turns out to be 1.9 per cent per annum. But the relative contribution of the low-income countries declined from 3.35 per cent to 2.36 per cent during the period 1995 to 2005. The East Asia and Pacific countries substantially raised their contribution to the scientific and technical journal articles during the period 1995–2005. The relative share increased from 2.1 per cent in the total number of scientific and technical journal articles in the world as a whole in 1995 to 6.22 percent in the year 2006. The scientific and technical journal articles increased at a rate 25.15 per cent per annum of the East Asia and Pacific countries, which was the highest among the regions classified in Table 6.

TABLE 6: SCIENTIFIC AND TECHNICAL JOURNAL ARTICLES IN THE GLOBAL ECONOMY

Regions/ Year	1995	1997	1998	1999	2001	2003	2005
Low income countries	14646 (03.35)	13572 (02.65)	13565 (02.65)	14376 (02.72)	13147 (02.03)	14,929 (02.14)	16,711 (02.36)
Middle income countries	42776 (09.79)	61762	61733	62409	84507	100,288	112,719 (15.91)
Lower middle income Countries	23775 (05.44)	35148 (06.86)	32967 06.43)	39216 (07.42)	61791 (09.02)	49,969 (07.16)	53,423 (07.54)
Upper middle income Countries	19001	26614	28767	23193	22716	50,319	59,296
Low & middle income Countries	57422	75334	75298	76785	97654	115,217	129,430
East Asia & Pacific countries	9164 (02.10)	14817 (02.89)	14817 (02.89)	13055 (02.47)	22722 (03.50)	31,351 (04.49)	44,064 (06.22)

Europe & Central Asia	30483	34905	34905	34679	39077	42,695	39,975
Latin America & Caribbean	6449	10093	10075	12033	16045	18,588	20,045
Middle East & North African countries	1136	3123	3106	3637	4699	5,358	6,354
South Asia	7851	8896	8896	9769	11611	13,487	15,429
Sub-Saharan Africa	239	3499	3499	3612	3500	3,738	3,563
High income countries	379529 (86.86)	437303 (85.30)	437339 (85.31)	451842 (85.47)	550846 (84.94)	582,180 (83.48)	578,656 (81.72)
Europe (EMU)	98365	115641	117764	122077	148169	156,184	158,066
World	436951	512637	512637	528627	648500	697,397	708,086

Note: Figures in parentheses are percentages.
Source: World Bank, World Development Indicators, Various Issues.

The second highest growth rate recorded by the upper middle-income countries, that is, 17.65 per cent per annum during the period under analysis. The relative share also increased from 4.37 per cent in 1995 to 8.37 percent in the world as a whole during the period 1995–2005. The Latin American and Caribbean countries had very low base in terms of their contribution to scientific and technical journal articles was concerned but the rate of growth was 17.59 per cent during the period 1995–2005. The relative share of the Latin American and Caribbean countries increased from 1.5 per cent to 2.8 per cent in 1995 to 2005. However, their contribution in terms of adding knowledge to global pool of knowledge through scientific and technical journal articles remained quite low. This is lower than even that of South Asian countries. The contribution of middle-income countries was 9.79 per cent in 1995, which was increased to 15.91 per cent in 2005, to the total global scientific and technical journal articles. The growth rate per annum turns out to be 14.85 per cent. The overall conclusion, which emerged from the analysis of the Table 6, is that although high income countries contribution to scientific and technical journal articles has declined but the relative share remained higher than 81 per cent. This clearly shows that there is high degree of concentration of output indicator of research and development in the high-income countries. The research collaborations that result into the publication of joint authorship scientific and technical journal articles remained concentrated (more than 70 per cent) among the high-income countries (UNESCO, 2005b).

TABLE 7: GLOBAL TRENDS OF PATENT APPLICATIONS FILED BY THE RESIDENTS AND NON-RESIDENTS

Region/ Patents	Residents 1997	Non-Residents 1997	Residents 2004	Non-Residents 2004
Low income countries	23772 (02.98)	648006 (17.99)	7259 (00.83)	12067 (02.54)
Middle income countries	126138	817452	105144	120688
Lower middle income countries	27027	449771	76157	90921
Upper middle income countries	99111	367681	28987	29767
Low & middle income countries	149910	1465458	112403	132755
East Asia & Pacific	106342 (13.33)	184288 (05.11)	66112 (07.58)	70866 (14.96)
Europe & Central Asia	31081	685716	34767	19989
Latin America & Caribbean	1708	175004	4498	29255
Middle East & North Africa	509	1207	215	871
South Asia	10236	26322	6765	11752
Sub-Saharan Africa	38	392921	16	22

High income countries	648093 (81.21)	2137327 (59.32)	759875 (87.11)	341015 (71.98)
Europe (EMU)	101037	1086902	72974	15757
World	798003	3602785	872278	473770

Note: Figures in parentheses are percentages.
Source: As above in Table 6.

Another important output indicator of innovation is the patent application filed in an economy by the residents and the non-residents, which are provided for the years 1997 and 2004 in the Table 7. The analysis of the table clearly brings out the fact that there was a substantial rise in the number of applications filed in the high-income countries both by the residents and no-residents between the period 1997 and 2004. The relative shares of application filed by the residents and the non-residents in the high income group of countries have increased from 81.21 per cent and 59.32 per cent respectively in the year 1997 to 87.11 per cent and 71.98 per cent respectively in 2004. This is ample evidence that allow us to conclude that there is a tendency of concentration of innovation output in the high-income countries. But the share of low-income countries declined over the same period so far as patent applications filed both by the residents and non-residents are concerned. The share of patent applications filed by the low-income countries has declined from 2.98 per cent in 1997 to less than one per cent in 2004. Again during the recent phase of globalization, the concentration of output indicators of innovation provided evidence enough to conclude that there is high degree of inequitable distribution in new knowledge generated across countries and regions.

Technology related transactions across countries and regions result into royalty and license fee receipts and payments. This indicator shows that how technology generating countries and regions gains from providing consultancy, turn key projects and sale and services. The analysis of royalty and license fee receipts and payments reveals that there is high degree of concentration of technology transactions in the high-income countries of the world (Table 8).

In the whole world, there were US $ 64334 million royalty receipts in the year 1998 which were increased to US $ 135278 million in the year 2006. During this period, the royalty and license fee receipts increased at 8.48 per cent per annum in the whole world. However, the royalty payments increased from US $ 61114 million to US $ 148518 million from 1998 to 2006 and the rate of growth turns out to be 9.8 per cent per annum. The share of royalty and license fee receipts of the high-income countries was 98 per cent in the year 1998 which marginally declined to 97 per cent in the year 2006. Obviously, these countries have been doing large proportion of the R&D expenditure of the global economy. But the share of royalty and license fee receipts is much higher than the total share of global expenditure incurred by these countries.

TABLE 8: TRENDS IN ROYALTY AND LICENSE FEE RECEIPTS, PAYMENTS AND HIGH-TECH EXPORTS IN THE GLOBAL ECONOMY.

Regions/ Year	Royalty & license fees receipts million $ 1998	Royalty & license fees payments million $ 1998	Gap of Receipt and Payments million $ 1998	Royalty & license fees receipts million $ 2006	Royalty & license fees payments million $ 2006	Gap of Receipt and Payments million $ 2006	High–Tech exports as per cent of manufacture exports 1998	High–Tech exports as per cent of manufacture exports 2006
Low income countries	106	688	−582	334	1,163	−829	13	06
Middle income countries	1177	6703	−5526	3,743	22,719	−18976	20	20
Lower middle income countries	395	1688	−1293	2,154	11,140	−8986	17	24
Upper middle income countries	781	5015	−4234	1,589	11,579	−9990	20	16
Low & middle income countries	1283	7391	−6108	4,077	23,882	−19805	18	20

East Asia & Pacific	330	3374	−3044	297	10,959	−10662	28	33
Europe & Central Asia	176	623	−447	1,129	5,998	−4869	09	09
Latin America & Caribbean	583	2350	−1767	753	4,146	−3393	12	12
Middle East & North Africa	73	566	−493	306	247	59	01	05
South Asia	19	206	−187	175	1,060	−885	04	04
Sub–Saharan Africa	102	273	−171	1,417	1,471	−54	–	–
High income countries	63051	53723	9328	131,201	124,636	6565	33	21
Europe (EMU)	9808	22443	−12635	23,049	44,309	−21260	15	16
World	64334	61114	3220	135,278	148,518	−13240	22	21

Source: As in Table 6.

It is significant to note that the share of royalty and license fee receipts of the low income countries was just 0.16 in the year 1998 and it marginally improve to 0.25 in the year 2006. This shows the high degree of inequality in terms of technology generation and participation of the low-income countries in the international technology related transactions. Somewhat similar trends are found in the royalty and license fee payments. The analysis of the Table 8 reveals the fact that high-income countries have net positive receipts from the international transaction of royalty and license fee payments and receipts. But most of the regions made higher payments in terms of royalty and license fee compared with the receipts. Therefore, the gap in the receipts and payments from the royalty and license fee was quite large. This clearly shows the high dependence of the developing countries for technology import from the developed countries disproportion to the innovation investment made and royalty and license fee received.

It is important to note from the analysis of the high-tech exports that are emerging from high income and low-income countries clearly showed a declining trend (table 8). This shows that industrial activities are moving from the high-income countries to other developing countries. The low-income countries could not able to receive either foreign direct investment or high-tech industries. The East Asia and Pacific countries and lower middle-income countries increased substantially the proportion of high-tech trade in the total manufacturing trade. The rise of high-tech trade in both the group of countries has been attributed essential to two factors. One, the operation of multinational corporations in these countries usually follow the practice of inter and intra-industry trade and therefore, the high-tech trade originating from developing countries may actually belong to multinational corporations manufactured goods in the developing countries (Amable, 2000 and Urata, 2001). Two, the innovation system has generated substantial innovation capabilities in the East Asian countries that have led to the rise in high-tech trade from these countries.

Internationalization of R&D and Revealed Technological Advantage:

The input-output indicators of innovations, during the recent phase of globalization, reveal that global innovations remained highly concentrated and centralized in the advanced countries. The dramatic transformation of national system of innovation across developed and developing economies in terms of shift of innovation generation activities from public to private sector has occurred. The government role seems to have been more of supportive and demand driven. The transnational corporations emerged as the dominant players in the global innovative activities. According to Reddy (2005), the development of TNCs R&D internationalization can be divided into four distinct phases. During the first phase, that is, the 1960's, the offshore R&D performed by TNC's was mainly through technology-transfer units and technical problem solving to reduce costs rather than sending R&D missions from headquarters. Second phase of internationalization of R&D by the TNCs (during the 1970's) aimed at to improve the local market share abroad through acquisition of companies and R&D was mainly adaptive in nature used for reverse engineering. The third phase of globalization of R&D in the 1980s marked the higher order R&D while establishing inter-organizational collaborations such as regional technology, global technology and corporate technology units with a view to cater to increasingly convergence of consumer preferences. This led to the rise in science and technology content in the new products, which forced TNCs to invest in R&D to remain competitive as well as legitimize the operation of TNCs abroad. The rising cost of researchers in the R&D bases at TNCs headquarters in advanced countries triggered fourth wave of R&D location abroad during the 1990s. The major aim of internationalization of R&D is to find highly developed science and technology base as well as right kind of highly skilled scientists and engineers available at low cost. There is growing tendency of the TNCs to disperse R&D bases from the headquarters to the select preferred locations in the very recent phase of globalization due mainly to the universally applicable IPRs regime. China and India were able to receive 885 R&D oriented Greenfield projects during the period 2002–2004. By the end of 2004, more than 700 foreign affiliate R&D centres had been started operations in China and more than100 TNCs had established R&D facilities in India. The choice of location of R&D bases by the TNCs have been based on the existence of strong or substantially developed national systems of innovation (UNCTAD, 2005). The leading global players of knowledge activities have recognized the innovative capability of the Asian countries and revealed in a recent UNCTAD survey their preference to locate R&D centers in Asian countries. Foreign affiliate R&D centers have been growing at a fast pace in the Asian countries. Apart from China and India, Singapore is now hosting more than hundred foreign affiliate R&D centers. China, India and Singapore have a very high degree of incidence of establishing foreign affiliate R&D centers up to 2004. The situation assessment survey has also revealed that the leading TNCs will prefer to locate R&D centers in most of the Asian countries (Table 9). China and India have emerged undisputed sites for location of foreign R&D centers between 2005 and 2009 and the 61.8 per cent of the TNCs accorded preference to China and 29.4 per cent revealed choice for India among the firms surveyed in 2004 by UNCTAD.

TABLE 9: INDICATORS OF FOREIGN FIRM INNOVATION INVESTMENT DESTINATIONS

Country	Current foreign R&D location of TNCs 2004 (per cent)	Prospective R&D location of TNCs 2005-2009
China	35.3 (3)	61.8 (1)
India	25.0 (6)	29.4 (3)
Singapore	17.6 (9)	4.4 (11)
Taiwan	5.9 (23)	4.4 (12)
Malaysia	-	2.9 (15)
South Korea	4.4 (26)	2.9 (16)
Thailand	4.4 (27)	2.9 (17)

Source: UNCTAD (2005).

Their respective global ranks are first and third. Other important Asian countries, which have been highly rated as preferred location for R&D centers by global knowledge players are Singapore (rank 11), Taiwan (rank 12), Malaysia (rank 15), South Korea (rank 16) and Thailand (rank 17) (Table 5). This is an ample proof of a well-developed innovative infrastructure facilities and conducing innovation institutional arrangements along with highly skilled innovative and low cost human capital.

The globalization of R&D was also emerged from the concern to maintain technological competitiveness of the European high-tech industry. The European Commission in the year 1982 started Framework Programme with a view to develop networking among firms, research organizations and universities and stimulate transnational linkage for locating opportunities and needs beyond their home markets.

TABLE 10:REVEALED TECHNOLOGY ADVANTAGES ACROSS INDUSTRIES AND COUNTRIES (2000-05)

Field of Technology	No. of spl	Code of Country
Electrical machinery, apparatus, energy	4	KOR, JPN, HKG, AUT
Audio-visual technology	5	JPN, HKG, NLD, KOR, SGP
Telecommunications	10	CAN, CHN, FRA, HKG, ISR, JPN, NDR, KOR, SGP, SWE
Digital communication	10	CAN, CHN, FIN, FRA, ISR, NLD, KOR, SGP, SWE, USA
Basic communication processes	8	FIN, IND, JPN, NLD, KOR, SGP, SWE, USA
Computer technology	7	FIN, ISR, JPN, NLD, KOR, SGP, USA
IT methods for management	5	AUS, IRL, JPN, SGP, USA
Semiconductors	3	JPN, KOR, SGP,
Optics	4	JPN, NLD, KOR, SGP
Measurement	11	CAN, DEU, ISR, JPN, NOR, POL, RUS, SGP, SWZ, UKR, GBR
Analysis of biological materials	20	AUS, AUT, BEL, CAN, DNK, FRA, DEU, IRL, ISR, NZL, NOR, POL, RUS, SGP, ESP, SWE, SWZ, UKR, GBR, USA
Control	11	AUS, BRA, DEU, IRL, JPN, NOR, POL, SGP, ESP, GBR, USA
Medical technology	21	AUS, BEL, BRA, CAN, CHN, DNK, FRA, DEU, IND, IRL, ISR, ITA, NLD, NOR, RUS, ESP, SWE, SWZ, UKR, GBR, USA
Organic fine chemistry	16	BEL, CHN, DNK, FRA, DEU, IND, IRL, ISR, ITA, NLD, POL, ESP, SWE, SWZ, GBR, USA
Biotechnology	20	AUS, AUT, BEL, CAN, CHN, DNK, FRA, IND, IRL, ISR, NLD, NZL, NOR, RUS, SGB, ESP, SWE, SWZ, GBR, USA

Pharmaceuticals	21	AUS, AUT, BEL, CAN, CHN, DNK, FRA, DEU, IRL, ISR, NZL, NOR, RUS, ESP, SWE, SWZ, UKR, GBR, USA
Macromolecular chemistry, polymers	8	BEL, CHN, FRA, DEU, ITA, JPN, NLD, SWZ
Food chemistry	17	AUS, BEL, BRA, CHN, DNK, IRL, ISR, ITA, NLD, NZL, NOR, POL, KOR, RUS, ESP, SWZ, UKR
Basic materials chemistry	14	BEL, BRA, CHN, DNK, DEU, IND, NLD, NOR, POL, RUS, SWZ, UKR, GBR, USA
Materials, metallurgy	14	AUS, AUT, BEL, BRA, CHN, FIN, FRA, DEU, IND, JPN, NOR, POL, RUS, UKR
Surface technology, coating	5	BEL, DEU, JPN, NOR, USA
Micro-structural and nana-technology	7	AUS, CHN, FRA, DEU, KOR, SGB, USA
Chemical engineering	23	AUS, AUT, BEL, BRA, CAN, CHN, DNK, FIN, FRA, DEU, IND, IRL, ITA, NLD, NZL, NOR, POL, RUS, ESP, SWZ, UKR, GBR, USA
Environmental technology	16	AUS, AUT, BRA, CAN, CHN, FIN, FRA, DEU, HKG, JPN, NOR, POL, KOR, RUS, ESP, UKR
Handling	18	AUS, AUT, BEL, BRA, DNK, FIN, FRA, DEU, HKG, IRL, JPN, NLD, NZL, NOR, POL, ESP, SWZ, GBR
Machine tools	16	AUT, BRA, CAN, FIN, DEU, HKG, ISR, ITA, NZL, POL, RUS, SGP, ESP, SWE, SWZ, UKR
Engines, pumps, turbines	12	AUT, BRA, CAN, DNK, FRA, DEU, ITA, JPN, NOR, POL, RUS, UKR
Textile and paper machines	8	AUS, AUT, BEL, FIN, DEU, ITA, JPN, SWZ
Other special machines	19	AUS, AUT, BEL, BRA, CAN, DNK, FRA, DEU, IRL, ISR, ITA, NLD, NZL, NOR, POL, RUS, ESP, SWZ, UKR

Thermal processes and apparatus	15	AUT, BRA, CHN, DNK, FIN, DEW, HKG, ITA, JPN, NOR, POL, KOR, RUS, ESP, UKR
Mechanical elements	15	AUT, BRA, DNK, FRA, DEU, ITA, JPN, NZL, NOR, POL, RUS, ESP, SWE, UKR, GBR
Transport	13	AUT, BRA, CAN, FRA, DEU, ITA, JPN, NOR, POL, KOR, RUS, ESP, SWE
Furniture, games	14	AUS, AUT, BRA, CAN, HKG, IRL, ITA, JPN, NZL, NOR, POL, KOR, ESP, GBR
Other consumer goods	15	AUS, AUT, BEL, BRA, CAN, CHN, FRA, HKG, IRL, ITA, NZL, POL, KOR, ESP, GBR
Civil engineering	21	AUS, AUT, BEL, BRA, CAN, CHN, DNK, FRA, DEU, IRL, ITA, NLD, NZL, NOR, POL, KOR, RUS, ESP, SWE, UKR, GBR

SOURCE: WIPO Statistics Database, July 2008.

During the period 1984 to 2002, there were five Framework Programmes initiated 43,317 new projects involving 31,345 multiple partners and 42,020 and 49,855 organizations and sub entities respectively (Roediger-Schluga and Barber, 2006). It is instructive to note that the European Commission Framework Programme remained quite stable and operational policy tool for catering to the need in search of high-tech industrial competitiveness despite the changes in the governance rules. The rise in the cost of frontier areas of research has forced even the TNCs to cooperate to establish joint R&D projects results into specializations in similar kind of new products and competitive advantage in the fast globalization of the operation of TNCs.

The patterns of revealed technological advantage across industries and countries are presented in Table 10. The revealed technological advantage is measured from patenting activity occurring during the period 2000-2005 that shows the field of technological specialization of a particular country in a particular product. The analysis of the revealed technological advantage brings out the fact that in one technology field, there are numerous countries that are possessing similar technological specialization. In the chemical engineering industry, there were as many as 23 countries showed technological specialization as revealed by the patenting activity. The pharmaceutical, civil engineering and medical technological fields show that there are 21 numbers of countries in each group possessed revealed technological advantages.

It is important to note that countries that specialized in the field of engineering, pharmaceutical and medical technologies are mainly the industrially advanced countries and the BRICS countries. Twenty countries are specializing in the technological fields of biological materials and biotechnology. The analysis of the revealed technological advantage presented in Table 10 shows that large number of countries was specializing in the same field of technologies. However, there are a very few technological field such as semiconductors where only three countries, that is, Japan, Korea and Singapore were exclusively specializing. The analysis of revealed technological advantage during the period of fast globalization shows that there seems to be high degree of concentration of specialization in the similar fields of technological specializations. This may provide empirical evidence in favour of inter and intra-industry theory of international trade. This evidence of convergence of technological specializations also shows that globalization may have effected diversity in technological trajectories.

The question of convergence of specialization across countries in the same field poses a formidable challenge to the national system of innovation during the liberalization phase for creating diversity. Even the operation of TNCs in the Asian countries and also R&D location remained highly concentrated in the field of ICT (UNCTAD, 2005). To through light on the question of whether similarity or diversity is occurring in the technological trajectories in the recent phase of globalization has put to empirical verification by Edquist and Hommen (2006). The authors have shown that revealed technological advantage were quite diverse even in the same field of technological specialization while selecting ten countries representing the Europe and the East Asia. Furthermore, it is argued by the authors on the basis of empirical evidence that national innovation system in these countries have not been converged rather have established distinctive role within an increasingly differentiated international division of labour. The East Asian countries have been able to provide institutional support to economic agents of production while extending tax subsidies, providing highly skilled manpower and network of institutional arrangements that allowed these countries to build capabilities for achieving distinctive revealed technological advantages (Singh, 2009).

Open National System of Innovation and Role of Public Policy:

National system of innovation has been evolved in the developed countries without external intervention and political pressures. Competitive edge of developed economies and of industries has been achieved with substantive public support both direct and indirect. This does not mean that developed countries have not learned from the experience of each other's during the evolution and development of national innovation system. Firms chosen to invest in other developed countries as well as formulated joint ventures to draw on the best practices of others are an ample proof of learning from each other's. Therefore, the national innovation systems have remained quite open and learning took place mainly under the framework of national technology policy.

Economic growth and competitive advantage of national economies in the post world war period remained highly dependent on public support policies (Stern, 2004). Economic agents of production have been nurtured through the support of right kind of economic incentives and institutional arrangements. Innovativeness of the economic agents of production in a national economy thus has remained also highly dependent on technology policy instruments and institutional arrangements (Yusuf, 2003). It has been widely acknowledged and recognized that the leading developed countries and industries, which are adding to the global pool of knowledge through novel innovations and maintaining competitive edge, are highly dependent on well enacted public support system in terms of instruments and institutions (Jaumotte and Pain, 2005).

On other hand, East Asian economies surged ahead in transformation process and succeeded in industrialising their economies as well as building innovation capabilities during the last quarter of the twentieth century. National innovation system is still at its stage of infancy. South Asian countries are striving to put in place the national system of innovation, which allowed its firms to be productive and competitive. However, openness in trade based on rules and regulations framed by global governance institutions have allowed in securing monopoly rights to firms, which have gained competitive edge from their respective national systems of innovation. The intellectual property rights enacted and implemented by World Trade Organisation has been increasingly being questioned both by the academic economists and governments as well as some global institutions. An interesting contribution in this regard is by the World Development Report of the World Bank 1998/1999. This report clearly identified the role of the government in developing countries to develop the capabilities to generate knowledge at home along with providing help to domestic agents of production to take advantage of the large global stock of knowledge. It is significant to note here that the United Nations Development Prorgramme (UNDP, 2001) has gone much ahead in terms of identifying the knowledge gaps existing between developed and developing countries and articulated the arguments against the strict intellectual property rights regime enacted and implemented by the World Trade Organization (WTO). Furthermore, the UNDP has not only suggested innovative and fundamental role of the governments of the developing countries in generating capabilities that matter for knowledge development but also identified knowledge as a global public good and role of international community in reducing the knowledge gaps (UNDP, 2001; and Stiglitz, 1999).

Apart from making suitable public innovation policies to strengthen national innovation systems, the government of developing countries should also strive hard to seek cooperation among themselves as well as of the international institutions and agencies to negotiate in the WTO framework. Specifically, the negotiation should be with regard to TNCs operation in their markets, for doing similar innovative investment as has been done in the home countries. It should also assess losses of domestic firms and seek compensation for using it to create innovative capabilities to strengthen innovative infrastructure at home.

Conclusions and Policy Implications:

The recent phase of globalization has dramatically reduced tariff barriers, increased flows of trade, technology and finance capital substantially. The rules and regulations governing transnational corporations have been altered to facilitate their operation across national boundaries. Even tax subsidies have been provided to attract foreign direct investment in the developing countries. All these developments have amazingly altered the development path of the developing countries from more domestic policy oriented to internationally policy driven and highly market oriented. This has led to drastically alter the economic structure of the developing economies skipping the stage of industrialization to become prematurely service sector oriented except the newly industrializing East Asian countries such as China, Malaysia and South Korea. The national innovation system has been undergoing an important structural change from predominantly public sector funded to private sector financed. The other structural change during the fast pace of globalization in the national system of innovation has occurred from fundamental research to applied and commercial oriented research. The gap of productivity and innovations remained rather substantial across countries. Global innovations in terms of input efforts and outcomes remained highly concentrated in the developed countries. There has been some evidence of reduction in concentration of innovation investment in the developed economies but the concentration and centralization was increased so far as output indicators of innovations are concerned. East Asian economies have been able not only to reduce the productivity gaps, but also have substantially contributed to reduce knowledge gaps. The growing transnational corporate R&D also remained concentrated in few activities and in a few countries. The internationalization of transnational corporations' R&D remained highly conditioned on the availability of low cost highly skilled human capital and well-developed scientific infrastructure in the developing economies. The increasing influence and operation of the TNCs in the developing economies to some extent have homogenized revealed technological advantages. This has put before the open national innovation system a formidable challenge for creating diversity and specializations across developing economies. The low-income countries remain unable to raise innovation investment intensity and even TNCs have also bypassed so far as location of R&D in these countries is concerned.

Therefore, there is urgent need to enact rules and regulations by the global institutional system to make mandatory for the TNCs to participate and develop innovation capability of the low-income countries. It is thus suggested that the international institutions when enact rules and regulations related to innovation protection and governance must keep space for public policy to allow developing countries to change their destiny. Since the profitability from protection of intellectual property rights of TNCs have dramatically improved therefore some minimum proportion of profits must be transferred for developing national innovation system in the developing countries. The over commercial orientation of the knowledge need not be allowed to reduce emphasis on the fundamental knowledge creation because fundamental knowledge generation ultimately feeds to the commercial exploitation of the knowledge. Global pool of knowledge should be strengthened while restoring faith in the public institutions and liberal financing for such long range and welfare oriented fundamental Research and Development in science and technology.

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Rabindra K. Mohanty

Globalization, E-Governance and School Education in Orissa: Challenges and Opportunities

Abstract:
This paper is a study of e-governance use in imparting mass education in the state of Orissa as it is meant for effective service delivery, better funds management, need based child tracking and transparency in data capture and dissemination process. Having discussed the concepts of globalization, e-governance and educational information management system EIMS) the dealt with the current status, governance arrangements and the basic issues related to school and mass education in Orissa in the context of globalization. The paper ends up with a suitable model building for effective implementation of e-governance in school system in Orissa.

Outlining the Objectives

Globalization as a borderless process, compresses time and space and creates a keener sense of the world as one, and so of interdependence. With it's spread, the basic education system has gone beyond their essential local character. National and local elites have given their credence to this process by accepting and incorporating them in their life styles and Government policies. Governments have placed tremendous emphasis on raising educational standards with the result that today public expenditure on education is often greater than the expenditure on any other Government activity. World Bank is one of the largest international providers of educational aids, as it recognizes education as a global right, a right to be available to all.

Enrolment rates in primary and secondary schools have risen, despite the fact that many drop out, millions children still do not go to school and even large numbers are educated in the most unsatisfactory schooling conditions. The teacher is poorly equipped, badly motivated and abysmally underpaid. Not unavailability but misuse of funds has been a major hindrance.

The great driving force behind globalization is technology, particularly telecommunication and information technology that is the information and communication revolution towards the last quarter of 20th century, which has culminated in the concept of e-governance. E-governance is a process of effective and efficient use of ICT for goal oriented governmental work output, transparent data capture and information sharing, equitable service delivery and strategic social welfare through participatory approach. E-governance is implemented in school and mass education in Orissa for effective service delivery, better funds management, and need based child tracking and transparency in data capture and dissemination. Web based services in school education in Orissa has been acknowledged by Government of India as the best and most efficient in the country.

This paper starts off with a discussion of the concepts of globalization, e-governance and educational management information system (EMIS). Then are dealt the current status, initiatives and the effect thereof with some focus on the gender dimension in Orissa in eastern India in the context of globalization. The paper ends up with a model discussing the challenges and opportunities for effective implementation of e-governance in school system in Orissa. The data base of this paper has been drawn from wide variety of secondary sources such as Books, Journals, Government Reports and officials statistics and information available in related web pages of District primary Education Programme (DPEP) and Orissa Primary Education Programme Authority (OPEPA), Bhubaneswar. Data mismatch between published reports and web resources were sorted out through personal discussion with authorities of OPEPA.

Globalization:

A great deal has been transcended today about the concept of globalization but it may help, at least as a challenge, to more easily establish what the diferentia specifica about this process is. The theoretical embedding of the concept of globalization lies in two analytical dimensions. Two analytical dimensions are: First, the distinction between distributions of people, goods and ideas worldwide, includes the comparison of their attributes (similarities, differences). Secondly, their interconnectedness on the world scale in terms of the (increasing) probability that change in one unit will affect some changes in the others.

The first point of view accounts for the widely discussed issues of homogenization and diversification; the second relates to issues of increasing autonomy and interdependency. Both of them at the same time represent the dimensions of individualization implying the strengthening of autonomous and unique actors (world citizens) in the context of the emerging world society. But uniqueness and autonomy are not alternatives to uniformity and dependency. Individualization is not an alternative to globalization. They represent a unity of opposites in the course of socio-spatial change. Homogenization of the world contradicts diversification but it is at the same time a condition for it. In order for this to be understood a distinction has to be introduced between two kinds of diversity: a) diversity on the basis of exclusion (separation) and b) diversity on the basis of inclusion (communication). Territorial diversity which was formed on the basis of exclusion or separation (like different dialects) contradicts with increasing connectedness and decreases as far as it limits the free flow of people, goods and ideas, which requires a certain underlying homogenization (EU — harmonization) world-wide. On the other hand, higher connectedness implies wider access to variety and creation of new combinations of it, thus contributing to diversification. We can thus observe both more standardization ('harmonization') as well as an increasing number of unique phenomena.

A great variety of separate observations on opposing trends of change can be better understood, like e.g. the ones concerning 'new localism'; 'the destruction of regional cultures' and 'revival of regionalism', 'the loss of national identity' and 'new nationalism' etc. (Mlinar, 1992). The old identities formed on the basis of isolation, the new ones on the basis of selective communication. The interrelation between Globalisation and universalisation is often debated. In view of this there is a misunderstanding when some sociologists call for the 'abandoning of universalism for true indigenisation' (Park 1998, 161). While the concept of globalisation has temporal and spatial parameters, universalism is a characteristic of principles which are applicable irrespective of time and place. However even universal principles are manifested and observable only in concretely defined times and places. Globalisation is an extension of the application of universal principles everywhere. But, the spread of universal principles, does not mean homogenisation, everything the same everywhere. Rather they can appear in practically limitless unique combination (Mlinar Zdravko 1997)

With regard to the interrelation between globalisation and internationalisation, the global does not entail the simple end of the nation state but rather its changing role. It is also becoming clear that it is not just a matter of relations between nations but also the growing diversity of territorial and non-territorial actors that have become independent and are linking up on a world scale. It would then be quite wrong to assume that internationalisation preserves the internally homogeneous structure of society, as exemplified by the 'billiard ball' metaphor. Internationalisation rests on relations between nations and hence on the assumption of a lower level of differentiation and individualisation than with globalisation.

There is no agreement about the definition of the term "globalization". Held et al (1999) have proposed a categorization, ordering the different theorists according to three main categories, namely the hyperglobalists, the skeptics, and the transformationalists.

The hyperglobalist approach to globalization starts with a rather broad conceptualization that globalization is a fundamental and dramatic political, social, educational and economic development. They emphasize the importance of capitalism and technology as driving forces. Implications for governance are according to this approach that the globalization processes definitely erode the power of the state. A main cause of this erosion is the mobility of transnational companies that presumably makes it hard for the state to have significantly higher taxes than neighboring countries. The historical trajectory of globalization according to this view clearly points towards a global civilization, in which nationality and geographical borders no longer have any significance. According to Held (1999:4), typical examples of hyperglobalists would be Ohmae and Strange.

Hirst, and Thompson (1999) represent the so-called skeptics. To them globalization is based primarily on economic indicators, and they accordingly see globalization mainly as a process of internationalization. When it comes to socio-economic consequences, the typical skeptic does not consider globalization such a fundamental and consequential phenomenon. Hirst claims that the major economic powers definitely have the power to exert governance — given the will. The skeptics conclude that there are still great inequalities both between and within countries, and that globalization does not have a great impact on this situation. The skeptics are rather critical towards both the concept itself and the processes it is intended to describe.

The transformationalist conceptualization of globalization appears to be situated somewhere in between the hyperglobalist and the skeptical definitions, as it is perceived as “the reordering of interregional relations and action at a distance”(Held,1999:10). In short, this is emphasizing the decreased importance of spatial dimensions, in that actions in one place have direct consequences for actors in other places. Thus, the concept is wider than the skeptics’ rather precise economic definition, but at the same time narrower than the all-encompassing definition of the hyperglobalists. However, Anthony Giddens (1999:3), employs a rather broad conceptualization and speaks of globalization as a “package of change” that covers all aspects of social, political and economic life. Concerning the causal dynamics of globalization, Held argues that this is the “the combined forces of modernity” (Ibid). As to state power and governance, the transformationalists may also be said to be less precise when saying that it is reconstituted and restructured.

E-governance

E-Governance is not only an offshoot of globalization but also a means to promote it with greater accessibility, accountability, transparency cross-sharing and interconnectedness. So E-Governance is said to be the pill of all ills of Governance. Governance is the societal synthesis of politics, policies, and programs. It is the use by government agencies of information technologies to improve and transform relations with citizens, businesses, and other arms of government. It involves making and implementing decisions, proper leadership, putting in place organizational arrangements, ensuring resources and funding, establishing accountability and measuring success. The infrastructure requirements include, telecommunications network, internal agency systems, cross-Government systems, service delivery network — access points, Internet access and skilled staff. The expected outcomes are better delivery of government services to citizens, improved interactions with business and industry, citizen empowerment through access to information and more efficient government management. The accruable benefits are increased transparency, greater convenience, reduced corruption, revenue growth and reduced cost of running government. E-Governance is not about translation of existing processes in computerized form but it is more of transformation of processes. It is not a job of IT experts but also of domain experts. Therefore in order to be successful in e-Governance we need experts who are skilled in Governance.

Orissa represents a state in eastern India with 4.7% of India's land mass and 3.58% of the population. The state is 8^{th} largest and 11^{th} most populous in the country with enormous growth potential in terms of natural and human resources. The good governance vision of Orissa aims at remodelling all the functions and organs of State Government on the basis of guiding principles such as global orientation, localized decision-making, interlinked planning, dynamic goal setting and adaptive methodology to fulfil all the needs and aspirations of the citizens. And this is what is being reiterated via the e-Government Vision of the State. The e-Government Vision aims at establishing a truly networked Government that would make it accountable and transparent.

Orissa School and Mass Education: An Overview

School education has to be a crucial area of focus if the foundation of a knowledge based society is to be built. The National and State Governments have been examining issues relating to school education for a better transformed society. Educational aspirations in the State of Orissa have been to make education available to all, contemporary and skill-centric with strong linkages to changing demands of the regional and global economies. The state desires to improve literacy levels, especially in rural areas and among socially and economically weaker sections of society by taking in to account localized contextual conditions during planning. Plans are made to increase the access, to maintain retention and to provide quality education to children in the school system as per Millennium Development Goal-2. The educational mission in the state has a definite premise that every child has a dream but more often than not it is shattered. Much to their dislike and distaste youngsters find themselves in a workplace and bonded to various situations. At a time when they should be playing they are sold into servitude. Plans are made and projects being implemented for the increasing the enrolment, retaining the enrolled and development of education of dropouts and non-school goers in the age group of six to fourteen years. The ultimate aim of e-Government Strategy has been devising ways and means of achieving the e-Government Vision, that is — reinforcing good governance and thereby contributing to the realization of economic and human development objectives of the State of Orissa. MDG 2 mandates that universal Primary Education be achieved by 2015 and in this respect; major components thus include 'Early Childhood Care Education', universalization of elementary education, reduction in school dropout rate, and promoting Sarbasiksha Abhiyan. All the aforesaid facets are brought under the system of e-governance for increasing quantity and standardizing quality to meet the requirements of globalization. The funding support for School and Mass Education in Orissa is available from World Bank, DFID, UNICEF and partly American India Foundation Trust. The Literacy rate of some of the States and Orissa's position therein can be seen from the table below:

TABLE-1
STATE LITERACY IN INDIA 1991–2001

Sl	State/UT	1991	2001
1	Orissa	49.09	63.61
2	MP	44.67	63.74
3	Kerala	89.81	90.86
4	Tamilnadu	62.66	73.45
5	Chhattisgarh	42.91	64.66
6	West Bengal	57.7	68.64
7	HP	63.86	76.48
8	Punjab	5829	69.65
9	Delhi	75.29	81.67
Source: Registrar General India (Compiled)			

Orissa appears to be a major state in India like Madhya Pradesh and Chhattishgarh who have made significant changes with regard to decadal increase in literacy rate. However Orissa has lowest literacy compared to the major states. The literacy level in Orissa at 63.61% is comparable with all-India average of 65.38%. However, there are considerable regional disparities between areas, and communities. The literacy rate of persons of seven years age and above is 63.61%. The age of seven and above is taken for this purpose because children below seven years of age are not expected to learn alphabets. Male literacy is 75.95% and female literacy is 50.97%. Among the districts, Malkangiri has the lowest literacy rate of 31.26%. Among the women, lowest literacy level is in Nabarangpur district, at 21.02%, and Malkangiri district at 21.28%. Khurda district which includes Bhubaneswar city, has the highest literacy of 80.19%. This district also has the highest female literacy of 71.06%. The high literacy figures of Khurda district is certainly influenced by the inclusion of the state capital in the statistics. Next to Khurda comes Jagatsinghpur district with 79.61% literates. Basic Facts about the School System in the state can be seen from the table below:

TABLE NO-2
BASIC FACTS ABOUT THE SCHOOL SYSTEM IN THE STATE

Facts (2006-07)	Primary	Upper Primary	Secondary/ High School
No.of Schools	46,722	16,403	7,408
Total Enrollment	44,85,000	18,17,000	13,52,000
No.of Teachers	114,105	36,392	62,030
Student Tr Ratio	39.3	49.92	21.79
Drop out Rates	General 10.53 SC 16.97 ST 22.88	General 18.05 SC 25.59 ST 32.44	General 61.00 SC 70.09 ST 74.00
Source: Economic Survey, Govt. of Orissa (Compiled)			

School system in the state comprises of Primary Schools (Class I-V) and Upper Primary Schools (Class VI–VII) and Secondary/High Schools (Class VIII-X). Primary and Upper Primary Education comes under Directorate of Elementary Education along with State Project Director, Orissa Primary Education Programme Authority (OPEPA). For the purpose of Universalization of Elementary Education in the State by 2010, a programme namely District Primary Education Programme (DPEP) was launched in the state in the year 1996-97 which is a centrally sponsored sceme with funding pattern of 85.15 between the centre and the State. High Schools are controlled by Directorate of Secondary Education along with Director of Teachers Education and State Council for Educational Research and Training (TE and SCERT). Higher Secondary (+2) Education unlike other States comes under Department of Higher Education.

Project DPEP initially operated from December 1996 to June 2003 under World Bank Assistance covering eight districts namely Bolangir, Kalahandi, Rayagada, Gajapati, Dhenkanal, Bargarh, Keonjhar and Sambalpur on the basis of low literacy rate and educational backwardness. The project cost was Rs. 229.75 crore. Subsequently, eight DPEP Extension Districts included Boudh, Kandhamal, Koraput, Malkangiri, Mayurbhanj, Nawarangpur, Nuapada and Sonepur under DFID assistance from 2001–08. The project cost was Rs. 313.80 crore. There are 46722 primary schools [class 1 to 5] and 16403 upper primary schools [up to class 7] totalling 63125 schools. This includes schools in the private sector, and non-formal schools run by village education committees and NGOs. Combined schools with teaching facilities for Primary, Upper Primary and Secondary sections have been taken as separate units. As on 2007 there are 7408 High Schools in the state.

The total enrolment in primary level [class 1 to 7] is estimated at 63.02 lakhs and the total enrolment in High schools [class VII to X] is estimated at 13.52 lakhs as per Economic Survey Report 2007–08. Student teacher ratio in the state indicates that there are 39.3 students in primary sections and 49.92 students in upper primary sections and 21.79 students in Secondary sections per teacher. But the drop out trend continues to remain alarming in the sense that higher is the class, higher is the rate of dropout. Further higher is the drop out rate among the students belonging to Scheduled Castes. Highest is the rate of drop out among the Scheduled Tribe students compared to students belonging to general and scheduled castes category.

E-governance and Orissan School Education:

District Primary Education Programme is first amongst the social sector projects in India that is being so closely monitored through a Management Information System (MIS), which now comes under the broad brand name of e-governance. DPEP, Orissa has launched their website <www.opepa.in> in 1998. This is the first website of DPEP in India. The state of Orissa has received three excellent awards for its innovations in e-governance in the school education system in the country. Internet and Intranet are the major components for successful operation of e-governance programme. Orissa has received the "Telecom Excellence Award 2006" for the most progressive state Govt. for use of IT in e-Governance through Project e-Sishu. SSA in Orissa was awarded as the best website during 10th National e-Governance conference on 3rd February 2007. Last year (2008) OPEPA received the "Prime Ministers Award for Excellence and Innovation in Public Administration". Two major parts of MIS are: Educational Management Information System (EMIS) and Project Management Information System (PMIS). The EMIS provides detail educational indicators for time series and single year down from individual school level up to the national level. EMIS relies on data from District Information System for Education (DISE) and Child Census. DISE is generated from three systems such as Geographical Information System (GIS), Education Personal Information System (EPIS) and Child Tracking System (CTS). PMIS provides intervention wise financial and physical targets and achievements of different institutions down from Village Education Committee (VEC) up to the State Project Office (SPO) level. Analysis of PMIS for the purpose of the present paper includes the projects/schemes interventions like E-sishu, Alternate and Innovative Schooling, Community Mobilization and Participation, Pedagogic Activities and Achievements, Capacity Building of Key Institutions/ Personnel, Computer Aided Education Programme and Gender Development.

District Information System for Education (DISE)

DISE is the software to connect the 30 districts in Orissa for data consolidating and sharing. OPEPA has established its own Intranet where all the district MIS units are equipped with one server each and connected to each other through VSAT connectivity using IPSTAR technology. Web based Software facility is provided for timely updation of the database at the district level. The district has been selected as a nodal point for collection, computerization, analysis and use of school level data. The system was later on extended to state and the national level. The state level EMIS cells coordinate the activities of the districts. NIEPA, New Delhi designed software for implementation at the district level and provided the necessary technical and professional support to DPEP districts. A first version of the software named as District Information System for Education (DISE) was released during the middle of 1995 with the financial assistance from UNICEF. The district level professionals were assisted in the establishment and working of EMIS units. A major emphasis was on user orientation in the use of educational and allied data for planning, management, monitoring and feedback on the DPEP interventions. The software provides a facility for school code generation, which is unique and consistent with various administrative levels. The software captures two types of information base: at the village and the school level. Village level data comprises variables related to the access to educational facilities of various types, identification of habitation without access to primary and upper primary schools based on distance norms, inventory of all types of educational institutions including recognized and unrecognized schools in the village, selected data on the number, enrolment and teachers/instructors in Non-formal Education (NFE) / Education Guarantee Scheme (EGS) and alternative schools, pre-primary education including Anganwadis and Balwadis. Data on age specific population and out of school children generated through household surveys forms part of the village data.

The core data includes school location, management, rural-urban, enrolment, buildings, equipment, teachers, incentives, medium of instruction, age-grade matrix, and children with disabilities, examination results and student flows. The data from the district to state level is transferred following multiple modes including the transfer through Internet. On-line support is built into the software. The website <www.opepa.in> provides considerable scope for sharing and dissemination of project related information. Regular chat/counselling sessions are held using electronic media. Efforts are being made to develop a network of districts and state level EMIS and provide interactivity using teleconferencing and other modern technologies. After compilation of the data; analysis of different types of educational indicators (i.e. Enrolment trend, Transition Rate, Repetition rate, Building less school, Class room requirement major repair etc) is done at the district level. The school based reports are shared with Block Resource Centre (BRC), Cluster Resource Centre (CRC), Panchayati Raj Institutions (PRI) and VEC level. Sharing workshops on the trend analysis is done at block level for the PRI members (Sarpanches/elected village leaders). DISE has been implemented in all 8-expansion districts, and funded by DFID and 8 Education for All (EFA) districts.

DISE 2001 with a better flexibility included the Upper primary schools. All the modifications and additions are made after three/ four rounds of discussion and workshops at National, Regional and State level. Suggestions were asked for and accordingly received from various levels, i.e. down from the schoolteacher up to the National Chief. Realising the need of quality, DPEP, Orissa has adopted a unique method for data collection. The Sub-inspector (SI) of Schools, Block Resource Co-ordination Centre (BRCCs), Cluster Resource Co-ordination Centre (CRCCs) and the teachers have been trained thrice, twice through Teleconferencing programme and once at the Block level training programme, about the DISE 2001. The DISE data were collected by two local educated youths per school/ village. After selecting these educated youths, they have been trained for 4 days about the data collection procedure, including two days practical at field level. These youths are collecting the Scholl level and village level data in 2days/ village, along with the CRCC of the same cluster. They are collecting the school-based information, discussing with the VEC and to crosscheck the data. The BRCC and the SI of Schools have visited some of the schools for random checking of the data. The Data Collector Youths, Schools Headmaster, CRCC, BRCC and SI of Schools countersign the data collection formats. Apart from this, the members of the District Resource Group, including the District Programme Coordinator (DPC) visit 20–30% schools (at random) for ensuring the quality of the data followed by a state level team. Finally, the DPC provides a certificate that “100% schools have been covered in DISE and all the data provided are authentic”.

Data collection, compilation, analysis and sharing of DISE data for 2007–08 are over and the same is available for use in planning for 2008–09. It is found that a substantial number of out of school children and repeaters still exist. Again, a large no. of students is also dropping out every year and there is a large number of fake enrolments. Astonishingly high repetition rates in all the districts despite no-detention policy of the State Government. Duplicate Enrolment of the children in near by school in almost all school was found where a near by National Child Labour Programme (NCLP) school exist. Fake students who are not existent physically were detected through the child data (0-14yrs) and were put to confirming the same at the VEC meetings. Re-entering of names of the students in the admission register has been done who have attained 14 years or more as 5 years child. The finding of exercise was shared with the D.I. of Schools, SI of Schools, BRCCs, CRCCs, District Project Office (DPO), State Project Office (SPO) SCERT and educational administration. The remarkable success of mass mobilization campaign can be attributed to the sharing of data with the stakeholder community. Based of the available data VECs and the School Head Masters of poor performing school were contacted by the State Project Director and District Collectors of the respective District directly through letters persuading them to take appropriate steps to bring out of school and dropped out children back to school and to improve school conditions.

Geographical Information System (GIS) for each school by latitude and longitude are integrated over digital maps to identify the exact location. Again this carries the detail infrastructural details of the schools. Education Personal Information System for each Teacher/SS on their personal information, pay roll and related court case management. The official website <www.opepa.in> carries all the information on SSA in Orissa. EPIS helps in managing the information regarding teachers and personnel involved in the elementary education system. All the above components are integrated and the outputs made web enabled to view all the three main stake holders i.e. children, teacher and school on one platform along with the State, District, Block and Gram Panchayat (GP) abstracts. The detail of a school with infrastructure, children, teachers and photographs are made available on single web page and shared to the public for their information.

Orissa Child Census — 2005: Orissa Child Census — 2005 was done to avoid the drawbacks in earlier Village level consolidated micro planning data. The major drawback of the database was that it only showed the number not the names and there was no reference date for collection of Micro Planning data. A fresh househod survey was done to collect the name of children, their enrolment status and whether they are physically disabled or not. These household wise children's' data have been computerized for all DPEP and expansion districts. The list of all out of school children (non-enrolled and dropped out) has been generated and shared with the VEC and concerned school. This out of school children data have been used for bringing back of these children. Orissa Child Census — 2005 was done to track children by their demographic, educational and physical status by tagging 52,000 revenue villages with the schools using unique EMIS Code. Around 45,000 personnel involving teachers, AW workers, VEC members, community members were engaged in data collection from around 78 lakh households through door-to-door survey during Orissa Child Census-05 using a 26 point household form.

The offices of SPO, DPOs, Department of School and Mass Education, Directorate of Elementary Education have been computerized and networked for office automation purposes. All the above offices are equipped with the DISE, Children Profile, Teachers' Profile and Geographical Information System (GIS) for quick decision-making. The SCERT, District Institute of Educational Training (DIET), District Inspector (DI) of Schools and BRCC/SI of Schools are also computerized. All the Block Resource Centres are connected with the District Project Office as well as with the State Project Office for smooth implementation and monitoring of project. The result of the Secondary Education of Orissa has been published in this website. The SPO of DPEP, Orissa has been connected to the INTERNET through 64KBPS-leased line, provided by Software Technology Park, Dept. of IT, and Govt. of India. All the DPOs are connected to the net through dial up line. Data and Mail sharing is being done through the system for a quick, economical and secured service. The Online connection of DPOs has been tested including Voice Conferencing. Software namely District Inspector of Schools Software (DISS) has also been created. This software provides adequate facility to DI of Schools regarding the Case Monitoring system, Pay Roll System, Personal Information System of Teachers as well as Staff of DI of schools, Rationalisation of teachers, Teachers transfer etc.

Project e-Sishu and Child Tracking:

Project e-Shishu was designed to achieve the three basic goals of SSA/DPEP such as 1) **Access:** By tracking the out of school children with their age and reason of being Out of school and bring them back into the mainstream education. 2) **Retention**: By tracking the In-school children and providing necessary inputs so that they continue to remain in the school and 3) **Quality of Education**: By tracking the achievement level of children and taking appropriate corrective measures. Child Tracking System (CTS) for each child from 0 to 14 years by name, sex, caste, date of birth and educational status for In-school children, status of Out of school Children and pre-school children in each individual village are managed and analysed. It has been possible to create the database of 10.5 million children (0–14yrs) using Intelligent Character Recognition (ICR) technology. Then is done the designing of CTS web based software for standardized reports available through the said website and used in the different interventions of OPEPA for implementation of SSA/DPEP activities related to school, Child and Teacher. Standard Child Code is provided to each child to track them in subsequent years. CTS data is being updated every year. Necessary innovations are done like inclusion of % of marks secured in Annual Exam of each In-school children was collected and fed to the database during validation and updating process. Linking achievement of students over a period of time in a school can measure teacher's accountability. Training modules are designed for teachers on basis of achievement level. Educational status of In-school children carries the name of the school, class, % of marks secured in last exam and attendance rate etc. Status of Out of school children carries the reason of being out of school, whether dropout or never enrolled and the present engagement of the child. Pre-school status carries the detail information of the child between 0–6 years with status of pre-schooling.

CTS data is also shared with and used by other administrative departments in the state as the base data. A Core committee is formed of the Secretaries of different departments under the Chairmanship of the Development Commissioner-cum-Additional Chief secretary, Govt. of Orissa for the use of the available data in CTS by all the concerned departments. Women and Child Development Department is using these data for the activities related to pre-school children and Mid-day meal provision for In-school children and for need based programme implementation of activities for gender and social categories. Scheduled Tribe and Scheduled Caste Development Department is using the list of tribal children for their course of action. Labour Department is using the information to identify different categories of child labours in different places. Health and Family Welfare Department is using the information for immunization and health check-up of children. Information Technology Department is coordinating the activities of these departments with provision of additional Hardware and Software supports. NGOs / Research organizations are using the information for their purpose as well.

Alternate and Innovative Schooling

In spite of huge expansion of schooling in formal and non-formal system a good number of children in the age group of 6–14 years are yet out of school. It has become a challenge for the Universalization of Elementary Education to ensure participation of a large group of children in the age group of 6–14 years who are out of school in primary and upper primary schools through opening of Alternative schools, New Primary Schools and opening of EGS and Alternate and Innovative Education (AIE) centres. Following table gives the picture of inter-district comparison of number of children out of school in the state of Orissa. Five tribal districts rank the highest in so far as the number of children out of school is concerned.

TABLE NO 3
INTER-DISTRICT COMPARISON OF NUMBER OF CHILDREN OUT OF SCHOOL

Sl No	Out of School Range	Districts
1	Upto 5000 Children	DEOGARH, SONEPUR, JHARSUGUDA, JAGATSINGHPUR, PURI, DHENKANAL, BOUDH, NAYAGARH, CUTTACK.

2	5000–10,000 Children	KANDHAMAL, KENDRAPARA, SAMBALPUR, ANGUL, JAJPUR, BARAGARH.
3	10,000–15,000 Children	KHURDHA, BOLANGIR, NUAPADA, BHADRAK, GAJAPATI .
4	15000–20,000 Children	GANJAM, BALASORE, MALKANGIRI, SUNDER-GARH, NAWARANGPUR .
5	20,000–30,000 Children	KALAHANDI, KEONJHAR, KORAPUT.
6	30,000–40,000 Children	RAYAGADA, MAYURBHANJ.

EGS and AIE was launched on 6.7.2001 in the State after closure of NFE Scheme, which could not succeed upto expectation. As of now in Govt. Sector 12870 EGS Centres have been operational out of which 11621 are primary and 1249 are upper primary schools. The enrolment figure is 367734, out of which 194257 are boys and 173477 are girls. In NGO Sector 1554 EGS Centres have been operational. The enrolment figure is 42726, out of which 22538 are boys and 20188 are girls. There are 234 AIE Centres have been operational and the enrolment figure is 9182, out of which 4387 are boys and 4795 are girls. 7769 para teachers have already been engaged through Zilla Parishad. Similarly, Village Education Committee appointed 1978 para teachers.

Almost all the 30 districts have opened the District and block level EGS Committees. District Advisory Committee, District Resource Group and Block/Cluster Resource Group have been formed. A group of 50 persons have been formed taking members from educationists, retired teachers, social activists, women activists, NGOs, Nehru Yubak Kendra etc. who are making spot visits in groups redressing complains arising out of formation of VECs and selection of Educational Volunteers (EVs). They are also receiving fresh demands submitted from people of hamlets/villages, which have not been enlisted earlier.

In addition, the programmes of tele-conferencing on Gramsat Phone-in programme in TV and AIR, Panel discussions, talks and interviews, advertisements in Media have been published in local and English papers for public awareness about the EGS and AIE.

Thus, the Scheme has been extended to every nook and corner of the State. The scheme has also been extended to neighbouring states as well. Residential Care Centers (RCCs) were operationalised to prevent migration and to retain in school children of migrant families. Total number of 8102 in-school children of migrant families of Bolangir, Baragarh and Nuapada districts retained in 232 RCCs. Mobile schools were opened for education of children at worksites of those migrated. 93 NGOs are partner in EGS and AIE Scheme. 25 Mobile Schools operationalised in Brick Kiln sites of Andhra Pradesh to address 1938 children. 35 AIE Centres functioning in Chhatisgarh (Raipur and Durg) for 2109 children. Further, 21 AIE Centres for 1283 children in and around Kolkota in West Bengal. For Oriya students in neighboring states, text books are supplied free by Orissa Government.

Researchers and educationists are unanimous with regard to the significance of ECCE for achieving universal primary education. ECCE, in general and pre-primary education in particular acquires greater importance in the context of declaring primary education a fundamental right of the child. Early Childhood Care and Adult literacy aspects are being adequately taken care of. Early Childhood Care and Education has an important place in the National Policy of Education (NPE) 1986 and the revised Plan of Action (POA 1992). The state had adopted the dual strategy of experimentation and strengthening with regard to ECCE. So far, (i) training module has been developed, (ii) Angan wadi Workers (AWWs) have been trained on preschool education, (iii) Preschool Education Kit with User's Manual has been developed and supplied to AW Centres on experimental basis, (iv) Supervision Format has been developed, tried out and supplied to districts for use by field functionaries to monitor preschool activities at AW Centres, (v) VEC/MTA have been oriented in on going programmes, and (vi) enrolment drive includes enrolment of preschoolers in AWCs. At present, 1678 numbers ECCE Centres are in operation and around 27038 numbers of children in the age group of 3–5yrs are enrolled in the ECCE Centres. 1678 numbers ECCE Instructors have been trained. Adult literacy programs are run in various districts and are at different stages of implementation. Out of 30 districts, 9 are continuing total literacy campaign [TLC]. 10 districts have approval of post literacy program [PLP]. 11 districts have completed PLP, and some of them have received sanction for Continuing Education Program. Besides, 22 residential schools and 28 camp schools have also opened enrolling 1926 adolescent girl children in the State.

Community Mobilization and Participation

In SSA/DPEP, Orissa strategies formulated to constitute and empower grassroots level community organization i.e., VEC, PTA and MTA in all the 30 districts of Orissa. These community level bodies were delegated powers, function and resource under SSA. The VECs have been participating in Civil Works, Micro Planning and School Mapping and developing School Environment and Supply of uniforms. The power of engagement of para teachers has been handed over to them under many programs, further devolution of powers to them is continuing. A VEC manual covering all VEC level activities developed and distributed. 301402 members of VEC (95%) trained this year on new training module. 3220 PRI members oriented on SSA activities. MTA formed in schools and trained on their role in enhancing girl's education. Awareness programme done through tele-conference and Radio Phone-in programme. GP education plan done with intensive participation of PTA/MTA/VEC. School display boards are in place at school points. Documentary film on exemplary VEC and MTA developed and disseminated. The name, qualification, Photograph and period of incumbency of teachers displayed in school board to ensure transparency and accountability. School display boards are in place at school points. Powers delegated to VEC for monitoring attendance and certify performance of Sikhya Sahayakas and Para teachers (Govt. resolution no 673/SME dated 10.1.2008).

VEC and MTA members are trained in two rounds on construction, community mobilization. Sharing workshops in the shape of women convention, tribal convention, Jati Mahasava are organized at district and sub-district level to promote community participation. Collectors level conference was held for sensitizing them on the importance of Universalization of primary education through community members. Besides, a large number of awareness programme have been organized through print and electronic media like newspaper advertisement, radio talks, jingles and TV talks have been conducted to create general awareness among people. To orient peoples representatives regarding their roles in

Universalizing Elementary Education. one-day training for all MLA of DPEP districts have been conducted in three phases. A series of programmes, discussions and phone-in programmes were broadcast. The Resource Groups have been formed at State, District and Sub-district level on Media and Community Mobilization. These groups have been trained and they are ready to assist in the programme as and when required, guidelines and handbooks have been prepared to organize training and orientation of stakeholders at various levels. Orientation of DIs and SIs of all the 14 Non-DPEP districts of Orissa on Sarva Shiksha Abhiyan. School Committee (VECs) are in place in all the 8 DPEP districts, 8 expansion districts and in almost all the 14 non-DPEP districts after issuance of Govt. circular on Orissa School Education (community participation) ules, 2000. To sensitize the Panchayat Raj functionaries regarding roles in universalizing elementary education, training programme for Sarpanches (elected representatives) of all Gram Panchayats of DPEP districts have been conducted and action Plans have been developed in each school.

Pedagogic Activities and Achievements

The vision of pedagogic activities is oriented towards capacity building of all teaches in position to promote active learning for all learners in the age group 6–14 irrespective of gender and social category with support of academic resource structure like DIET, BRC and CRC through effective curricular practices. First attempt made in this direction has been to create, empower and strengthen the Resource Group at State level, District level and, Block level. State Resource Group comprising 42 resourceful members were involved in planning pedagogical activities like teacher development, material production, development of textbooks and supplementary materials, learner evaluation, monitoring and providing onsite support to teachers and other resource groups. District Resource Groups has been constituted in all of the DPEP and SSA districts through a series of 2 day visioning workshop. 312 members selected as DRG members in 8 DPEP expansion districts and 833 in 22 SSA districts with specialization in different instructional fields. Block Resource Groups were located in each block of the DPEP expansion and SSA districts with 10–15 experienced teachers after exposing the participants to rigorous seven-day training programme. As on 31.03.2006 there are 3961 BRG members across the State.

The State curriculum framework prepared by the Directorate of TE and SCERT in collaboration with OPEPA and UNICEF through consultations with stakeholders at different levels. The curriculum for elementary stage i.e., for Class-I to VII renewed in line with the National Curriculum Frame Work (NCF) developed by NCERT and the draft curriculum was sent to the Director, TE and SCERT for the approval by the syllabus committee. A state level workshop was conducted during 20–22nd March, 2006 with technical support from curriculum group of NCERT and the National consultant. Based on DPEP experience 19 numbers. of Activity-based textbooks have been developed for class-I to V and are in vogue through out the state. Manuscripts for class VI text books have already been developed and to be reviewed after the finalization of curriculum in consonance with NCF-2005. Teachers' Handbooks developed for each subject from class-I to III and distributed to schools, BRCs and CRCs. Teachers' Hand Book for Class IV and for class-V are in process. State Institute of Educational Technology [SIET], Bhubaneswar, prepares audio and audio-visual aid for teaching in primary and secondary levels.

47 government secondary training schools and 13 DIETs provide training in basic teaching education called Certified Teachers [CT]. 13 institutes provide Bachelor in Education [B. Ed.] courses. A perspective training plan developed by the State for all categories of teachers — Primary, Upper Primary, Education Volunteers and SSSs/Para teachers as per SSA norm. Out of 86,166 Primary teachers in position 80,392 teachers were trained for 7 days duration during 2005–06. 46,806 teachers of Primary Level exposed to 5 day duration subject training on English during 2005-06. Module for English prepared and tried out in collaboration with ELTI. All the 21,044 Education volunteers (EVs) have undergone 30 day duration induction training during 2004-05. 1967 EVs have undergone 5 day training through another training module developed for EVs at the State Level with focus on multi-grade, multilevel situation during 2005-06.

Capacity Building of Key Institutions/ Personnel

A cell in the Directorate of TE and SCERT called Quality Enhancement Unit (QEU) created in the year 2003 to function under the direct control of the Director, TE and SCERT with funding support from OPEPA to boost SSA/DPEP activities. All 13 DIETs planning and conducting teacher training programmes of DPEP and SSA with help of DRGs and BRGs constituted at the district and block levels respectively. Faculty members of DIETs and DRCs in position oriented on different training modules. All the 75 DI of Schools declared as Additional District Project Co-ordinators for effective implementation of DPEP/SSA. Mobility support and contingency support extended to all 75 D.I.s. The offices of the D.I.s of schools computerized and D.I.s oriented on Pedagogical issues and office automation. 483 BRCCs as against 933 required engaged in 30 districts of the State. All BRCCs trained through a 6-day orientation programme at different DIETs of the state. The D.I. of Schools and the DPCs oriented on different interventions of DPEP/SSA so as to ensure quality education. Development of school plan and monitoring done basing on the data gathered through school categorization format and school supervision format. School categorization Format revised during 2005–06 with special focus on quality aspects and schools to be recategorised as per the revised format during 2006–07. DIET-BRC-CRC linkage made functional for effective pedagogical monitoring. DIETs involved in formulating the Pedagogical plan of the district. Educational Quality Improvement Programme (EQUIP) was launched in the State with technical support of DFID to upgrade the Quality of learning across the State. Quality school Programme experimentally introduced in collaboration with UNICEF, Orissa in 10 blocks of puri, Ganjam and Koraput districts to ensure quality education at the primay level. Under this programme, Learning Continuum Resource-based educational ladder introduced from class-I in 1010 schools during 2006-07 academic session.

District Level Shishu Mela is also organized in district headquarters with joint initiative of C.I., D.I. and DPC each year. Identification and nurturing of young talents. Sishu Prativa Utsav (SPU) organized annually during November in collaboration with UNICEF, Orissa Office, Directorate of Elementary Education and Directorate of TE and SCERT, Director SIET to identify and nurture young talents. District Level Shishu Mela was also organized in district headquarters with joint initiative of C.I., D.I. and DPC during 2004-05 and 2005-06.

Sharing of good practices:

Tele-conference programmes conducted in regular intervals to share the good practices all over the State with BRCCs, CRCCs, SIs, DRGs and DIET faculty members.

The component of Learners' Evaluation was streamlined. The Common Annual Primary School Examination was introduced w.e.f. 2002 out of SSA funds. The districts were empowered to have their own question sets to conduct the examination. The question setters oriented on new pattern of evaluation so as to make the evaluation continuous and comprehensive. Achievement of learners of each class in each subject mapped and documented subject wise and class wise across gender. Results of Common Annual Examination (CAE) shared with parents through PTA meetings. The results of the Unit tests, half-yearly examination and Annual Examination to be analysed critically on quarterly basis from 2006-07 to ensure quality of learning through NCERT tool by incorporating additional variables like social category and Children with Special Needs (CWSN).

Computer Aided Education Programme

The Sarva Shiksha Abhiyan (SSA), the national programme for universalisation of elementary education has correctly incorporated "EDUCATION FOR LIFE" as one of the major objectives. The need of Computer Aided Education arises, even at elementary level, for empowering the children to welcome and face the future with smile and confidence. Further objectives included making learning effective and interesting and to generate supplementary materials in digitized from with help of graphics, animation, voice etc. There was a need to bridge the digital gap between children of public schools and government schools, rural schools and urban schools. Under this scheme Biju Pattanaik Computer Aided Education Programme (BiCEP) was launched in 5th September 2004 at 600 schools of elementary level and Digital EqualizerProgramme(DE) launched in the year 2004 in 10 schools of secondary level.

Effective learning of children through multi media content CDs have been developed and supplied to the 600 Upper Primary Schools covered under BiCEP. 67 content and competency based CDs covering different subjects (Language-Oriya and English, Math, G. Science, S. Science and Co-curricular activities) supplied to BiCEP schools.

Content CDs in Santali language has been developed and supplied to schools. CDs in Soura language is in process. Validation of another ten scripts of Azim Premji Foundation has been completed and CD development is in process. A teacher hand book on BiCEP developed and shared with the teachers during training. A core team of 22 members from diverse background were oriented on Computer Aided Education. District Core Team (DCT) (District Pedagogy Coordinator, programmer and one selected teacher) oriented on BiCEP. Another 3-day orientation of the DCT proposed during 2006–07. Two teachers from each BiCEP school trained on — "Computer Operation and CD viewing". 2-day orientation of teachers on classroom transaction through multimedia CD and one day orientation of HMs of BiCEP schools is in process. An Innovative project named as "Evolving Demonstrable Model on Computer Aided Learning" has been approved to be implemented in 60 schools of Nayagarh district on a pilot basis during 2008–09.

Digital Equalizer Programme is a project under American Indian Foundation (AIF) Trust. The former President of USA, Bill Clinton is the Honorary Chairman of the AIF Trust. AIF Trust is a charitable trust, set up in India. AIFT has proposed to expand the use of Computers and Networking technology in education sector. American Indian Foundation's Digital Equalizer (DE) programme is one of the foundation's flagship programmes, whose aim is to enhance students' learning by using information connection technology in order to improve the quality of education in schools. This would in turn, enable the students to participate in the technologically advanced global economy. As a part of their programme, AIF Trust is running Digital Equalizer Programme in selected High Schools of Orissa. The first phase of DE Programme had started from the year 2004 in 6 High Schools of Bhubaneswar & 4 High Schools in Angul districts. 56 more High Schools has been selected in different districts to implement the next phase of DE programme in the state.

Gender Dimension

The new millennium has brought in new perspectives and challenges of development. One of the major indicators of development is education. Girls have emerged as an important focus group of the education programmes. Their educational backwardness has not only denied them in reaching their fullest potential, but has also slowed down the pace of national development with regard to education as well as other developmental Programme. Basic issues pertaining to girls education in Orissa nay in the country have been Low participation of girls in school, inappropriate schedule, lack of girl child friendly curriculum, lack of lady teachers or teachers are not gender sensitive, low performance and Competence level of girls in school, communities are not aware about the importance of girl's education and girls engaged in domestic activities and sibling care. However, as per 2001 Population Census, the rural female literacy rate in Orissa is less than national average. Following Figure gives a picture of rural-urban and gender differences with regard to literacy rate in the state. A difference between rural and urban is not only heavy but also the same between male and female is abysmally high.

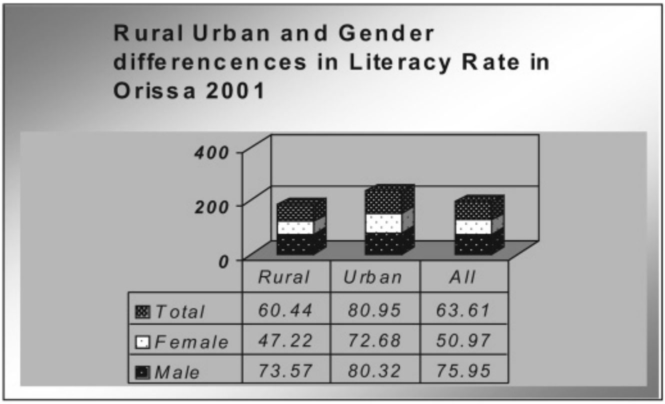

Figure 1

Keeping the above issues in view, several activities were undertaken for the development of girls' education in the sate. These activities included Distribution of School Uniforms, Personality Development Camp and vocational training, Remedial teaching including bridge course, Teachers Training on Gender Sensitivity and Community Mobilisation with MTA training.

24,12,343 Girls from Class I to VII have been provided with School Uniform in 2007 through the VEC, MTA and PTA members involving Local Members of Legislative Assembly, PRI members and local Officers. The distribution of School Uniform and the system of mid-day meals has led to improvement in the attendance rate of the Girls. Interest has been generated among the Parents and the Girl Children towards school System. Personality development camp has been organized in Puri, Nayagarh, Bhadrak, Jagatsingpur, Jajpur and Kendrapara district where more than 2000 girl child has received training on various aspects YOGA, Life skill education, Puppetry, Handicraft, Tailoring and Greetings Card making, preparation of pickle, papad and *buddy*. Girls have been provided with Information regarding Police, Postal and banking Transaction, Health and Hygiene. Besides Various competitions like Song, General Knowledge, Essay, Debate, Antakshari, Fancy-dress etc were held. These camps created awareness about their Rights, information on Postal and Banking Transactions, Health and hygiene etc. Exploration of various hidden talents among the girls through different Competitions could be possible.

Remedial Teaching has been conducted in various Schools for low achiever Girls.in Nayagarh and Bhadrak district covering more than two hundred children which resulted in improvement of competency level of the students in different subjects and improvement in the attendance rate of the low achiever Girls and prevented them from dropping out of the Schooling System. For mainstreaming of overage, dropout and never enrolled Girls 89 number of Bridge Course Centers have been opened in Sundergarh, Kendrapara, Ganjam and Balasore district with a total enrollment of 1556 girl child. To make the Classroom Girl Child Friendly and reduce the gender biasness from the School Environment, two days Training have been imparted on Gender Sensitization through Module (Sikha) where twenty fife thousand six hundred fifty teachers have been trained for improvement in the participation of Girls in Co-curricular and class room activities.

To motivate the community towards Girls Education Different Activities undertaken like girls club formation, Street Play, Pala, Daskathia, Puppet Show, Video Show on Gender issues, Mothers Rally, PRI training, Interactive session of Mothers and Girls etc.

Further actions included development and distribution of posters, pamphlets, Brochures on importance of Girls Education. 46891 MTA were constituted in 30 districts of Orissa and the members received training in Orissa regarding their role and function in promoting girls education (enrolment, retention and enhancement of quality education). Activities being undertaken by MTA regarding involvement in school activities included Green fencing, plantation and Gardening, Development of corpus fund, Telling story in off period, Serving Mid-day meal to schoolchildren and Beautification of school building (Co lour, wall painting, Putting information board, wall magazine). These members were actively involved in different school functions. (Ganesh puja, Saraswatipuja, Independence day, Republic day). Health camp for in schoolgirls has been conducted in various districts to create awareness regarding health. Involvement of MTA members in outside school activities included Community Mobilization, Identification of out of schoolgirls, Enrolment of girls in school, checking drug abuse in tribal pockets and Distribution of books and dress.

In addition to the above initiatives, there are two other major schemes such as National Programme for Education of Girls at the Elementary Level (NPEGEL) and Kasturba Gandhi Balika Vidyalaya (KGBV) in operation in the state. NPEGEL was launched in the sate in November 2003 and is implemented in 27 districts comprising 189 educationally backward blocks as on 2007. Similarly Kasturba Gandhi Balika Vidyalaya (KGBV) is a Government of India scheme for setting up residential schools with boarding facilities for out of school girls belonging to SC, ST, OBC and minority girls in the state. Total number of 114 KGBVs were sanctioned and opened till 2007 in which 9736 number of Girls were enrolled. Out of the above girls students enrolled there are 2359 number of SC, 4828 number of ST, 2108 number of OBC, 303 number of BPL, 21 number of Muslim and 117 number are of others category.

Challenges and Policy Implications

In the backdrop of above analysis and discussion, it has now been imperative to size up the implications in order. The e-governance system in the school education has made a remarkable success as is evidenced from three excellent awards for best website in the country and effective child tracking, received from government of India during last three consecutive years. Global aid and international assistance have brought in the desired result in EMIS and PMIS not only at the process level but also at its outcome aspects, more so in the context of Elementary Education in the state of Orissa. In primary education, focus has been shifted to activity-based teaching, so that the students become more interested and have less fear of school, and the teachers are also motivated. In fact the process aspect suggests that with e-Governance the service delivery paradigm in school education system of Government is fast changing. It is now possible to make a before and after division between Governance of the Past and that at Present. The past Governance is now e-Governance. The Departmental Centric Approach has given way to a People Centric Approach. The implicit Process Orientation has been replaced by a Service Orientation with accountability. Output based Assessment of the past is now seen with Outcome based Assessment. A Closed and Restricted View is reversed by an Open and Integrated View. That which was secluded with Implicit Secrecy is now on Network exhibiting explicit transparency. The following table compares the past and present paradigms.

TABLE-4
GOVERNANCE PAST AND PRESENT

Governance	e-Governance
Departmental Centric Approach	People Centric Approach
Process Orientation implicit	Service Orientation with accountability
Output based Assessment	Outcome based Assessment
Closed and Restricted View	Open and Integrated View
Secluded	Networked
Implicit Secrecy	Explicit Transparency

However this e-Governance project in school education has not been an unmixed blessing and hence facing bottlenecks at the process level. As on 2006 out of total 46,989 villages in the state only 38,044 villages have been electrified (Economic Survey 2007–

08, p.11/10) creating problems for implementation of e-governance in school system in 8945 villages. Hardware setup in some districts is not updated as yet. Problems in room, equipments and Hardware setup at DI offices are the main hurdles in districts for implementing EPIS. This has resulted in data capture and filtration towards core data. A minor data mismatch was fond between published reports and web pages of OPEPA. Usual explanation was the website has not been updated. In fact most parts were fond updated. Data available in Annual report of OPEPA even does not match with report of Economic Survey especially about number of schools. Some streamlining is necessary and it can be done by OPEPA.

There are local language issues in some cases and lack of planning for tribal languages in others. All citizens bear the opportunity of introducing an e-Governance initiative. Again amongst the complete population there is only a fraction of population who have access to internet; there is still a smaller fraction that is skilled to use internet; there is further a smaller fraction which is using are using internet for Government services. Thus any e-Governance application is not for a small fraction of population and therefore the need is to ensure such delivery channels universally accessible. Further the online services which are designed are made so sophisticated that they become inaccessible to the common man. Besides the population in villages may be provided with the Internet Kiosks for community access to e-Governance. Service improvement and process efficiency are key objectives of e-Governance under the collaboration of various organs of the Government through Partnerships with the private sector. The goals must be clearly defined and the performance should be measured against those goals.

At the level of outcome, whatever success achieved at the elementary school level is due to unstinted efforts made by OPEPA team in the state through funding support from global funding support and international aid for the projects/schemes interventions like E-sishu, Alternate and Innovative Schooling, Community Mobilization and Participation, Pedagogic Activities and Achievements, Capacity Building of Key Institutions/ Personnel, Computer Aided Education Programme and Gender Development. In the absence of similar support for high school education, the secondary sections, Sanskrit teaching and minority schools tend to go neglected. Inadequacies in building infrastructure, equipments, road communication and electricity needs have not been properly addressed. At the level of outcome, the challenges are clear and vivid. The drop out rate is higher at higher classes. Data shows a declining drop out trend but the overall rate is very alarming. Higher is the drop out rate among the students belonging to Scheduled Castes and the same is highest among Scheduled Tribe students compared to students belonging to general and scheduled castes category. E-governance for secondary schools is yet to be implemented and the process has just begun. The picture on rural-urban and gender differences with regard to literacy rate in the state has been and continues to be another grave challenge. The difference between rural and urban when compared is not only heavy but also the same between male and female is abysmally high.

Thus both the process and the out come aspects need to be appropriately challenged for success and sustainability of e-governance in the globalizing world. All the components of the system such as school system, the environment, funds management, DBMS and IDS system need to co-ordinate among themselves at both intra and inter-departmental levels in such a manner that challenges discussed above can be best met. Accordingly a model is suggested below (Figure-2) for such desired success and sustainability.

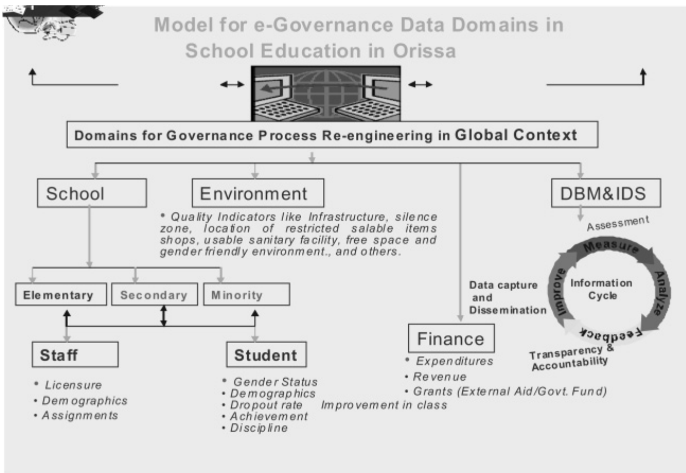

Figure 2

In the model above, the picture one male and female indicates a gender sensitive approach in the Global School Governance model. The group of men and women in the line 2 indicates that there is enthusiasm, consent and support from public for the participation and partnership in the implementation of governance process. Our planning is to involve the stakeholders in the process of bridging the digital divide so that the scope for participatory approach and community ownership of responsibility will be more visible in a networked environment.

In the school domain aspect, the model speaks loudly about the aspects of donor caring as most of the funding coming for elementary education programme to the utter neglect of High School and the minority education especially the Madrasas. The model desires to Empower Parents, Teachers, Children, Media to take transparent, accountable initiatives to further strengthen the hidden force of educational empowerment and to further the step ahead. Equal care and opportunities are to be made available to all sections of school education for a sustainable future.

The role of the staff and student in different sections of school system are to be set in proper perspective. **Licensure** refers to the granting of a license, which gives a 'permission to practice' honestly and diligently. Periodic checking of para teachers and sikhsa sahayaks be done and the headmasters of schools be sensitized so that duplication and engagement of unrecognized substitute teachers can be avoided. Corruptions in mid-day meal system is matter of empirical curiosity. The staff demography indicates there should be a strategic action to appoint and post the teachers in the own district schools to teach students so that this may have an impact on the morals and motivation of teachers to continue in a particular school which is not far away from her/his own districts. The cost effectiveness of the living habitat and the cultural barriers cum adaptability to the environment can accordingly be addressed. On the other hand it will go a long way in improving the performance of a teacher. Assignments indicate course curriculum that a teacher took as classroom deliverables and the indicator also focus on the aspects of the number of subjects a teacher is assigned for teaching per day and the duration of his/her assignment in a day. This is a yard stick for measuring work burden. So it indicates the quality parameters for allowing a teacher to teach to a particular class of students and to pursue specializations.

Gender dynamics is asked under student aspect to signify the particular aspect of girl child education ratio as a matter of concern. On student demographic aspects trans-migration due to parental transfer, distance of the school from the student's house, language barrier, cultural barrier and other aspects can be best addressed. The higher drop out rates at secondary level needs to be appropriately addressed. Information Empowerment will provide a platform to reflect the need base analysis and the role of perspective funding agencies, State, District, Block, Panchayat , Ward level Govt. machinery & Public at large to have a common interface in Education Empowerment & Development. On achievement front the students performance, national standard, state standard, district standards is best judged so that there is every chances to negotiate with donors/funding partners to take advance action plan. Discipline is a case of observation of student's performance on the aspect of their behavior, development of their capacities, their internal strength and academic performance, development of spirit of cooperation, participation and nationalism. E-governance may be extended to high school education and strategic planning be made for reducing drop outs and to reduce disparities at rural-urban and gender aspects.

With e-Governance the other important aspect is e-Readiness. The priority for is to build e-Readiness in following areas like Infrastructure, Institution, Laws, Leadership and commitment and Human capacities. Environment domain says about both external and internal environment which is accepted as basic standard to carry out a model school for successful running and what is the current standard so what kind of initiatives can be taken to improve the school can be judged. Intra and Inter-departmental coordination necessary for arranging building infrastructure, equipments, provision of electricity, road communication, usable sanitary facility, free space and a silence zone, establishment of restricted salable items shops, and gender friendly environment.

The finance domain clearly indicates the supply and demand aspects of a particular school and the gap in between. It demands that international aids and assistance be extended to high school system as well for bringing out quality product, to ensure employability through vocationalization and to check drop out rate and gender disparities. State Government must negotiate with to promote competition and investment opportunities from different agencies.

The DBM&IDS part clearly speak of governance, data management and data dissemination aspects. Multiple point data capturing and one point data analysis, reflection or hoisting and multiple point data dissemination in the E- Governance as a flat system in the school education in Orissa has given rise to some problems about core data and feeding the same to central data processing unit (use of artificial intelligence to the data channel/ core data) for authentication resulting in data mismatch. There is lack of coordination between inter & intra departmental system in the absence e-networking among the departments. So a centralized DBMS is the only hope to short out the current problem of DATA CORRECTNESS and data authentication for achieving the projected outcome to meet the national and international standards.

Thus the key issues for e-governance in school education system in Orissa require to be addressed through interoperability and standardization. Interoperability includes a design of integrated service delivery sites for capturing the data in Web-based form and processing and sharing in common format at various sections, projects, district level bodies and interdepartmental levels. Standardization is necessary not only in respect of technologies and infrastructure but also for other key issues relating to delivery of services in the school education system in Orissa.

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SOCIO-POLITICAL IMPLICATIONS OF INTELLECTUAL PROPERTY RIGHTS (IPR)

Sambit Mallick

Changing Protocols of IPRs and Scientific Practices in the Age of Liberalization: The Case of Plant Molecular Biology in India

Abstract:

This paper examines the actual and potential impacts on developing countries such as India of the global trend towards a stronger protection of intellectual property rights, and captures the changing scientific practices, cognitive and political, in the wake of this new institutional regime. Interdisciplinary and inter-institutional collaborative networking in the area of plant molecular biology has become the hallmark of the Intellectual Property Rights (IPRs) regime. As research in plant molecular biology has potential for attaining patents, the practitioners seem to reorient their approach towards their own research vis-a-vis the protocols enshrined in the IPRs. The plant molecular biologists located in various institutional settings in India seem to be engaged in collaborative networking with the industry. As a corollary, we witness a shift from science as a public resource to science as an intellectual property. The present study, through in-depth personal interviews with sixty-eight plant molecular biologists in India, attempts to capture the transition in scientific practices reflected in the attitudes, interests, values and ideologies of the scientific community in India. The scientific community[1] in India is confronted with the dialectic of resistance and accommodation under the stringent norms of IPRs regime dictated by liberalization of India's economy.

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[1] When I use the term, "scientific community", I do so keeping the problematic of the term in mind. The problematic of the term, "scientific community" lies in the fact that the scientific community not only in India but also beyond no longer possesses shared perspectives, meanings, values, common interests, attitudes, goals, ideas, institutional frameworks, ideologies, etc. Further, the problematic of this term has shaped my understanding to examine the issues related to the emergent policy structure and also forced me to look at the other broader issues involved. Nevertheless, it is beyond the scope of this paper to critically engage in mapping out the debates on the theoretical contours of the term, "scientific community".

Today developing countries, as a whole, and, India, in particular, are rapidly experiencing changes in scientific research and the associated practices in the new institutional regime. This new institutional regime is marked by the Intellectual Property Rights (IPRs) of the World Trade Organization (WTO). The IPRs regime is something, which is not just influencing the economic context of science and technology but has also brought about a new set of interests and values, which tend to transform the social institution of science and the research system. The advancement of systematic knowledge, prominence attached to open publications to claim priority, high premium placed on professional rewards and constitution of peer groups from the discipline-based scientific elite, which remained the hallmark of academic science and governed the scientific communities in the post-World War II era, is undergoing changes. Putting it succinctly, not only the conventional "ethos of science" outlined by Robert K. Merton (1973) but also the scientific community as the "paradigm-bound community" sketched by Thomas S. Kuhn [1970 (1962)] are getting challenged in the wake of the emerging situation, which is evident in the works of Etzkowitz and Webster (1995), Gaillard, Krishna and Waast (1997), Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow (1994), Ziman (1996), etc.

Against this backdrop, the aim of this paper is to reflect on the key dimensions of the IPRs regime that influence scientific research in India and the subsequent response of the scientific community in India engaged in research in plant molecular biology. To be specific, the objectives of this paper are to:

(1) Assess the changes in the attitudes, values and practices associated with research in the changing institutional context, and, as a corollary, changes in research thrust in plant molecular biology in Indian universities after adopting the principles of the WTO;

(2) Examine the patterns of collaboration between plant molecular biologists in universities, on one hand, and, scientists in other R&D institutions — both public and private, on the other;

(3) Look at the institutional mechanisms that have been created and/or are likely to be evolved to enable the plant molecular biologists to re-orient their approach towards research in the changed and changing contexts of knowledge production (in the larger context of liberalization of India's economy).

This paper draws on a range of sociological analyses that have explored the culture of scientific research reflected in the changing conceptualization of relations between basic and applied sciences — their controversial effects, emphasis on scientific collaboration, gap between laboratory and field based research, and finally the problematic of science — policy boundaries. The study is based on in-depth personal interviews with 68 scientists located in different institutional settings (24) in India engaged in research in plant molecular biology. Different institutional settings refer to universities — central, deemed, state and agricultural, research institutes — the Council of Scientific and Industrial Research (CSIR)-sponsored and the Indian Council of Agricultural Research (ICAR)-sponsored, and mission-mode organizations. A brief profile would suffice here. The field study spanned from 2005 to 2007.

TABLE I SCIENTISTS ENGAGED IN RESEARCH IN PLANT MOLECULAR BIOLOGY INTERVIEWED (2005-07) FROM DIFFERENT UNIVERSITIES AND SCIENTIFIC INSTITUTES IN INDIA

Name of the institute	Number of scientists interviewed
New Delhi	**20**
University of Delhi, South Campus, Delhi	5
Jawaharlal Nehru University, New Delhi	3
Guru Gobind Singh Indraprastha University, Delhi	5
Indian Agricultural Research Institute, New Delhi	3
International Centre for Genetic Engineering and Biotechnology, New Delhi	2
National Centre for Plant Genome Research, New Delhi	2
Kolkata	2
Bose Institute, Kolkata	2
Cuttack	7
Central Rice Research Institute, Cuttack	7

Bhubaneswar	1
Orissa University of Agriculture and Technology, Bhubaneswar	1
Chennai	10
University of Madras, Chennai	2
Anna University, Chennai	2
Indian Institute of Technology, Madras	2
MS Swaminathan Research Foundation, Chennai	4
Madurai	6
Madurai Kamaraj University, Madurai	6
Vellore	3
Vellore Institute of Technology, Vellore	3
Pune	5
University of Pune, Pune	1
National Chemical Laboratory, Pune	2
Agharkar Research Institute, Pune	2
Bangalore	3
Indian Institute of Science, Bangalore	2
University of Agricultural Sciences, Bangalore	1
Hyderabad	11
University of Hyderabad, Hyderabad	4
Osmania University, Hyderabad	2
Directorate of Rice Research, Hyderabad	3
Centre for Cellular and Molecular Biology, Hyderabad	2
Total	68

Different universities and research institutes can be classified as follows:

International	
Public:	1
Private:	–
National	
Public	
Universities	
Central Universities:	3
Deemed Universities:	2
State Universities:	6
Institutes of National Importance:	1
Mission-oriented Research Institutes/ Organisations	
CSIR-sponsored Research Institutes:	4
ICAR-sponsored Research Institutes:	6
Private (Foundation):	1

I.A.: 1. International Centre for Genetic Engineering and Biotechnology, New Delhi

II.A.a.i: 1. University of Delhi, Delhi
2. Jawaharlal Nehru University, New Delhi
3. University of Hyderabad, Hyderabad

II.A.a.ii: 1. Indian Institute of Science, Bangalore
2. Vellore Institute of Technology, Vellore

II.A.a.iii: 1. Guru Gobind Singh Indraprastha University, Delhi
2. Osmania University, Hyderabad
3. University of Madras, Chennai
4. Anna University, Chennai
5. Madurai Kamaraj University, Madurai
6. University of Pune, Pune

II.A.b.: 1. Indian Institute of Technology Madras, Chennai

II.A.c.i: 1. National Centre for Plant Genome Research, New Delhi
2. Bose Institute, Kolkata
3. National Chemical Laboratory, Pune
4. Centre for Cellular and Molecular Biology, Hyderabad

II.A.c.ii: 1. Indian Agricultural Research Institute, New Delhi
2. Central Rice Research Institute, Cuttack
3. Orissa University of Agriculture and Technology, Bhubaneswar
4. Directorate of Rice Research, Hyderabad
5. Agharkar Research Institute, Pune
6. University of Agricultural Sciences, Bangalore

II.B.: 1. M.S. Swaminathan Research Foundation, Chennai

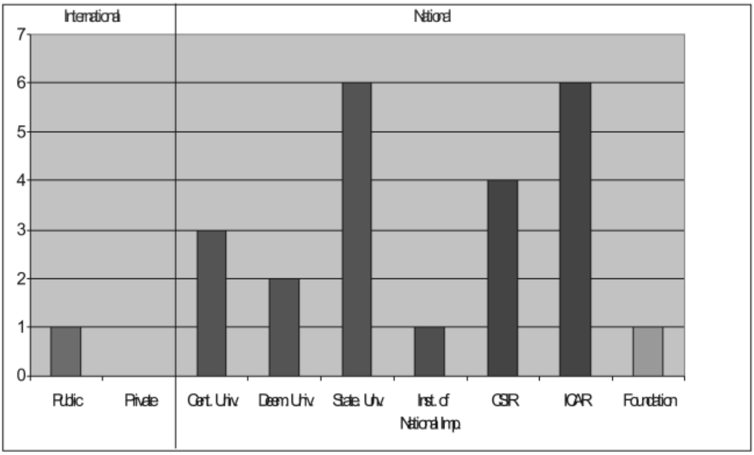

Figure I **Nature of Universities and Research Institutes in India visited**

Abbreviations:
Cent. Univ.: Central Universities; Deem. Univ.: Deemed Universities; State. Univ.: State Universities; Inst. of National Imp.: Institutes of National Importance; CSIR: Council of Scientific and Industrial Research-sponsored research institutes; ICAR: Indian Council of Agricultural Research-sponsored research institutes

Scientists in India interviewed are affiliated to:

I. International

A. Public:

2

B. Private:

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II. National

A. Public

a. Universities

(i) Central Universities:

12

(ii) Deemed Universities:

5

(iii) State Universities:

18

b. Institutes of National Importance:

2

c. Mission-oriented Research Institutes/ Organisations

(i) CSIR-sponsored Research Institutes: 8

(ii) ICAR-sponsored Research Institutes: 17

B. Private (Foundation): 4

Total number of scientists interviewed: 68

The Structure of Scientific Collaboration Networks

A social network is a collection of people, each of whom is acquainted with some subset of the others (Newman 2001: 404). Such a network can be represented as a set of points (or vertices) denoting people, joined in pairs by lines (or edges) denoting acquaintance. One could, in principle, construct the social network for a company or firm, for a school or university, or for any other community up to and including the entire world. Social networks have been the subject of both empirical and theoretical study in the social sciences since 1950s (Wasserman and Faust 1994; Watts 1999; and Scott 2000), partly because of inherent interest in the patterns of human interaction, but also because their structure has important implications for the production of knowledge. It is clear, for example, that variation in just the average number of acquaintances that individuals have (also called the average degree of the network) might substantially influence at the level of policy framework.

In science studies, Derek J. de Solla Price (1963: 77, 79) was the first to notice that scientific collaboration “has been increasing steadily and ever more rapidly since the beginning of the [twentieth] century", a process he deemed "one of the most violent transitions that can be measured in recent trends of scientific manpower and literature", surmising that "if it continues at the present rate, by 1980 the single-author will be extinct". The consequences he saw were more extensive and enduring than a mere shift in the practices or work habits of scientists:

We tend now to communicate person to person instead of paper to paper. In the most active areas we diffuse knowledge through collaboration. Through select groups we seek prestige and the recognition of ourselves by our peers as approved and worthy collaborating colleagues. We publish for the small group, forcing the pace as fast as it will go in a process that will force it harder yet. Only secondarily, with the inertia born of tradition, do we publish for the world at large (Price 1963: 80).

This powerful transformation of scientific practices continues in ways and with consequences that Price did not anticipate. Collaborators today communicate from different continents and cultures, synchronously or asynchronously, in the languages of different nations and disciplines, through a spectrum of technologies, using diverse forms of expertise to produce heterogeneous mixes of knowledge, products and solutions to problems (Walsh and Maloney 2002). The "select group" that grants "prestige and recognition" accomplishes its collective purposes despite centrifugal forces. The published productivity of the group may not differ in quantity from that of an equal number of dissociated individuals, so the impetus to collaborate lies elsewhere[2]. In this context, Olson and Olson (2002) put it thus:

The best technology must be complemented by activities that build trust and understanding through sustained, face-to-face social interaction. Tensions and paradoxes are essential features of collaboration, even within established, co-located research groups, so the mere occurrence of face-to-face interaction does not insure that understanding and solidarity will result.

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[2] Price (1963: 79) thought that groups were part of the accumulative advantage process in science, allowing high-publishers to publish even more by gathering the fractional contributions of marginal performers into a publication.

Now it would be pertinent to begin our inquiry into the nature of scientific collaboration with the fundamental questions: What is collaboration? Why collaborate? These questions have elicited complicated and qualified answers. ‘Collaboration is a family of purposeful working relationship between two or more people, groups, organizations. Collaborations form to share expertise, credibility, material and technical resources, symbolic and social capital’ (see Katz and Martin 1997; Maienschein 1997). The more emergent issues include: how do collaborations work? How productive are they? What is collaboration becoming? What is driving the transformation? Hackett (2005) proposes that the landscape of scientific collaboration is changing in the following ways.

(a) *Social organization*: traditional small research groups are now complemented by episodic working groups; contractual agreements between organizations; international collaborations that strive to span the North-South divide; interactions amongst scientists, engineers, commercial ventures, and the university offices and experts that broker such agreements (Owen-Smith 2005).

(b) *Intellectual content and cultural reach*: interdisciplinary research has been rising for more than a decade, spurred by science policy and by the rising prevalence of fundamental research that engages practical ends (Stokes 1997).

(c) *Technologies of collaboration*: the “invisible college” concerning oxidative phosphorylation described by Price (1963) was fueled by a mailing list through which researchers working in the area circulated manuscripts. Today, e-journals, websites, digital libraries, blogs, collaboratories, and other applications of scientific cyber infrastructure accelerate research communication, with consequences for the process and products of research that are coming into focus.

(d) *Understandings of collaboration*: studies on collaboration that once equated it with co-authorship and explained it as a direct consequence of specialization and access to research technologies have been supplanted by a distinction between collaboration and co-authorship, concern about the inherent paradoxes or tensions of collaboration, attention to the importance of place for the conduct of science (Gieryn 2002; Henke 2000), and awareness that scientists, students of science, and decision-makers are all embedded in scientific research and science policy.

In conceptual terms, these differences are the dimensions that describe the transformation of collaboration (Hackett 2005): (a) *extent*, measured as a distribution over substantive, social, or geographic space, or over time; (b) *intensity*, measured as the frequency or significance of interaction among persons, places, or units of time; (c) *substance*, or the aims and content of collaborative work, which now include producing fundamental knowledge, developing technologies, guiding decisions, making things, training, and bonding; (d) *heterogeneity*, or the variety of participants, purposes, languages (ethnic, national, disciplinary, sectoral), and modalities of collaboration (face-to-face, electronically mediated in various ways, and episodic); (e) *velocity*, or the rate at which results are produced, analyzed, interpreted, and published; (f) *formality*, ranging from contractual arrangements among nations or organizations to handshake agreements and unstated understandings among friends and acquaintances.

In light of this, it is pertinent to capture how there is a growing consensus of the fact that innovation is the result of a coupling between science and technology components, on the one hand, and, market forces, on the other (Callon, *et al.* 1991). And, this relationship between science and technology, and market forces has significant implications for many developing countries including India. The scientific community in India, by and large, is of the opinion that given the lack of appropriate economic structures that could organically generate such linkages, the State requires to intervene and mediate to induce linkages between the full-time laboratories, universities, industry and the market. Science and technology policy mechanisms could be structured in such a way as to create networking programmes at the meso or science agency level, targeted to specific result-oriented tasks, for example, alternative fuels and developing new molecules for drugs. Different interest groups, from market to university, have become partners with financial stakes, and the State is expected to underwrite the risks, if any, in the initial stages. Universities or the academic sector in India can assume a significant part of the professionalization of scientific communities, PhD training, oriented basic research and forging innovation links with the government and industry, which would also entail *reorganization of scientific communities in* *terms of "hybrid" groups and research programmes* (according to a scientist at the Jawaharlal Nehru University, New Delhi). In light of this, it is desirable that India must take the form of networking. Of course, it depends on the specific context. Such networking strategies in research in India play a major role in responding to the ongoing market challenges. Nevertheless, one should also recognize that there is no single model of type to benefit from networking strategies. As Krishna, Waast and Gaillard (2000: 214) put it:

The ongoing penetration of commercial and industrial interests into academic and non-academic research settings has not only resulted in the loss of autonomy, but catalyzed different work cultures, styles of research, behaviours and goal orientations to coexist not necessarily in single physical environment but on single research programme dispersed across a wide range of organizations [institutions] in a networking mode of interaction and work. Such research programmes are constituted by multidisciplinary teams often cutting across scientific disciplinary boundaries, extending to social and human sciences (research programmes on energy and environment are good examples).

There is an increasing emphasis on scientific collaboration cutting across disciplines and institutions in India engaged in research in plant molecular biology. Furthermore, the study focuses on the nature of funding (both national and international), as reflected by the scientists' account of the support of funding bodies to their work. The funding agencies, through interdisciplinary and inter-institutional collaboration, insist on concrete deliverables from the relatively big-budget projects sponsored. As a corollary, changes in the institutional mechanisms have significant implications for the practice of science — in terms of scientific collaboration, the role of 'boundary organizations' (Guston 1999: 90) to provide a space where common languages and ways of talking across the two domains of science and politics can be created, to bring together the different stakeholders (scientists, regulators, bureaucrats and decision-makers, and so on) working in these different domains, and to dwell in the interstitial spaces between these social worlds — broadly speaking, of science and policy respectively — yet they carve out distinct lines of responsibility and accountability to each one. In light of this, it would be quite apt to quote a scientist from the Guru Gobind Singh

Indraprastha University, New Delhi who reflected upon the changing axis of scientific research in terms of interdisciplinary and inter-institutional collaboration in his research:

Since last two and a half years, I have been working with a theoretical physicist in the University of Delhi or metabolic modeling. I am also working on a collaborative project under the CSIR with Dr. Beena Pillai, Institute of Genomics Centre and Integrative Biology, New Delhi to use gene chip technology to study nitrate responsive genes in plants. Both of these collaborators are outside our university — one is from a university (University of Delhi) and another, from a CSIR-sponsored institute (Institute of Genomics Centre and Integrative Biology, New Delhi). I also have one informal collaboration for bioinformatics with a plant molecular biologist from the Centre for Biotechnology, Jawaharlal Nehru University, New Delhi. We are communicating that research now. I also got a collaborative project with the All India Institute of Medical Sciences (AIIMS), New Delhi for genetic diagnosis in which we have some expertise in real time PCR, and they wanted to use our expertise. But, that is still pending for ethical clearance in the Ministry of Health, Government of India because it involves human subjects. Even though much of my published research till date is to do with plants or cyro bacteria, the tools and techniques, and the expertise that we have developed is as useful in medical research, is as useful in theoretical research — that is what I mean by growth of science in the interface of disciplines. I can imagine a pediatrician from the AIIMS, New Delhi approaching a plant biologist for collaboration on pre-natal genetic diagnosis or a theoretical physicist approaching a plant scientist for metabolic modeling. My international collaboration has been largely a fallout of a visit abroad where I did a piece of work, which itself is an extension of what I am doing here. So, when I came back, I brought back here some tools and resources related to that work, and I am continuing that work here. This was when I went on a Royal Society Fellowship to the UK (a bilateral programme between the Government of India and the UK in 2001). In 2000, I went on a detour for a conference to work out the preliminary details of this collaboration. Then, I came back and applied for this fellowship and got it. And, in 2001, actually I went to the UK to carry out the collaboration. This was a very short summer trip for three months. When I came back, I brought back some of these tools and training. And, I am, in fact, continuing in that area now. So, some initial part of the publication that may come out of this work will be published as a collaborative output. But, whatever we are able to continue here will be our own contribution in that area.

As a scientist from the Madurai Kamaraj University, Madurai puts it:

I have been involved in network projects where joint authorship is being encouraged. We brought materials from Germany by which we can bring about new things to the society. I was also engaged in a DRDO-sponsored project, titled: Development of EST Data Base and Characterization of important genes. Very often our research gets funded by only national funding bodies whereas so many people drawn from the natural sciences, engineering, humanities and social sciences come together to common platform to solve the real-world problems of the society.

Similarly, the concern for scientific collaboration has also been raised at various fora — conferences such as Guha Research Conference, workshops, government bodies like the Council of Scientific and Industrial Research, the Department of Science and Technology, the Department of Biotechnology, the Indian Council of Agricultural Research, etc. Reflecting on his own experiences as a potential collaborator vis-a-vis collaborators from other disciplines and institutions and funding agencies, a scientist from the University of Delhi, South Campus goes down the memory lane:

Collaboration started with this: a need has been felt by the scientists through conferences, thought processes and interactions. We usually do have meetings to formulate projects and submit the research proposals to the respective governments in the case of international research projects. In the case of India, national funding bodies like the DBT, DST, ICAR and CSIR do support our kind of research. In fact, as part of our collaboration, some time back, the Rockefeller Foundation sponsored a project on rice and rice genome.

Both national and international collaborative projects have been supporting the research of the scientific community in India, besides the infrastructural facilities that their respective institutions are providing. Apart from the government bodies supporting research of the scientific community in India, today industry also has started playing a key role, as industry-sponsored research projects are relatively big-budget projects and they aim at concrete deliverables within stipulated period of time. Nevertheless, with the entry of industry along with government and academia into undertaking research projects has raised several ethical questions because industry usually gets its products patented, which goes beyond the reach of developing countries, as a whole, and, India, in particular. Despite the initial ambivalence, scientists, especially drawn from the northern, western and southern parts of India, gets accustomed to the protocols of the IPRs. On the other hand, scientists drawn from the eastern region of India, particularly Kolkata (West Bengal) and Cuttack (Orissa), still remain one of the fiercest critiques to the IPRs regime. It does not imply that there are no differences of opinions about the IPRs regime among the scientists of a specific region or institute. Though majority of the scientists in the northern region welcome the ushering in of the IPRs regime and subsequently they can mark the changing structure of science in India, a particular scientist from the Guru Gobind Singh Indraprastha University, New Delhi anticipates problems relating to patenting or commercializing the inventions or industry playing a dominant role in scientific collaboration:

We have consulted a few patenting lawyers to know the legal domain of patenting a product in the Indian context. I teach a course on the Intellectual Property Rights. I am aware of the importance of patenting, whether or not we may use it for any monopoly, patenting is necessary to exclude others from practicing inventions. It is not necessary for you to practice or patent inventions. When I exclude others from practicing it or patenting it, I can still license it free to people who want to use it. So, patenting is a negative right. I am fully aware of it. At a university research using public funds, we might sometimes use these patents as a pre-emptive technique to prevent industry from monopolizing that kind of innovations, and to make that research more affordable and available to the public, at large. Or, I might even decide to license it to the industry, if I push into that kind of economic compulsions to support my research or my career. These are the realities of the age in which we live.

But, as of today, I am not pursuing that as a goal, but we are aware of it.

Bases of Scientific Collaboration

Scientific collaboration can be successful, provided there is a combination of factors contributing to its formation. The collaboration among scientists in research activity has become the norm (Beaver and Rosen 1979). The increasingly interdisciplinary, complex and expensive characteristics of modern science encourage scientists to get involved in collaborative research. Complementarities of expertise, sharing materials for research, physical assets and nature of funding bodies determine the basis of scientific collaboration. Funding agencies, particularly government agencies, facilitate active research collaboration as part of their funding conditions. For example, the CSIR, the DST, the DBT, the ICAR, etc. have initiated many technology transfer policies that enhance interaction among researchers throughout R&D organizations. In particular, some technology programmes require inter-organizational collaboration for funding and research.

Nevertheless, the benefits of collaboration are more often assumed than investigated, despite the ubiquitous nature of collaboration in science. Most studies on collaboration include an underlying assumption that collaborative activity increases research productivity (Lotka 1926; Price and Beaver 1966; Zuckerman 1967; Godin and Gingras 2000). Many collaborations centre on the joint use of expensive or unique equipment without which research would be not only less productive but also impossible (Meadows 1974; Thorsteinsdottir 2000). In the age of "triple-helix science", some research seems to require collaboration to bring about special expertise and knowledge not otherwise available but crucial to research outcomes. As mentioned in the first paper, the triple-helix model is not confined to a single discipline. Rather, it is transdisciplinary, reaching across multiple disciplines and institutional settings. It involves the close interaction of many actors throughout the more reflexive process of knowledge production, resulting in a more socially accountable production of knowledge. In many cases, what is found from a variety of universities and research institutions in India that collaboration is the key mechanism to mentor graduate students and post-doctoral researchers and enhance the productivity of individual scientists.

However, sometimes the fact that researchers and policy-makers "perceive" that collaboration increases productivity does not make it so. Indeed, a few scientists reflect upon as to why collaboration may undermine productivity. Transaction costs are usually an unavoidable consequence of working with others. Staying in touch with various media or stringent bureaucratic procedures, engaging in social ingratiation, awaiting others to comment, respond, or do their part of research — these are some of the factors taking time and energy even in the best collaborative relationships. As a scientist from the Bose Institute, Kolkata puts it:

Most active collaborators have had projects that were never finished or that had disappointing results because one or more of the collaborators did not live up to expectations. Many researchers, especially senior researchers, collaborate not so much to increase their own productivity as to mentor graduate students and post-doctoral researchers. While such collaboration is likely to enhance the productivity of some parties, others are likely to be a drag on the productivity of the more experienced researchers; to the latter, therefore, this may represent a "tithe" given voluntarily.

Scientific collaboration in India is more often international in character in the case of CSIR-sponsored institutes and mission-oriented organizations. On the contrary, the ICAR-sponsored institutes and universities undertake mostly national collaborative research projects. Nevertheless, there is an increasing number international collaborative research projects in universities. But, universities at present are not at par with CSIR-sponsored institutes and mission-oriented organizations. Perhaps, the organizational set-up of each of these institutes determines the nature of scientific collaboration — whether it be national or international. By organizational set-up, I mean different institutional settings have outlined different norms for undertaking research. Further, individual scientists play a crucial role in undertaking big-budget projects sponsored. As a scientist from the M.S. Swaminathan Research Foundation, Chennai emphatically notes:

The bases of collaboration are two-fold: (a) potential of the scientists; (b) as a corollary, the demands of the agriculture institutes (problems related to agriculture). To be precise, I would like to mention that complementarities of expertise as well as challenging problems related to agriculture and agriculture institutes like the NARS have become the bases of my collaboration *always* [italics added].

A scientist from the Centre for Plant Molecular Biology, Osmania University, Hyderabad expresses in the similar fashion:

Everything [complementarities of expertise, sharing of materials for research and physical assets] is required including funding to pursue research in the area of crop biotechnology. Today research in this area is very expensive. So, funding is needed definitely. But, it is not just the funding — actually, in the university, I say at least my perception is in the university system the research what we have taken up at least in India — if you see all over the country — it is not that commanding, I would say, in general. I do not say that there are no good laboratories. There are, of course, good laboratories, but at least in general, I am trying to address this problem. Now at least, the universities should focus on, say, I have taken a PhD student — he may not be able to turn out with a wonderful thesis where the research will lead to discovery. But, at least, now we are exposing [the student] to the research area — how really it should be done and what are the basic techniques that the student really requires to learn and the expertise s/he can get, and those are the things we have inculcated — the research interests in the student. Once s/he joins a national laboratory or some other institute, s/he will able to turn out good. Basically, what we are trying to do is that we are taking their energy and talent, and we are trying to motivate them and give the required skill by which they can pursue research in a better way using their talent and depending upon the situations where they land up. But, per se, when I train a student, really, I feel very happy because at least, what the job that is assigned to us, we are doing something. But, from this kind of effort, if we find something new, then it is good and special. Most of the time, the monotonous things are happening. That is the reality of the day.

Dwelling upon bases of collaborative research projects, a scientist from the Guru Gobind Singh Indraprastha University, New Delhi mentions:

In terms of how we really start identifying collaborators, we are more driven by the idea. So, in order to carry out our ideas, if we know somebody who has a specialized resource, like I am looking for a mutant which somebody else has developed for some other purpose, but I need that mutant to answer any questions. I enter into a collaboration with him. I can access that mutant. I work with it or I bring it back to me, and thereby we keep continuing these things. So, for me, collaboration is of two types: one, collaboration in which I find people who contribute to my ideas, to the execution of my ideas where I am at the centre of the collaboration, in a way. The other kind of collaboration is where I am peripheral to somebody else's central ideas. That, I published two papers with a colleague of mine at the University of Mumbai less than five years ago. She does clinical biochemistry research dealing with diabetic in laboratory animals, rats, chemically induced diabetic in rats. She works in enzyme levels ultration that happened in diabetic rats. Since I am molecular biology expertise, she wanted to find out, if I can help her in addressing the same questions at the gene level. So, I got into a tie-help; I trained her students to carry out this work. We planned out some of the gene level work and it came out, and two papers have been published jointly on changes that happen in anti-oxygen enzymes as well as their genes in diabetic rats. So, the enzyme part was done by her and the gene part was done by me. But, the whole interest of working on clinical biochemistry of diabetic was hers, not mine. So, she was centre to the collaboration and I was peripheral. I was contributing technology and she was contributing the core ideas. Thus, I have been more successful so far as a peripheral contributor to somebody else's core ideas, both in terms of the pubic research on diabetic as well as public research in metabolic modeling, which theoretical physicists do. My own collaborations where I have got collaborators to my own areas, these are inherently slower because the research work has been built up since last couple of years and the published outcome is yet to come. In this sense, I have been a collaborator on both sides where I am at the centre of the collaboration as well as at the periphery of the collaboration. And, where I have been at the periphery of the collaboration, they have all been non-plant scientists — it has just somehow happened, it is more of a chance. Also, my own collaborators, where I am at the centre, are non-plant scientists. In a sense, one can say that I have somehow got better grips in expertise in plant research. So, areas which are beyond plant sciences are required I take their help, except the one collaboration on mutant plants from the UK — that person was a plant person and other persons were not plant persons. That was the only plant based collaboration and all other collaborators of mine not essentially plant scientists, but they contribute specialized skills into my collaboration.

Now it becomes clear that complementarities of expertise along with sharing of materials for research, physical assets and nature of funding *a la* determine the bases of scientific collaboration. However, sometimes scientists do want to collaborate, if their goals and ideologies do not match. As a scientist from the National Centre for Plant Genome Research, New Delhi puts it:

Whichever collaborative project I have undertaken, I have undertaken collaboration in the form of 1:1. Nothing can force me to collaborate. Whenever my work needs collaboration or when I complement to my work or when I feel that individually alone, I cannot handle it, or sometimes for the sake of good scientific results, I go for undertaking collaborative research projects. At this stage, I need not identify any collaborator, as I have always Professor Asis Dutta here at the NCPGR with me to help me out as and when required. For collaborative research, the research goals and ideologies need to be similar between the collaborating partners in our kind of research in plant molecular biology. In this era, independent work or working without collaborative efforts rarely brings out interdisciplinary output. That is why we these days go for collaboration. But, for the sake of productive scientific results, our objectives and goals should be common so that we can bring about novelty in our research.

I have always prioritized complementarities of expertise and material for research as the basis of my collaboration. These two factors are extremely important in today's science. Professor Asis Dutta has expertise on biochemistry, plant sciences and nutritional genomics. And, my collaboration with him has reached the stage of plant molecular biology. My students are also extremely bright in collaborating with me, and our collaboration has resulted in several novel things that have been applied to own patent.

Problematic of Scientific Collaboration

In this context, the problematic of the conceptualization and measurement of collaboration requires to be foregrounded. More specifically, does one focus on the productivity increments related to particular scientific outputs, such as publications, or take a much broader view of increments to scientific capacity? And, if one examines increments in the capacity to do scientific work, does one focus on the individual, the research group, or some concepts of a scientific field? We have to consider the impact of collaboration strategies on "scientific and technical human capital" (Bozeman, *et al.* 2001; Bozeman and Rogers 2002). Scientific and technical human capital is the sum of scientific, technical and social knowledge, skills and resources embodied in a particular individual (scientist). It is both human capital endowments such as formal education and training, and social relations and network ties that bind scientists and the users of science together. Scientific and technical human capital is the unique set of resources that the individual brings to her/his own work and to collaborative efforts. Scientific and technical human capital can be understood at the level of the individual scientist or research group, and it is possible to measure the individual scientist's training, skills and even tacit knowledge, as mentioned above in the excerpts from the interviews with the scientists engaged in research in plant molecular biology cutting across institutional settings. Further, it is possible to measure the individual scientist's ties to networks and transactions with others in those networks.

Examining collaboration from the standpoint of a multi-level scientific and human capital model shows that productivity implications are part and parcel of the analytic focus. Thus, for example, any particular collaboration may be a productivity decrement for specific individuals but a productivity increment for a field, educational cohort, or "knowledge value collective" (Lee and Bozeman 2005). As a scientist from the Indian Institute of Science, Bangalore puts it:

A senior researcher choosing to collaborate with a graduate student may, from one perspective, not be making the most productive use of her/his time. Working alone or with another senior scholar would perhaps result in equal or higher quality achieved in less time. But, the same activity may be quite productive from the standpoint of the work group or the scientific field, because the collaboration is likely to lead to greater increment in scientific and human capital than would work performed alone.

Nevertheless, funding in India is not so lucrative today so far as basic research is concerned. Perhaps, the decision-making bodies and the scientific elite in the country tend to lose sight of the essence of pursuing research in basic sciences. As a scientist from the Central Rice Research Institute, Cuttack mentions:

For basic research, funding bodies are less. If I go for or if there is a chance for patent or if there is a chance of business-oriented activities having commercial potential, in such cases, funding organizations are more. So, that is what is. Then, basically, most of the time we want our quick results or quick reputation. So, we do not want to put much of our time on these things [basic sciences]. That is another reason. Then, we go for certain international programmes. Sometimes we do specific research. People are often interested in participating in these activities. Certain research as such is not very much important — you are not doing something preliminary activity or extra-ordinary thing, or others have done it and you are doing just a routine type of job because of other interests, say for money or foreign tour or other things, etc. So, that is one reason. These are the basic reasons for this, I feel. But, some of the people are there who crave for basic research. However, the problem of basic research is that you may not get success. After putting a huge amount of labour, you may not be able to succeed. ... Very often do I not get the necessary funding from the funding organizations, as more and more basic components have characterized my research thrust. The less I reflect upon the nature and functioning of funding agencies to support basic research, the better. I do not want to be drawn into unnecessary and avoidable troubles by disclosing everything before you. Today the scientific community in India has to devote its time, energy and money for basic research, if it wants India to be a leader in scientific achievements in the world. Having said this, I do not intend to say that there should not be any support for applied research. Obviously, more and more funding should come in support of applied research. However, the scientific community in India cannot afford to lose sight of the domain of basic research.

Reduction in the budget for pursuing research in basic sciences is also quite evident, if we have a look at the Data Book, Government of India, Ministry of Science and Technology, Department of Science and Technology, New Delhi (March 2004). Table 4.1 indicates the trend in cuts in the budget for pursuing research in basic sciences as compared to applied sciences.

TABLE II GOVERNMENT EXPENDITURE ON BASIC RESEARCH AVERAGE ANNUAL RATE OF CHANGE

Average Annual Rate of Change (%)						
Current Prices				**Constant Prices**		
Period	Central Govern-ment	State Govern-ments	Total Govern-ment	Central Govern-ment	State Govern-ments	Govern-ment
				Base: 1993–94		
1980-81 to 1985-86	18.15	37.28	19.59	41.01	26.67	10.34
1985-86 to 1990-91	23.69	14.3	22.77	60.1	5.16	12.96
1990-91 to 1995-96	9.38	11.46	9.55	-0.71	1.18	-0.56
1995-96 to 1998-99	16.43	13.12	16.13	8.44	5.36	8.16

Source: Data Book, Department of Science and Technology, Ministry of Science and Technology, Government of India (March 2004)

Note: 1. Central (Federal) Government excluding Public Sector Industry

2. Government = Central Government excluding Public Sector Industry + State Governments

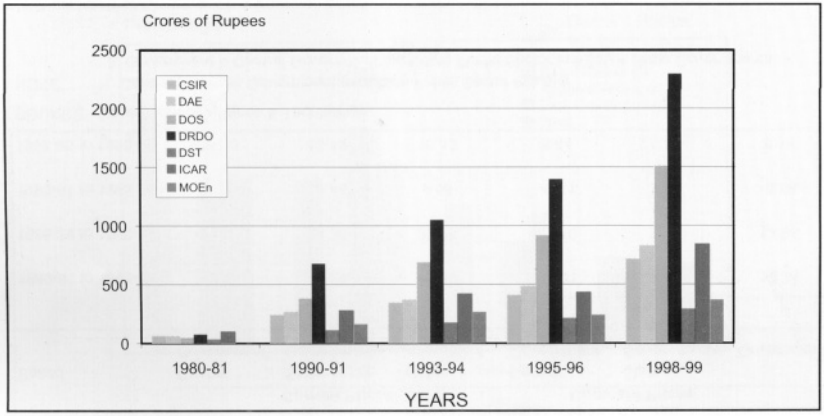

Figure II Central Government Research and Development Expenditure by Selected Scientific Agencies

Source: Data Book (2004), New Delhi: Department of Science and Technology.

TABLE III NATIONAL EXPENDITURE ON RESEARCH AND DEVELOPMENT (R&D) AND RELATED SCIENCE AND TECHNOLOGY (S&T) ACTIVITIES (1998–1999)
(CRORES OF RUPEES)

Expenditure on			
Sector	**R&D**	**Related S&T**	**S&T**
Central Government	8055.02 (62.5)	680.15 (74.1)	8735.17 (63.2)
State Governments	1026.54 (8)	237.42 (25.9)	1263.96 (9.2)
Public Sector Industry	651.01 (5)	–	651.01 (4.7)
Private Sector Industry	2790.41 (21.6)	–	2790.41 (20.2)
Higher Education	378.56 (2.9)	–	378.56 (2.7)
Total	**12901.54 (100)**	**917.57 (100)**	**13819.11 (100)**

Source: Data Book (March 2004), New Delhi: Department of Science and Technology.

Note: S&T Expenditure = R&D Expenditure + Related S&T Expenditure

TABLE IV NATIONAL EXPENDITURE ON RESEARCH AND DEVELOPMENT (R&D) AT CURRENT PRICES FOR SELECTED COUNTRIES
(MILLIONS OF US DOLLARS)

Country	Current Prices							
Australia	1795.2 (1981)	1918.6 (1985)	2176.5 (1986)	2483.1 (1987)	3271.2 (1988)	3972 (1990)	4750.2 (1992)	5351.7 (1994)
Canada	4783.9 (1985)	8244.2 (1990)	8000 (1991)	8510 (1992)	8795.8 (1994)	9005.8 (1995)	9211.1 (1996)	10136.6 (1999)
Japan	27126 (1981)	30233.6 (1983)	37269.6 (1985)	68007.7 (1987)	82930.7 (1988)	102231 (1991)	109248.8 (1998)	Not estimated henceforth
Germany	16970 (1981)	16652.2 (1983)	16820.3 (1985)	31853.6 (1987)	33974 (1989)	46413.2 (1993)	Not estimated henceforth	Not estimated henceforth
France	11494.4 (1981)	11788.2 (1985)	16352.9 (1986)	20190.3 (1987)	21929 (1988)	28907 (1991)	31621.6 (1994)	Not estimated henceforth
UK	11890 (1981)	9974.2 (1983)	10165.8 (1985)	12870.8 (1986)	18873.5 (1989)	20998 (1991)	20733.1 (1993)	25711.9 (1998)
US	63810 (1980)	116796 (1985)	139255 (1988)	164493 (1992)	169100 (1994)	193206 (1996)	205742 (1997)	244143 (1999)
India	1596.7 (1984)	1979.1 (1986)	2405.2 (1988)	2270.4 (1990)	1930.8 (1992)	2172.4 (1994)	2349.3 (1996)	3066.7* (1998)
Israel	680.5 (1981)	800.7 (1982)	1005.4 (1983)	772.8 (1985)	1017.1 (1989)	1152.5 (1990)	1489.7 (1992)	1940.2 (1995)
Pakistan	250 (1982)	230.7 (1983)	273 (1984)	263.7 (1985)	315.3 (1986)	320.8 (1987)	Not estimated henceforth	Not estimated henceforth
Republic of Korea	348.6 (1980)	1327.7 (1983)	1327.7 (1985)	4195.7 (1989)	4733.1 (1990)	5670.5 (1991)	6391 (1992)	9826.1 (1994)
Brazil	1150 (1978)	1459.1 (1982)	1168 (1983)	802.3 (1984)	869.4 (1985)	Not estimated henceforth	Not estimated henceforth	Not estimated henceforth
Nigeria	183 (1983)	129.9 (1984)	92.8 (1985)	45.8 (1986)	21.5 (1987)	Not estimated henceforth	Not estimated henceforth	Not estimated henceforth
Philippines	82.9 (1980)	46.3 (1983)	36.7 (1984)	75.4 (1989)	68.1 (1990)	71.6 (1991)	115.3 (1992)	Not estimated henceforth

Source: 1. Statistical Yearbook, UNESCO (2002).

2. Data Book (March 2004), New Delhi: Department of Science and Technology.

3. World Science Report 1998, UNESCO.

4. Science and Engineering Indicators, National Science Foundation.

Note: 1. Figures in brackets indicate year.

2. * The data relate to the financial year 1998–99. Source for exchange rate is Economic Survey, 2000–01.

3. Canada — data do not include humanities and social sciences; from 1975, these are only excluded from the productive sector (integrated R&D).

4. Japan — not including data humanities and social sciences in the productive sector (integrated R&D).

5. Germany — data prior to 1991 refer to FRG. For 1985 and 1987, total expenditure includes respectively 470, 615, 330 and 664 million DM for which a distribution between current and capital expenditure is not available.

Not including humanities and social sciences in the productive sector.

6. UK — for 1981, 1985 and 1989, data do not include funds for R&D performed abroad.

Not including data for humanities and social sciences, except for 1989.

7. US — not including data for law, humanities and education. Total expenditure does not include capital expenditure in the productive sector. In 1980, capital expenditure for R&D in private non-profit organisations is excluded.

8. Republic of Korea — not including Military and Defence R&D. Data for 1980 exclude law, humanities and education; from 1981, not including humanities and social sciences.

9. Brazil — not including private productive enterprises.

10. Nigeria — data relate only to 23 out of 26 national research institutes under the Federal Ministry of Science and Technology

11. Pakistan — humanities and social sciences in the higher education and general service sectors and not included. Not including Military and Defence R&D.

12. Israel — not including data for humanities and law financed by the universities current budgets.

13. Philippines — not including private non-profit organisations in 1980.

14. Available data for various years for different countries are reported.

15. Conversion of national currency into US $ is based on Statistical Yearbooks (1998), UNESCO.

Table IV depicts the national expenditure on Research and Development (R&D) at current prices for selected countries — both developed and developing. The CSIR, established in 1942, had no independent laboratories worth mentioning till Independence, but by the 1950s, a network of fifteen national laboratories in the physical, chemical, engineering and biological sciences was created chiefly due to the efforts of Bhatnagar and the support he received from Nehru. This development is known as the "Nehru-Bhatnagar effect". By 1997, there were about thirty-five national laboratories under the umbrella of CSIR involved in various S&T areas. From a small number of 100 R&D personnel in 1947, the CSIR had grown to 2,000 in the 1960s and to 6,000 in the 1980s.

The New Institutional Structure of Scientific Research

This paper aims to understand how scientists encounter the science — policy boundaries in the ordinary course of doing their research. It aims to provoke scientists to reflect as openly as possible on their own experiences of, and engagement in, policy-making domains. These scientists sometimes refer to institutions that mediate between policy- or decision-makers and scientists; these are called "boundary organizations" in social studies of science (for instance, Guston 1999) but given their proper names and acronyms by scientists. Empirical evidence suggests that there are often occasions when such boundary organizations remain absent from the drawing up of contracts, agreements and the negotiation of research boundaries at the science — policy interface.

The present study attempts to gain a picture not only of the ways in which research and policy-making domains are inter-connected, indeed quite densely so in some cases, but also of the presence and absence of boundary organizations as mediators of the science — policy boundaries experienced by scientists themselves. The purpose of this paper, however, is not to investigate one or several boundary organization(s). Rather, it is to gain some perspective on the way that the scientific community in India encounters the kinds of science — policy relationships that these boundary organizations are supposed to address. In this context, the sociologically significant questions include: What are scientists' experiences of the science — policy interface, both as individual scientists and research group? As a corollary, are boundary organizations important mediators of this interface?

Before dwelling upon the study and its findings in detail, it will be useful to explore briefly the concept of "boundary organizations" and the way they are thought to achieve a mediating role between science and politics. Early research on boundary organizations characterized them as somewhat useful and much needed new institutional forms, bringing with them the possibility, at least, of "stabilizing the potential chaos of the science — politics boundary"

(Guston 1999: 90). They are expected to perform at least three important functions in a political and technological climate in which scientific, commercial, regulatory and public domains are becoming increasingly inter-connected (see Jacob and Hellstrom 2000; Slaughter and Rhoades 1996; Shorret, *et al.* 2003; Webster 1994; Ziman 1994):

They provide a space where common languages and ways of talking across the two domains of science and politics can be created;

They bring together the different parties (scientists, regulators, bureaucrats and decision makers, and so on) working in these different domains;

They dwell in the interstitial spaces between these social worlds — broadly speaking, of science and policy respectively — yet they carve out distinct lines of responsibility and accountability to each one (Guston 1999: 93; 2001: 401).

The boundary organizations are expected to ward off the perceived threats of politicized or over-commercialized research and strive to monitor imbalances and misunderstandings in relationships between researchers and those sponsoring research (Waterton 2005: 436). The concept of "boundary organization" can be seen *relevant to other cultural and institutional settings* (from the interview with a scientist at the Vellore Institute of Technology, Vellore)[3]. In India, for example, we might characterize as boundary organizations the grant review boards of some research councils, the research and technology transfer offices within universities, and certain departments and offices within the Government of India (for instance, the Centre of Scientific and Industrial Research, the Department of Science and Technology, the Department of Biotechnology, etc.). All these bodies perform at least three functions deemed characteristic of boundary objects outlined above.

The present study argues that boundary organizations are proliferating in India, as the issues societies face in scientific, technological, economic and social terms pose challenges that neither "science" nor "policy" can address in isolation. We can also observe even greater degree of proliferation of boundary organizations in the

[3] See, for example, the special issue of *Science, technology and human values*, Volume 26, No. 4 (autumn 2001) on 'Boundary organizations in environmental policy and science'.

UK, the US, and so on (see Wilsdon, *et al.* 2005: 51). Nevertheless, it would be pertinent to raise certain questions: whether boundary organizations do stabilize the relationship between research and politics, however, is still a question for empirical verification. As a corollary, in what ways do these boundary organizations perform their tasks, and with what effects on scientists, science and knowledge-making?

Scientists' Reflection on Science

There appears to be an enduring belief in the discipline of science studies that scientists are the kind of actors that "do" boundary work rather than reflect upon and analyse their roles in it (Kuhn 1970: 47; Gieryn 1995: 394; Knorr-Cetina 1981; Woolgar 1988). Contrary to this assumption, the present study is based on the idea that contemporary scientists are both experiencing, in increasing intensity, science — policy boundaries of various kinds, and have the ability to "sit back" and reflect on their own involvement in this boundary work. This helps us explore how contemporary scientists might reflect on their own knowledge-making, whilst assuming that such knowledge-making might be affected changing science — policy boundaries.

The study attempts explicitly to provoke scientists to talk in ways with reference to what Woolgar (1988) calls "moralizers", or the kind of everyday work that goes into making scientific knowledge. Modalities, such as reference to: (a) agency (the discoverer, scientist, author); (b) the agent's action (claiming, writing, constructing); and (c) antecedent circumstances bearing upon the agent's action (motives for making claims, interests in acting in a certain way, and so on) usually tend, according to Woolgar (1988: 71), to be omitted from scientists' account of their own work. As others have found (Gilbert and Mulkay 1984), scientists tend to express in a largely "empiricist" way about their work. That is, they tend to 'depict their accounts and beliefs as a natural medium through which empirical phenomena make themselves evident' (*Ibid.*: 56), thus neglecting their own role, how they did the research, and under what circumstances.

As mentioned earlier, the objective of the present study to capture the scientists' "talk" that includes reflection about "moralizers", to increase the amount of "contingent" talk that, in Gilbert and

Mulkay's (1984: 57) terms, 'enables speakers [scientists] to depict professional actions and beliefs as being significantly influenced by factors outside the realm of empirical biological phenomena'. The empirical results of the study endorse many of the insights that Gibbons, *et al.* (1994), Nowotny, *et al.* (2000) and Etzkowitz and Webster (1995) have produced about the nature of contemporary science and science's "changing social contract" in what they call a "Mode-2" and "triple-helix" forms of knowledge production.

In this regard, it is important to note that more elderly scientists are interviewed, as they commonly reflect, for example, on the pressure introduced by institutional changes that have taken place since the introduction of the IPRs in WTO in 1995. The pressure, here, refers to the shrinking of funding for basic research institutes and the increasing emphasis on contract, industry-sponsored and/ or user-related work. Scientists engaged in research in plant molecular biology across various institutional settings in India in which interviews are conducted seem to obtain their funds from an enormous array of sources (including research councils, industry, national government bodies, foreign funding agencies, etc.). It appears that one of the essential skills of the contemporary scientists is to "parallel process" (Waterton 2005) — that is, to carry out several pieces of research simultaneously) and to attract new research grants from a variety of sources.

There exists a very self-conscious awareness amongst many scientists interviewed of the potential compromises and adjustments in research within this kind of context. Such compromises and adjustments are often a result either of constraints imposed by the frequently short-term nature of funding, or because of the commercial interests and influence of some scientists' sponsors. Lack of funding for basic research pursuits, competition for funding and the growth of triple-helix user-oriented research also seem to have had the effect of eroding a sense of community among scientists, as mentioned earlier. As a community, scientists appear weak and fragmented. In this context, a striking finding was a lack of reference to stabilizing boundary organizations of the sort that Guston (1999, 2001), Miller (2001) and Waterton, *et al.* (2001) have described, despite the fact that scientists do encounter the science — policy boundary increasingly often.

Changing Science — Society Contract

A "new contract" between science and society (Gibbons, *et al.* 1994; Nowotny, *et al.* 2001), the commodification of science (Etzkowitz and Leyesdorff 1997, 2000), the commercialization of science within universities (Jacob and Hellstrom 2000; Godin and Gingras 2000) and the changing notions of and changing conceptualization of relations between pure and applied science (Callon 1994; Pavitt 2001) demonstrate that analysts are trying to understand the nature and effects of changing funding structures in science and the implications of these for the hitherto existing structure and character of science. What such authors are studying, in effect, is a historical change in the cultural classification of science (Gieryn 1995: 419; 1999). And, this historical change has made boundary work involving science more likely (Abbott 1988).

In this regard, it would be pertinent to dwell upon the questions relating to the protocols laid down in the IPRs, as discussed in detail in the third paper, that were driven by the strategy of the Government of India designed to encourage efficiency by demarcating and splitting the so-called "basic" and "applied" sciences. The aim was to promote greater competition within the research base and increase the proportion of research that had industrial relevance, thus speeding up the process of innovation in scientific research. And, subsequently, since the 1990s, cuts were made to the publicly funded basic science budgets that would make up a much larger proportion of their overall budget through contract research, often "applied" in nature. As a consequence of which scientists in both university and institute settings face the question of demonstrating the applied and/or "user" benefits of research in funding applications.

The scientific community in India dwells upon primarily two important effects of the new institutional regime on scientific research. On the one hand, by bringing about an imperative to make research useful to solve the real-world problems, this regime introduces a discourse on the accountability of scientists for the science funding they enjoy. On the other, by cutting institutional research budgets and attaching resulting savings to research pots available to scientists to bid for in accountable ways, it brought about financial conditions in research institutes and universities, which implies that research is henceforth to become much more commercially- and/or contract-dependent.

The senior scientists who witness the uptake of the protocols of the IPRs within their own institutes and universities (which, in turn, are affected by their sponsoring research councils such as the CSIR) have some particularly interesting observations to make about the science — policy boundaries both in the pre- and post-IPRs regime. Their reflection involves selecting certain pivotal and important aspects associated with "good science" of the past. More specifically, scientists often contrasted a picture of a stabilized set of ideals underpinning science with much less secure and more valuable portrayal of science observed by them to follow in the wake of the new customer/contract relationships set in place with the implementation of the norms of the IPRs.

Delving into the nitty-gritty of the changing situation, scientists tend to reach back to many of the received wisdoms about science, including many of the demarcating boundaries around what constitutes "good science", including the Mertonian norms of science[4]. They often portray the aspects of science such as universalism, communism, disinterestedness and organised skepticism as being put under challenge.

Concluding Remarks

I have examined in this paper at the way changing culture of scientific research in India influence the practices of scientific research in the IPRs regime. The observations have been made with respect to scientists working in a variety of institutional settings. The advent of scientific collaboration in the wake of WTO regime seems to have forced scientists to re-negotiate scientific boundaries and to do some delicate boundary work. Today scientists face the task of bringing science closer to politics and policy thus demonstrating social accountability, legitimacy and relevance. More specifically, the task is to avoid either science or politics over-extending into the other's territory — a prospect that is evidently disorienting and poses serious threats to idealized identities of science and scientists.

Scientists often refer back to selected traditional norms of science in order to re-orient their approach towards the networking

[4] Merton's (1973) well-known four "norms" of science include, "universalism", "communism", "disinterestedness" and "organised skepticism".

between government, university and private R&D institutions. Their awareness of the effects of commodification in science is narrated as though first-hand experience of this new terrain is the most reliable knowledge that they possess. They also try to cope up with in the seemingly unstable terrain of more commodified research. In this context, I am not going to argue that scientists are actually in the process of reclassifying a satisfactory version of "science" and of "policy" through their work. Rather, they are learning to live with multiple versions of actively negotiated science — policy boundaries, most of which seem to have different qualities and make different demands as scientists.

Studies on boundary objects and boundary institutions may help us to understand certain relatively "managed" aspects of science — policy boundary. However, such studies perhaps tend to underplay the highly diverse nature of boundaries that contemporary scientists appear to be establishing in partnership with funding and policy bodies. It is important to understand to the complexity and ambivalence captured within many of the constructed science — decision-making boundaries obstructing scientific collaboration.

Earlier, we have argued that contemporary scientists seem to both "do" and "watch" boundary work. Scientists' accounts of their own boundary work, however, often remain in the private sphere and may be characterized as a "folk sociology" (Gilbert and Mulkay 1994; Woolgar 1988; Latour 1993). Such observations about the conduct and role of science in the current funding and policy culture do not seem to be open to debate by practicing scientists as a community. Such kind of changed and changing practice is due to the changing conceptualization of relations between basic and applied sciences and bridging the gap between the laboratory and the field. This may indicate a lack of institutionalized digestion, discussion and management appropriate to recent shifts in the culture of science. This may be the point where what is required are boundary organizations, of one form or another, enabling some of the reflections of scientists on their lone experiences to be shared.

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Deepthi Shanker

Intellectual Property and Traditional Knowledge: The Indian Experience

Abstract

This paper is a debate over the exploitative link between the IPR and Traditional Knowledge systems. The first part of the paper discusses the importance of IPR in the context of knowledge based societies. The second part of the paper opens up the issues of ideological incompatibilities and conceptual discrepancies between the two. The issue of Bio-piracy and the legal complications are discussed. The third part of the paper examines the solutions to bridge the gap. Documentation of Traditional Knowledge is discussed as a possible solution to facilitate the process of making a 'Knowledge Claim' non-controversial.

Intellectual property (IP) has been considered as a fundamental human right for all people since the adoption of the Universal declaration of Human Rights (UDHR) in 1948. Intellectual Property Rights (IPR) are the legal protections given to individuals over their creative endeavors. It gives the creator an exclusive right over the use of his/her creation or discovery for a certain period of time. IPR may include patents, copyrights, trademarks, trade secrets, industrial designs, geographical designs, new plant varieties etc. Traditional Knowledge (TK) refers to the information given by the people as a result of their experience and adaptation to the local cultures and environment. It is a knowledge system, which has evolved over time and continues to develop. Discussions over the protection of 'Traditional Knowledge' have been widely debated across the world in the recent years. In short this paper is an attempt to highlight the growing importance of IPR in upcoming knowledge based societies. The evolution of IP institution in India in the era of globalization is accompanied by several challenges and the issue of Traditional Knowledge is one among them.

Objectives of the paper

Following are the objectives of the paper.

To indulge in academic debates on Knowledge societies and to understand the IPR in the context of globalization and knowledge societies.

To explore the incompatibilities and discrepancies between Traditional Knowledge System and Intellectual Property System by understanding the nexus between the two.

To understand the legal complications of Bio-piracy and India's experience on the issue.

To examine the solutions for protecting Traditional Knowledge and to discuss the role of NGOs involved in the process.

To arrive at a policy implications that there is a need to raise awareness of Traditional Knowledge in science and technology education

A note on Intellectual Property

Intellectual Property refers to certain kinds of exclusive rights that are treated by law more or less like 'property' though they are not physical objects. Intellectual Property (IP) is an general term used for various legal entitlements attached to certain types of information, ideas or other intangibles in their expressed form. In other words, the term Intellectual Property reflects the idea that the subject matter is the product of the mind or the intellect and hence IP rights may be protected at law in the same way as any other form of property. Intellectual Property (IP) is a class of property emanating primarily from the activities of the human intellect. Any property, movable or immovable, for instance is legally protected to prevent it from being stolen. Similarly, the rights in an intellectual property created need also to be protected to prevent infringement. The legal rights accrued on the intellectual property are termed Intellectual Property rights (IPR). The most common examples of intellectual property rights recognized by TRIPS (Trade related aspects of intellectual property rights) are Copyrights, Patents, Trademarks, Design, Geographical indications, Trade secrets etc. Intellectual Property Rights (IPR) allows the person to assert ownership rights on an creation, invention or innovation and its consequent outcome. So, intellectual property can be brought, sold, exchanged, licensed or gifted like any other forms of tangible property.

Globalization and IPR regime in India

Emergence of WTO and several deliberations under Uruguay round have changed the world economic order. Indian government has opened up the economy to the world market and this has helped the Indian economy to strengthen the flow of international capital and technology resulting in a robust economic position. Changes brought about by liberalization reflected in the technological dynamism experienced by a Indian economy, as its industrial capitalism got integrated through globalization. Technological regime in India has been adapting to dynamics and hard conditions through the means of globalization process. (Pattnaik, 2005). The new economic order resulting out of the economic globalization has posed several challenges and IPR regime is just one of them. There have been several academic battled over the concept globalization and scholars have divergent views over it. While the academic debates continue, a common term synonymously used with globalization is integration in terms of people, capital, ideas, technology and services (Houck, 2005). Globalization empirically gets translated into greater mobility of factors of production (capital and labor) and greater world integration through increased trade, foreign direct investment (FDI) and enforcement of intellectual property rights (Mulanovic, 2005). IPR have become important in the face of changing trade environment characterized by global competition, high innovation risks, skilled human resources and rapid changes in technology.

The first Indian patent laws were formulated in 1856, which were modified from time to time. After Independence, new patent laws were made in the form of Indian Patent Act 1970. This act has been amended in 2000, 2003 and 2005 to be fully in compliant with the provisions of TRIPS. India has also become the member of Paris Convention patent Cooperation Treaty and Budapest Treaty. Other legislations related to IPR include Biodiversity act 2002 which ensures maintenance, sustenance and development of biodiversity and Information technology Act 2000 which looks at the security aspect of material being transacted on internet. Since the beginning of 1990s, when Indian became the member of the WTO, impacts of globalization became a part of life and there were significant changes in economic, political and cultural systems. New legislations were enacted, existing were updated, new mechanisms were instituted for creation of IP and its protection and efforts were towards a evolving a new culture and environment conducive for IPR and its protection. The Department of Science and Technology set up the

Patent Facilitating Centre at the technology Information Forecasting and Assessment Council (TIFAC) in 1995 in order to raise awareness of IPR among scientists and others. IPR cells became mandatory in many government departments and education institutions. The science and Technology Policy released in 2003 also emphasizes on IPR and related issues. It focuses on the transformation of new ideas into commercial successes, which is considered as important for the country to achieve high economic growth and global competitiveness. The policy states that IPR should not be viewed as a self contained and distinct domain, but as an effective policy instrument that would be relevant to socio, economic, technological and political concepts. (Science and Technology Policy, 2003).

In the era of globalization, almost everyone is a user and a potential creator of intellectual property. Hence, Intellectual Property Rights (IPR), which protects the creation or innovation, should be of natural and greater significance to the society. Any studies relating to the issue of IPR is a contribution to the literature on globalization. Recently, the issue of IPR in general and TRIPS agreement in particular is indeed an widely debated topic in the field of global politics, economics, culture and global legal system and thus generously contributing to the studies on 'globalization'. Since past five years, there has been about 60 percent rise in IP filings in India. It indicates the growing awareness about IPR among the general public in India. Some of the India's pharma and biotech companies have challenged the largest multinational companies of the world and have withstood litigation in various foreign jurisdictions. There has been growing demand for patent and other IP professionals as the Indian economy and society is the process of becoming largely knowledge driven. The emerging new knowledge economy and society demand a better understanding IPR and its management.

Knowledge societies

Discourses on Knowledge economy/Knowledge society have become a way to characterize the new relationships between the state, society, education and economy. Although the terms are often interchangeably used in the contemporary discourses, the term 'knowledge society' is much broader than 'Knowledge economy'. The former encompasses in itself more intellectual activity than narrow industrial, economic and commercial concern. The term Knowledge economy can be defined as production and services based on Knowledge intensive activities that contribute to an accelerated pace of technical and scientific advances, as well as rapid obsolescence. The key component of a knowledge economy is a greater reliance on intellectual capabilities than on physical inputs or natural resources (Powell and Snellman, 2004). The discourse on knowledge economy emphasizes the shift to knowledge intensive high skill labour force, international circulation of brains, transferable skills. Competency and knowledge management serve as a key to individual and organizational capacity (Nokkala, 2004). Economic wealth is generated through creation, production, distribution, consumption and management of knowledge and knowledge based products (Harris, 2001).

It is argued that idea of knowledge society often emerges as an extension of the more concrete knowledge economy or is simply deduced from the existence of information technology. Hence, it has been a popular view to account for the idea of the knowledge society with the accentuation of knowledge as the decisive resource, especially in technical and economic terms (Nassehi). It is indeed crucial to identify the specificity of sociological processes around knowledge and the sense in which knowledge processes, structure and forms are constituted by the society and economy at the same time (Adhikari and Sales, 2001). However, Ungar (2003) argues that the term is frequently evoked but seldom defined or explored in a systematic way. Thorlindsson and Vilhjalmsson (2003, p. 99) note that although the concept of the knowledge society is not fully developed, it generally acknowledges the social forces, which might intervene. It is crucial to relate it to the issues of power like who owns the knowledge and the politics of knowledge exchange. Robert E Lane (1966) is known to be the foremost author for employing the term 'Knowledge society'. He justifies the use of the concept by pointing to the growing societal relevance of scientific knowledge. Bell also employs the term 'Knowledge society' in the context of his discussions of the emergence of post-industrial society and at times uses the concept of knowledge society interchangeably with the notion of 'post industrial society'. Peter Druker (1959, 1969, 1994), Alvin Toffler (1980) and others initiated and contributed to the idea that the industrial manufacturing society was being gradually transformed into an 'information society'. Druker (1969) also drew attention to the significance of team work in a knowledge society and emphasized upon the distinction between people who work with their hands and people who worked with their minds and thought. He argues that in a knowledge society, a dominant class of people is likely to be those who work with their minds. Stehr (1994, pg. 06) argues that the knowledge societies have not occurred suddenly, but rather a result of gradual process during which the defining characteristics of society changes and a new one emerges. He adds that contemporary society may be described as a knowledge society due to deep influence of scientific knowledge on all its aspect. Manuel Castells (1997) extends his argument that the contemporary society is depending more on knowledge in economic production, political regulation and everyday life. For him, information technology revolution did not create the network society, but without information technology, the Network Society would not exist.

As changes were evident there were gradual shift from information to a greater emphasis on knowledge. In contemporary societies, knowledge is indeed the key driver of economic and social life. Knowledge based economy can only be considered as a subset of knowledge society as it limits its focus to the changed role of knowledge in economic activity. It has been argued that sociological work adopting less determinist views has stressed continuity and hence 'information revolution' becomes a part of the continuing development and utilization of technologies (Mumford, 1966). It also subtly suggests that there is a need to adopt a approach to understand 'Knowledge society and economy' which view it as a part of continuity and evolving history of connections between technological innovations and economic, social, political and cultural opportunities which either facilitate or resist innovation and change (Thorns and Michael, 2006). According to Knorr Cetina, there is a need for a more sociological approach to knowledge and one needs to understand the social processes in which knowledge is generated and from which it is turned into commodity. It is argued that if the term 'Knowledge economy' is primarily concerned with knowledge as a commodity and the value of intellectual labour in creation of wealth, then the term 'knowledge society' should focus upon the social climate in which the 'knowledge economy' resides. Knowledge society should relate to much broader social context that motivates and facilitates the development and exchange of knowledge (Thorns and Michael, 2006). In other words the concept of knowledge society attempts to acknowledge the presence of social and cultural factors, which might influence knowledge growth at any point of time rather than viewing knowledge growth from purely reductionist terms.

Intellectual Property and Knowledge Societies

The role of innovation created through human capital with emphasis on intellectual capabilities in production and consumption is indeed an important theme with in the broader framework of knowledge society. But however the role of IP in modern societies although is crucial is been typically ignored or submerged with the economy based discussions. Emphasis is largely on the culture of innovation (Thorns and Michael). The power of the Internet is posing a fresh threat to the control of IP. It raises fundamental issues as to whether it is possible to protect the flow of information, as computer systems are vulnerable to security breaches. Ensuring security of such system itself has become a significant growth industry. It is obvious as web-based achievements are now extended to all aspects of life like leisure, recreational, employment etc. (Liebowitz and Watt, 2006). Hence the speed of innovation raised genuine questions with respect to the protection of IP in the contemporary environment. The shelf life of new products could be only a matter of months given the current speed of diffusion (Thorns and Michael, 2006).

Knowledge now can be created in virtual research communities, which has in its fold intellectual capital accumulated through the participation of several members of network communities through computer-based technologies. Communication of intellectual capital is natural given the new enterprising and business environment. Questions like who owns the IP created in the virtual communications become quite significant (Delanty, 2001). Thus it needs to be noted that digital access and Internet connectivity etc are key aspects in knowledge creation activities and demands more focus. It is important that sociology now extends their attention and focus on power and access in the context of Information and Knowledge societies in relation to Intellectual property. It can be costly to exclude people from information because it limits innovation of ideas. Excluding people from information largely means appropriation of information by few. One can notice the shift from 'politics of exclusion' to 'politics of inclusion'. Emphasis on ideas and those who generate them is increasing the value of well-educated section of society. Hence knowledge society gives utmost value to trained and qualified section of people in the population. It could possibly have implications on society by creating and furthering inequalities between different sections of population. The existing digital divide could gradually lead to knowledge divide and which might get accentuated with IP and battle for appropriating knowledge and ideas.

As explained earlier, the concept of IP refers to various protections given to human creations including patents, trademarks and copyrights etc. Ideas are beginning to gain 'economic values' during the transition towards 'Knowledge societies'. Hence, IPR becomes important as it revolves around the issues of producing; selling copies of your or others' ideas (Kenny, 1996, p.70). IPR is directly concerned with the privatization of knowledge for monetary gain and knowledge being viewed as commodity. Since knowledge is increasingly viewed as product that can be traded, ideas and people who create the ideas are also increasingly becoming valuable. This has brought about significant changes to IP in the emerging knowledge societies. There has been frequent argument about the accessibility of information. Those who support a more Open system of exchange generally favor a move towards a balance between the interests of the IP holders and users. Drahos (2005, p.149) argues that the current problem, facing knowledge economics is that their law making processes have been influenced by owners of intellectual property as a result the rights of owners have strengthened. Such debates about openness and ideas versus restriction of knowledge are quite popular. Recently, the international law has focused on strengthening exclusively of IP rights rather than making knowledge more accessible. The Digital Millennium Copyright Act (1998) is a good example. Policing the borderless transmission of information is indeed proving to be very difficult. The rights of participating users need to be strengthened by creating a more balanced access to and use of knowledge. As knowledge is becoming the key resource in the current knowledge base society and for future economic growth, the struggle over IPRs will intensify making it more crucial. As a consequence, a detailed analysis of whether IP protection facilitates or restricts the flow of new innovations and creative activities becomes the need of the hour.

Philosophical views on IPR

Anthropologist and Sociologist have been debating several theoretical views on the subject of IPR particularly about patenting of life. For instance modernization theorists view patents as a necessary means of protecting the rights of corporations to their innovations. They argue that the patent is one of the tools, which has helped the industrial society. Patents have encouraged innovation and it protects the rights of the inventors. They do not support the fact that the industrialized counties are patenting genetic material from developing countries. Rather they feel that the developing counties should develop patents in defense (Novak, 1996). Dependency theorists view that patents are just another method used by the industrialized countries to maintain dominance over the developing world. They argue that multinational corporations are patenting much of the third world genetic material and thus denying the indigenous people's rights of their age-old knowledge system and work. Dependency theorists do not feel that patents could be an effective means to combat patents as viewed by the modernization theorists. Marxists on the other hand view patents as an individual state's means of furthering the interests of its industrialists (those who receive the patents) at the cost of its workers (those who actually develop the patents). Anthropologists and sociologists opine that the patents can have severe consequences on the society. This throws open several questions and debates on human rights, farmer's rights, free access, cultural rights, environment rights etc.

Kathy Bowey (2001) questions the philosophical concern about Intellectual Property Rights with particular reference to copyrights. She argues that the philosophy and culture of copyright law should be studied not by looking for it at the outer limits. It is not just that a legal practice or legal reasoning supports a culture of commodification. Within the broader agenda of commodification, there is also a process whereby copyright law naturalizes several forms of discrimination. The author is actually talking about the marginalized section of people, which include indigenous population, stakeholders of Traditional Knowledge and whose values and communal structures divide them from the skilled collaborators and the norm itself. The author argues that such a practice of cultural exclusion is disguised by the politics of copyright jurisprudence and other forms of IPR.

Traditional Knowledge System

Traditional Knowledge (TK) refers to the information given by the people as a result of their experience and adaptation to the local cultures and environment. It is a knowledge system, which has evolved over time and continues to develop. It helps in sustenance and maintenance of the community and its culture. The expression 'Traditional Knowledge' includes broad range of subject matter. It includes traditional agriculture, medicinal knowledge of local biological resources, animal breeds, local plants, crop and tree species. It may also include key information like those trees and plants that grow well together or indicator plants that show the soil salinity or that which are known to flower at the beginning of the rains etc. It may include practices and technologies such as seed treatment, storage methods and tools used for planting and harvesting. It even includes belief system that plays a fundamental role in peoples' livelihood maintaining their health and protecting and replenishing the environment. Following are some of the examples of Traditional Knowledge.

The use of **plao-noi** in Thailand for the treatment of ulcers

The use of **turmeric** in India for wound healing

The use of **hoodia** cactus by king Bushmen in Africa to starve off hunger.

The use of **joublie** in Camerooon and Gabon as a sweetener.

The traditional Yogasanas of India

The term 'Tradition' which is used in describing this knowledge system does not necessarily imply that this knowledge is old or non-technical in nature. It only reflects that it is 'tradition based' which is attributed to the traditions of the communities. It is not just related to the nature of the knowledge, but to the way, in which that knowledge is created, preserved and disseminated. Traditional knowledge is collective in nature and it often considered the property of the entire community and not belonging to any single individual within the community. It is transmitted through specific cultural and traditional information exchange mechanisms like oral transmissions, sign systems etc. (Hansen and Justine, 2003). The term Traditional Knowledge system and Indigenous Knowledge System are often used interchangeably. However some scholars recently prefer the expression Indigenous Knowledge System to Traditional Knowledge system as the connotations of tradition knowledge denotes the nineteenth century attitudes of simple, savage and static which could possible limit the understanding. On the other hand the expression Indigenous Knowledge System is much broader and represents dynamic contribution of any community to problem solving (Warren, 1996). Whether the expression is Traditional Knowledge or Indigenous Knowledge, the central content and understanding of the term remains the same. Indigenous knowledge is the practical knowledge and experience of people who have direct link to their immediate environment. Local expertise is indeed central to Indigenous or Traditional knowledge. The environment of Indigenous or Traditional knowledge system plays a crucial role in the production system. Language also plays equally important role in understanding indigenous or traditional knowledge system.

Nexus between Traditional Knowledge and Intellectual Property Rights

Instances reveal that there have been several problems in developed as well as developing countries while trying to protect the traditional knowledge under intellectual property laws. Difficulties and obstacles stem mainly from the failure of traditional knowledge to satisfy requirements for intellectual protections. Besides the prohibitive costs of registering and defending a patent or other intellectual property is too high and not everyone could afford the expenditure even though intellectual property protection could potentially apply to particular knowledge. It is often argued that there has been a clear bias in the operation of these laws in favour of the creative efforts of big corporations at the cost of indigenous groups. For instance, modern intellectual property laws have allowed the industries and companies to monopolize the benefits derived from their use of indigenous knowledge with utter disregard for the moral rights and material financial interest of the indigenous people themselves. Secondly, an important purpose of proprietary rights is to enable individuals to benefit from the products of their intellect by rewarding creativity and encouraging further innovation and invention. But in many indigenous worldviews, any such property rights, if they are recognized at all, should be extended to the entire community. They are the means of maintaining and developing group identity as well as group survival rather than promoting or encouraging individual economic gain, which goes against the philosophy of IPR. Thus with the rapid global acceptance of western concepts and standards for IPR, many incompatibilities have begun to surface.

It is argued that the Intellectual Property regimes of the west focus on protecting and promoting the economic exploitation of the inventions with the rationale that it promotes innovation and research. But it largely serves the interest of the developed nations at the expense of the developing nations. Western Intellectual Property law, which is rapidly, assuming global acceptance, often unintentionally facilitate and reinforce a process of economic exploitation and cultural erosion. It is based on notions of individual property ownership, a concept that is often alien and can be detrimental to many local and indigenous communities in developing nations. As a result it creates conflict of interest between the developed and developing countries. Making the matters even more complex is the fact that property rights, as they are understood in western legal system often do not exist in the indigenous and local communities that hold traditional knowledge. Thus holders of traditional knowledge argue that, current intellectual property regime was designed by western countries for western countries (Hansen and Justine, 2003).

There are several challenges, which need to be addressed as a result of the connections between Intellectual Property and Traditional Knowledge. For instance many expressions of folklore and forms of traditional knowledge do not qualify for protection because they are too old and besides they are already in the public domain. Providing exclusive rights of any kind for an unlimited period of time also would seem to go against the principle of IPR as intellectual property can be rewarded only for a limited period of time, thus ensuring the return of intellectual property to the public domain for others to use. In some cases, the author or inventor of the material is not identifiable and thus there is no actual 'rights holder' in the usual sense of the term. Sometimes, the author or invention is often a large and diffuse group of people and the same creation or invention many have several versions and incarnations. In fact, many, if not most forms of traditional knowledge is held collectively or 'communally'. Textile patterns, musical rhythms and dance forms are good examples. Besides these, there are lot of tradition material that is unfit by its very nature for protection by intellectual property norms. Examples include spiritual beliefs, methods of governance, languages, human remains etc. Often, an author outside of the group that created the folklore will create a derivative work using folklore as a basis but with enough derivatives originating to benefit from the copyright protection. For example, sound recordings using traditional music are common. Many creators of folklore find this situation doubly unacceptable, as they are unable to benefit financially and otherwise. The same holds true for patents. Many discoveries and forms of traditional medicinal knowledge based on plants or animal parts or fluids generally cannot be patented either because they are obvious or because they are in the public domain. But on the other hand ironically, drugs derived from such plants and animals are generally patentable. The companies that develop and refine that molecule will own the patents.

Among the latest controversy is the issue of IPR relating to Yoga. It reveals the anxieties and confusions over traditional knowledge and its incompatibility with IPR. They have been media reports claiming that some 'Asanas' have been patented although no patent have been granted so far to any Yoga asanas. The issue is contributing to the ideological debate of misappropriation of India's traditional knowledge by western world. It is true that patents, copyrights and trademarks have been obtained in the US on yoga-related accessories, courses etc. As Yoga is becoming transnational, it cannot be dealt in isolation. It is inevitable that traditional knowledge of yoga has to deal with issues like IPR. As Aoyama (2007) asserts, the commercialization and globalization of traditional arts and practices generate new tensions and facilitate new modes of appropriation and consumption, as they are made widely available. IPR has played a significant role in marketing and appropriating traditional yoga to suit the needs of the global consumer society. There has been instance where patent application on yoga mats, devices and other apparatus have been filed in many countries. But mere grant of patents on accessories used for practicing yoga asanas should not be viewed as misappropriation of traditional knowledge. There is no need to be alarmed as such, because, no yoga asana per se can be patented. What is been patented and can be patented is perhaps the yoga related apparatus. But however, there are several complications with regard to yoga and the issue of patent rights. The question as to can a method or system in which asanas are selected and arranged in a particular order, to be done in a specific condition to be covered under a copyright remains unanswered. If so, then would someone teaching that without getting license from the copyright holder be an infringement? The government of India has a key role to play. It has to be clear as to what constitutes misappropriation of traditional knowledge. It should take a position and should try to bring about effective legal challenges on it. Only then the effective strategies can be evolved to deal with the situation (Srinivas, 2007).

Traditional Knowledge and Biological Resources

Traditional Knowledge is largely associated with biological resources and hence it is an intangible component of the resource itself. Biological diversity which encompasses all species of plants, animals and micro-organisms occur at three levels namely; species level (living organisms), genetic level (genetic variation) and ecosystem level which refers to the habitats, biological communities and ecological processes that occur in such habitats. The convention on Biological Diversity (CBD) came into force on 29th December 1993 and it envisages that the benefits occurring from commercial use of TK has to be shared with people responsible for creating, refining and using it. Article 8(j) of the CBD provides for respecting, protecting and rewarding the knowledge, innovations and practices (KIP) of the local communities. It has also proposed to enact a legislation to realize the benefits arising out of the convention. Discussions of TK invariably involves discussions on The Biological Diversity Bill

2000 introduced in the parliament which addresses the concerns of access to, and collection and utilization of biological resources and knowledge by foreigners and sharing of benefits arising out of such access. There have been several cases of bio-piracy from India. Turmeric, Neem, Karela (bitter guard), Brinjal are just some of them. An important criticism in this context relates to foreigners obtaining patents based on Indian biological materials. Besides, there are also criticism, that TRIPS agreement aids the exploitation of biodiversity of privatizing biodiversity expressed in life forms and knowledge (WTO, 2000)

The issue of Biopiracy

The term Biopiracy actually refers to the misappropriation of knowledge or biological material from traditional communities. So, Biopiracy is a negative term for the appropriation, generally by means of patents over indigenous knowledge, particularly the biomedical knowledge without compensation to the indigenous groups who originally developed such knowledge. Instances of biopiracy are becoming increasingly evident with the rapidly growing IPR regime. The increasing discrepancy between IPR regime and traditional knowledge is negatively affecting indigenous communities across all continents. What is a matter of serious concern is that the western corporations will continue to adapt, incorporate, build upon or directly claim indigenous knowledge without due acknowledgement or compensation for the communities that developed that knowledge. There are several classic cases of Biopiracy across the globe like case of Enola Bean, the case of Hoodia Cactus etc. Some of the famous Indian examples are the case of Neem Tree, Basmathi rice, Turmeric etc.

a. Neem Tree.

The classic example of Biopiracy in India is the Neem Tree (Azadirachta Indica). This tree has been a part of Indian culture for thousands of years. It is used as pesticide, antiseptic, medicine, contraceptive, cosmetic etc. The Neem tree was developed over the course of centuries by means of traditional plant breeding. It is indeed an important social and cultural symbol in Indian society as it is used in large scale for medicine, agriculture and religious purpose in India. But in 1985, the US firm Vikwood, LTD received US patent 4,556,562 on a 'storage stable neem extract'. A few years later, it sold this patent to WR Grace and Company. Later in 1995, WR Grace and Company obtained US patent 5,411,736, on a method of using neem oil as an insecticide. Though the WR. Grace and Company claims that the extract is produced using newly developed techniques and the patent covers only the extracts so processed, there is room for suspicion and doubts. Firstly, the originality of the method was not clear completely. Secondly, even if the method were original, the vast majority of the work leading up to this patent was the traditional agriculture, which bred the neem tree, as we know it today. This was followed by intense protest and legal response from Indian government, which has opened up the issues of Biopiracy across the globe in a loud voice. It has exposed how Bipiracy contributes to the inequality between developing countries, which are rich in biodiversity and developed countries rich in pharmaceutical industries are exploiting those resources.

Basmathi

Basmati is an long grained rice peculiar to India. In 1997, the company RiceTec,Inc obtained US patent 5,663,484. The patent covers number of lines of basmati rice. Thus, by breeding existing strains of basmati rice, developed by traditional agricultural methods in India, RiceTec obtained what the USPTO views as a patentable product. Indain government has responded to it. It is claimed that government had already taken steps to challenge the grant of the patent for these strains of basmathi rice (Maharaj).

c. Turmeric

The use of Turmeric for various purpose in Indian household dates back to several centuries. It is been used for culinary purposes, medicinal purpose, as cosmetic, as antiseptic etc. But in 1993 December, the patent for turmeric was issued to University of Missippi Medical center. Indian government challenged the patent on the use of Turmeric for healing purpose. After a complex legal battle, the US patents and Trademarks office ruled on Aug 14 that patent issued on turmeric was invalid as it was not a novel invention. The patent was contested by India's council for scientific and Industrial research (CSIR), which combined scientific evidence with legal evidence to take on the bio-pirates.

India has been foremost country in exposing many developed countries patent laws and Biopiracy. Vandana Shiva, a global campaigner for a fair and honest Intellectual property Right System says chasing every patent based on traditional knowledge involves huge expenses and efforts. WTO has to take positive and proactive steps in protecting the indigenous knowledge. Patent laws need to be changed and the companies should give an undertaking that the patent they are seeking is not based on traditional wisdom. Vandana Shiva points out that the examples of bio-piracy make it clear that it is not just Indian patent laws that need to be changed. Even the American laws also need to be changed to fit into a fair and honest global Intellectual Property Rights Systems. The neem tree case was an eye opener. Indian government had filed a legal opposition against the patent claiming neem extract product as patentable product by the multinational companies of the western world. The use of neem extracts for fungicide and pesticide has been practiced for centuries and investigated scientifically and commercially for decades prior to the claim to invention by the USDA- Grace patent. This was a hard struggle of five years and every possible evidence was brought from Indian farmers ad scientists. The detailed cross-examination proved beyond doubt that the patent was based on pirated knowledge. On May 10, 2000, the patent was revoked.

The 'neem challenge' began in 1994 resulted in launching of neem campaign in India. So the "neem Team" — an international network of patent warriors to support the national campaign was formed. The main idea behind 'Neem team' campaign was to challenge big money and political power of the multinational corporations and governments by the ordicary people's solidarity. Neem experiment was a new way of defending one's freedom in the era of globalizations and corporate rule. The neem also seems to have brought some important implications for patent laws and TRIPS. The idea was to challenge the International Patent System using neem rather than winning over the legal battle on neem patent. The proof of Biopiracy as accepted by EPO (Euoropean Patent Office) now provides an opportunity for revisiting the European Patent Convention, US Patent laws, TRIPS and the patent Cooperatior Treaty all of them which fail to be based o global cross cultural scrutiny. On investigation, about 'prior art', it is quite evident that TRIPS and PCT are imposing IPR frameworks on countries like India. It is been a well-known fact after these experiences that global recognition of patens without global recognition of prior art is a recipe for Biopiracy. The Neem case is also a signal of caution to Indian parliament to amend patent laws and the western patent systems could be exploitative (www.en.wikipedia.org/wiki/ Biopiracy).

Bio-Piracy: The Legal Complications

'Biopiracy' refers to the way the corporations- 'almost all from the developed world –claim ownership of or take unfair advantage of the genetic resources and Traditional Knowledge of the developing countries. Bio-pirates are those who are responsible for the following acts;

The theft, misappropriation of, or unfair free — riding on, genetic resources and Traditional Knowledge through patent system.

The unauthorized and uncompensated collection for commercial ends of genetic resources and traditional Knowledge.

It is a well-known fact that the transaction cost involved in getting the Biopiracy patents examined and revoked in foreign patent offices on a case by case basis could be quite expensive for any developing country. Hence, there is a need for an internationally enforceable legal regime, which can ensure an effective protection for the rights of communities and their knowledge resources. UN convention on Biological Diversity (CBD) which came into force in 1993 clearly acknowledges the legitimate rights of the holders. It has following three objectives.

a) the conservation of biological diversity

b) the sustainable use of its components

c) fair and equitable sharing of benefits arising out of the utilization of genetic resources.

Thus CBD seeks to regulate access to genetic resources and associated traditional knowledge and at the same time ensures the sustainable use of it. It also appreciates fair and equitable sharing benefits especially for the local and indigenous communities who have acted as the custodians of these precious resources for ages. India, which is a contracting party to the CBD has already enacted a legislation i.e. 'The Biological Diversity Act, 2002' in the line with provisions of he CBD. The legislation makes an attempt to address the concerns and issues relate to access, collection and utilization of biological resources and Traditional Knowledge by foreigners and the benefit-sharing issues arising out of such access. It also contains provision for creation of a regulatory body called the National Biodiversity Authority (NBA) person seeking any kind of intellectual property right (IPR) in or outside of India for any invention based on any biological resources obtained from India is required to obtain prior permission of the NBA, which may determine benefit-sharing fees or royalty for h benefits arising out of the commercial utilization of such rights. But despite all these provisions with various broad international efforts, how and why incidents and instances of Biopiracy are increasing. How can a most popular product like Neem or turmeric can be pirated even after laying down regulations to protect the resources from under exploitation? The question and anxiety is natural for any scientist or anybody who is concerned. The answer could be the following.

Instances of biopiracy continue to occur despite these regulations largely because of the gaps in the negotiations at eh international level. For instance, even if an invention is based on the use of some biological material or Traditional Knowledge, the patent applicant has no obligation whatsoever under the TRIPS agreement of the WTO to disclose in his patent application the geographical origin of that material or knowledge. Secondly thee is also no such compulsion on the patent applicant under TRIPS to provide evidence on PIC (Prior Informed Consent) obtained from the legitimate holders of the bio-resources and Traditional Knowledge system in question. Thirdly and consequently, there is also no provision under TRIPS to ensure equitable sharing of benefits between the patent holder and the resource-owner either. TRIPS is an important international treaty, which provides the universal 'minimum' standards of protection for all IPRs, including patents and that as many as 148 (till now) member countries of the WTO are bound to comply with it in their respective national legislations.

But there seem to be some gaps in TRIPS agreement, which is not compatible with the explanation provided by developing countries like India with regard to the protection of Traditional Knowledge. The argument over it has reached a dead lock. To summarize it in brief, following needs to be understood.

1. Article 29 of TRIPS provides 'conditions on patent applications' which is not exclusive i.e. it does not prevent a member from imposing additional conditions on the patent applications that what are compulsory under this Article, provided such additional conditions are compatible with other provision of the TRIPS agreement.

2. India has utilized this flexibility of TRIPS in the patent (amendment) Act, 2002. This amendment has introduced a new obligation (in section 10 (4) of the principal (1970) act, which stipulates the requirements of a patent application). The patent application is obligated to disclose the source and geographical origin of the biological material in the patent application when used in an invention. Such provisions are perfectly compatible with TRIPS since it is not violating other provision of this agreement. The Patent (amendment) Act 2005, passed by the parliament recently also has introduced some important provision in this regard. The provision included in the context of pre-grant and post-grant opposition is revised. The revised section 25 (1) which, deals with pre-grant opposition and section 25 (3) deals with the post grant opposition.

3. Despite these provisions, there are some significant differences in the interpretation, which is creating a dead lock between the TRIPS provision and the negotiations or the rationale behind the negotiations of the developing countries to modify TRIPS provision with a objective of protecting the indigenous resources and traditional knowledge system from instances of Biopiracy.

4. Discrepancies are on the following issue. For instance according to Article 27 (1) of TRIPS, an invention has to satisfy three criteria in order to qualify as patentable, i.e.; (a). Novelty, (b). Inventive Step (c). Industrial Applicability. It is in line with this stipulation of TRIPS that section 2 (j) of the Indian Patents Act (as per the amendment of 2002) has defined the term 'invention' to mean "a new product or processes involving an inventive step and capable of industrial application". The question that arises is if an invention is anticipated on the basis of Traditional Knowledge of any country then can it at all be regarded as 'novel'? The answer will term 'novelty' or newness is defined and interpreted. As the TRIPS agreement does not specify the definition of novelty, the members are fee to define and interpret the term in their own ways. Indian law clearly reveals that if some TK, oral or otherwise is used for anticipating

an 'invention' then the patented subject matter does not satisfy the criterion of 'novelty' according to the Indian interpretation of the term 'new'. Thus the Indian Patent Act recognizes even the existence of oral or non-written part of what is called 'prior art' in the terminology of the patent laws, and refuses to allow patenting of any 'invention' based on such 'prior art'.

5. But there seem to be no definite consensus over the definition of the term 'Novelty' between the two worlds. TRIPS agreement is silent over the definition of the term 'novelty' and as a result of this there is significant differences arising to exist in the national patent laws of different countries with regard to the concept of 'novelty' or interpretation of the term. For instance, US patent law does not consider that the 'novelty' requirement has been lost when an invention has been divulged outside the United States by 'non written' means such as sale or public use. Meaning, the public use or sale in a foreign country does not constitute 'prior art' according to US patent law. Only existence of a patent or a published description of the invention is considered to be part of 'prior art' in case of a foreign country. This is clearly in sharp contrast with the definition of 'new invention', which has been inserted in the Indian Patents Act by means of amendment in 2005. Indian law, unlike US law does not discriminate between the home country and foreign country, while determining the 'novelty' of an 'invention'.

6. The provision of the US law implies that a patent conferred by the US patent office, which involves, say an act of Biopiracy of an Indian TK, can be challenged by India only if some written proof of that knowledge can be produced, otherwise such Biopiracy could possibly continue. Thus, although patents are supposed to be granted for new inventors, this denial or non-recognition of non-written 'prior art' elsewhere (in the US law) allows patents to be granted for existing knowledge and use in other countries. This is the loophole of the US patent law, which facilitates bio-piracy of non-written TK of many developing countries by the MNCs in a most legitimate way possible.

The Biological Diversity act, 2002, which is already mentioned create sufficient room for combating the Biopiracy threats at the national level in India. But the problem continues to exist and remain unsolved at a global level because such kind of similar protective shield for Indian bio-resources and TK is not guaranteed under the national patent laws of other countries. Such provisions (as in Indian Patent Act) are not available under TRIPS agreement and it dos not make obligatory for the member countries to include in their respective patent laws provisions aimed at protecting the bio-resources and TK of the country of origin against Biopiracy. Thus the protection of these precious assets cannot be guaranteed until and unless certain compulsory provisions are included in TRIPS in this regards, which all the members' countries would be obligated to comply with (Das, 2005).

Traditional Knowledge, Biopiracy and WTO

India along with other developing countries has been fighting against Biopiracy at the WTO for quite some time now. Several communications have been made to the TRIPS council of the WTO time and again by these groups of countries emphasizing that the rights of the holders of TK to share benefits arising out of innovation based on their knowledge and the associated bio-resources should be recognized in the TRIPS agreement. According to these countries, such an step calls fro harmonization of the provision in TRIPS with those of CBD. In the absence of clear provision I TRIPS providing for a mutually supportive relationship of that agreement with the members obligation under CBD, implementation of the TRIPS agreement may allow acts of bio-piracy and thus results in systemic conflicts with the convention. These loopholes in the agreement has been repeatedly pointed out by India and other allied countries. On these grounds, it has been argued by them that it is essential to make an amendment of the TRIPS agreement in order to accommodate some essential elements of CBD, which may essentially and possibly avoid such conflicts. So India and other allied countries have proposed in the WTO that the TRIPS agreement should be amended in order to make the members abide by the rules that an applicant for a patent relating to biological materials or to TK should provide, as a condition, the fallowing to acquire the patent rights namely:

a. Disclosure of the source and country of origin of the biological resource and of the traditional knowledge used in the invention

b. Evidence of prior informed consent (PIC) through approval of authorities under the relevant national regimes.

c. Evidence of fair and equitable benefit sharing under the national regime of the country of origin.

Although the mere recognition of the subject under the Doha Ministerial Declaration was initially perceived as a significant step towards solving the problem, the developments on the mater in the Post-Doha period has given little or no scope for celebration. It has been quite disappointing as the principal resistance t the proposal of amendment of TRIPS for accommodating the new patent disclosure requirements in order t bring TRIPS in line with CBD has come from the United States. The US feels that the objective of TRIPS and CBD are distinct and hence there is no conflict between them and that these agreements can and should be implemented in a mutually supportive manner. The US clings to its obsessive argument that the introduction of the proposal new patent disclosure requirements will however not ensure the achievements of the objectives envisaged by CBD and may further have more significant negative consequences. For example, it is argued that the new patent disclosure requirements could add new uncertainties in the patent system. US believed that these changes could undermine the role of the patent system in promoting innovation and technological development. It also feels that new patent disclosure requirements may lead to significant administrative burdens for the patent offices of the member countries and which would result in addition costs (Das, 2005).

The problem of bio-piracy is global in nature and it cannot be resolved with just domestic legislation alone. An appropriate legal and institutional means for recognizing the rights of tribal communities on their TK us necessary at the international level. There is also need to institute mechanisms for sharing the benefits arising out of the commercial exploitations of biological resources using TK. This could be possibly done by harmonizing the different approaches of the convention on Biological Diversity on the one hand and the TRIPS Agreement on the other. The former recognizes sovereign right of the state over their biological resources and the latter treats intellectual property as a private right. India has in fact proposed that in this context, patent applicants should be required to disclose the source of origin of the biological material utilized in their invention under the TRIPS agreement should also be required to obtain 'prior informed consent' (PIC) of the country of origin. This would enable the domestic institutional mechanisms to ensure sharing of benefits of such commercial utilization by patent holders with indigenous communities whose TK has been used. Acceptance of the practice of disclosure and PIC by all patent offices in the world is inevitable and necessary in order to prevent bio-piracy (www.twnside.org.sg/title/cteindia.htm).

Solutions and Possibilities

Reforms are underway to reduce the incompatibilities and discrepancy between the two systems namely traditional Knowledge system and the institution of Intellectual Property. There is significant pressure to integrate traditional knowledge and the related issues in the WTO set of rules. There have been attempts made to codify traditional knowledge at the international level through a series of legally binding treaties. International Treaties are important for traditional knowledge as they set standards and guidelines for business, trade, human rights, access and benefits sharing, conservation, management of biological resources etc. These issues have the potential to impact upon Traditional Knowledge and its protection. Besides it has also been a realization that IPR can actually benefit from traditional knowledge holders by promoting both their material and moral interest without much exploitation. The key to realize these benefits is in understanding how the intellectual property rights system works and the place that 'Traditional Knowledge' can have in the system so that it can be protected. The modalities for protecting TK are still emerging and evolving. Several issues in this context like protecting, recognizing and rewarding of TK especially associated with biological resources are very complex. Countries are grappling to understand their issue and there has been no clarity both at the domestic as well as at the institutional level. Conventional forms of IPR like patents, copyrights, trademark etc are not adequate to protect indigenous knowledge because they are based on protection of individual property rights while TK is largely collective in nature. Communities collectively hold the knowledge. In addition to it, much of informal TK is developed over a period of time and is retained in oral tradition over generations. On such a situation, conditions of novelty and innovative step necessary for granting patent might not be satisfied. However, there have been several efforts towards the protection for TK in India. One of them is documentation of Traditional Knowledge.

Documenting Traditional Knowledge

It is now increasingly becoming important to record and document Traditional Knowledge. Documentation is fundamental to both preserving the knowledge of current and future generations as well as protecting intellectual property rights. But documenting TK is a difficult task. Traditional knowledge along with its scientific potential has several cultural aspects, which cannot be ignored while applying IP rights to TK. It could be spiritual, historical cultural which needs to be determined. *Spiritual category* includes knowledge used during religious ceremonies, considered sacred within a community and known only by sacred and religious persons, which is not to be taken out of its religious context. *Subsistence category* consists of knowledge necessary for the basic survival of the community. Included within this category is knowledge used for food production or any knowledge vital for life and survival. *Economic category* consists of knowledge with strong ties to the economic survival or benefit of the TK stakeholders. It includes knowledge used to produce products for trade or to provide any other substantial economic support to the community. *Traditional Secret* consists of knowledge that is held as a secret among the community. Disclosing knowledge within this category to the general public would be culturally inappropriate. *Medicinal category* consists of knowledge used to cure or prevent medical aliments within a community. Historical knowledge may be related to the history of the community or a specific practice known or used by ancestors that is no longer practiced but still remembered. (Hansen and Justine, 2003)

Knowledge Claim

An element of traditional knowledge for which intellectual property protection could potentially apply is called a 'Knowledge Claim'. If knowledge is based on a biological resource, then this traditional knowledge claim could contains three essential components namely genetic resource, preparation or process and an end result or product derived from a preparation or process. The genetic resource is typically a plant. The process encompasses the various ways of using the plant for an end result. It may include methods of growing, harvesting, extracting, preparing, or applying the plant. The end result is the benefit from using the biological resource and the process. It is also important to mention the specific part of the plant used like stem, leaf, flower, fruit seed etc.

Example

Genetic resource	Processes	**End Results**
Plant (ex: Maca)	Growing Preparing Administering	Increased Livestock Reproduction Improved Human fertility

In this chart, 'plant' (e.g. maca) is a genetic resource. The processes are growing, preparing and administering. The two end results are Increased livestock reproduction and Improved human fertility. These three categories namely (plant, process and product) can be combined in a variety of ways producing several claims. For example, from the simple chart above, it is possible to deduce six claims:

1. A method of growing maca to cause an increase livestock reproduction
2. A method of preparing maca to cause an increase livestock reproduction
3. A method of administering maca to cause an increase livestock reproduction
4. A method of growing maca to improve human fertility
5. A method of preparing maca to improve human fertility
6. A method of administering maca to improve human fertility

Knowledge claims can either be held or practiced by no one, an individual, multiple individuals, a community, or people outside the community. A TK claim should be documented in a manner that by reading the documentation one could fallow the described process and recreate the same result. (Hansen and Justine, 2003)

1. If read by a patent examiner, they could determine how closely, if not exactly, a claim being made by someone else resembles the traditional process or product described.
2. If the process being described may be appropriate for intellectual property protection, it is described technically enough to meet the requirements for a patent application.

In order to meet the above conditions, the TK should be documented to include the following information

Name of descriptive title of the process or product

Who is claiming the process or product

Summary of the process

Resulting product or Results of process

Variations on the product

Results

An example of TK Documentation

To illustrate how a claim may be documented, let's look at an entry from the Honey bee Network's Innovation Database, a large online database of grassroots innovations detailing contemporary and traditional innovative practices.

Claim	Curing Joint Pains
Inventor	Hirabhai Kodarbhai Rawal
Address of Innovator	Sabarkantha Gujarat
Details of Innovation	Hirabhai Kodarbhai Rawal has a special way of treating his animals for stiffness of the body. He prepares a mixture of 250 g variyali (Foeniculum vulgare), 50 g turmeric powder, and 500 g Dalda ghee. This, when given to the animal to drink, loosens the stiffness in the body of the animal and relieves joint pains. Half this dosage is prescribed for very young animals
Reference from	Honey Been, 9(4): 15, 1998

Role of NGO's

NGO's can play a very significant role in the protection of Traditional Knowledge. People's Biodiversity Registers (PBRs) is a unique example in the state of Karnataka whose attempt is towards documentation of local people's knowledge by completing biodiversity registers. The People's Biodiversity Register (PBR), a nation wide initiative for documenting knowledge of local people about biodiversity at village or panchayat level is undertaken though the exercise of 'community registers'. The register records information on biological diversity, which can be source of documentation, relevant to IPR issues. The primary objectives of PBR programme are as follows (Chhatre, A and et.al. Srishtigyaan, 1998:2).

1. Management of bioresources at local level
2. Developing strategies for sustainable extraction and development
3. Management and monitoring of outflows of bioresources
4. Equitable sharing of benefits arising from the use of local bioresources.

The Centre for Ecological Sciences, IISc, Bangalore under the leadership of Dr Madhav Gadgil also pioneered the cause and has established 75 plant biodiversity registers in different pats of the country. SRISTI, the society for Research and Initiatives for Sustainable Technologies and Institutions in Ahemedabad is a popular NGO known for documenting innovation developed by individuals at the village level. The initiative is known as Honey Bee Network and has been fast growing since 1980s. The objectives of SRISTI are as fallows: (SRISTI; 1997:3)

1. Protection of intellectual property rights of grassroots innovators through policy and institutional changes at national and global levels.
2. Documentation, dissemination and analysis of the innovation developed by people themselves.
3. Supporting people to people learning through networking
4. Undertaking action research to generate incentive model so that grassroots creativity is recognized, respected and rewarded.
5. Validating and adding value to local innovations through experiments and research.
6. To implant the insights learned from grassroots innovations in formal education systems so that the cognitive and conceptual space available to these innovations is expanded.

The Jaiv Panchayat: Living Democracy is a movement initiated by Research Foundation of Science, Technology and Ecology (RFSTE) in early 1999. It aims to establish sovereignty of local communities on their biodiversity resources. The members of Jaiv Panchayat are entrusted with the task of inquiring and recording information on biological resrouces and its various uses in the form of Community

Biodiversity Registers (CBRs). On June 5th 1999, the first Jaiv Panchayat completed the Community Biodiversity Registers (CBRs) in Agasthyamuni village Garhwal district of UP and the register was prepared y local people. The examples of Kalpavriksh and Beej Bachoa Andolan (Sacve the Seeds Campaign) in UP are also unique. Kalpavriksh with the help of the villagers of the Teri Garhwal district of UP in 1995 have been involved in documenting various bio-resources and conservation practices used by the community. Beej Bachao Aandolan, which is a network of local farmers, is involved for number of years in reviving and spreading indigenous crop diversity with the help of Kalpavriksh members.

Policy Issues

Policy objectives while considering the IP protection of TK needs equal attention. Some of them in the context of protection and documentation of Traditional Knowledge could be as fallows. Firstly, protection of TK from knowledge extinction or erosion and thus focus on knowledge conservation. Secondly protection, conservation and promotion of TK should evolve as a strategy for sustainable development. Thirdly, unauthorized commercialization of TK with gainful intent should be prevented. Fourthly there should be protection of human and moral rights of TK holders, which could be cultural specific. Fifthly there should be management of cross cultural knowledge transactions between traditional and modern knowledge system. It shall ensure the meaningful understanding of the concepts like 'novelty', 'inventive step' etc. Sixth, attempts should be towards conservation of biodiversity as it is directly related to protection of TK. It also includes the conservation and protection of cultural diversity, which is precondition of conservation of biological diversity.

There is a need to raise awareness of TK/IK in science and technology education as these issues will assist in the broader context of enhancing the contribution of science and technology to human development both globally and locally. As suggested by Rhea (2002), following should be considered in order to raise awareness of TK/IK in science and technology education.

1. Teachers become familiar with conventions that frame the understanding of IK/TK system and traditional ecological knowledge before including it in the curriculum.

2. Teachers develop skills to ascertain the accuracy of any TK/ IK brought into science and technology education

3. Documentation and learning process should be evolved and developed with the joint partnership of both indigenous and non -indigenous people. The holder of Traditional knowledge system and the researchers have collaborative learning partnerships.

Overall, it is important that there is some meaningful collaboration based on trust and respect between the indigenous people and non-indigenous researchers so that the knowledge emerging can be utilized effectively.

Conclusion

The growing interest of IPR is becoming sharper and important in the present knowledge based economy and the information based business in the world economy. The role of IPR is important both in guaranteeing the diffusion of new ideas and in securing the returns to investments in these business. The evolution of the new IP institutions is also accompanied by various challenges and policy issues in the context of new knowledge based economy. The issue of Traditional Knowledge could be one such challenge.

It is crucial to bring together network of people who are economists, lawyers, sociologists, political scientists, policy makers etc. in order to address many of these issues and discuss their implications both at domestic and at global level. Interaction among the academicians, policy makers and practioners are crucial to tackle the emerging issues of IP. It is believed that studies in the area of IP policy are still in a scattered and uncordinated way an there is a serous lack of inter-disciplinary approaches to understand the subject. Besides the technical, economic, legal approach, the study of IPR requires political and sociological approaches to the analysis. Also it needs to be noted that, Intellectual Property policy is an issue of international coordination and has to be set up through concerted actions at international level.

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C. Raghava Reddy

Plant Tissue Culture in Horticulture: From Community Knowledge to Proprietary Knowledge

Abstract:

Traditionally, horticultural plantlets, the primary inputs for orchard and ornamental crop cultivation, have been propagated by nurserymen using conventional breeding techniques like budding, grafting, layering, etc. Plant tissue culture (PTC) technology, one of the commercially successful agricultural biotechnologies, enables *in vitro* production of various horticultural plantlets *en masse* hitherto produced by nurserymen and farmers in a manner similar to industrial production. PTC technology not only industrialized horticulture plant propagation but also paved way for the emergence of global plant tissue culture industry. The PTC industry offers several horticultural plantlets like high value ornamental plants, high volume fruit and commercial crops like banana, sugarcane, potato, etc. As part of globalization plant tissue culture industry, primarily located in the Europe, outsourced the production of plantlets to the PTC units located in the third world countries like India where cost of production is less expensive and abundant skilled workforce is available. However, over the years, the Indian PTC industry not only produced plantlets for export purpose but also evolved as a key player in the domestic horticulture market offering plantlets. The present paper delineates the changes in the knowledge use pattern in production process by comparing the conventional propagation system and the plant tissue culture production system and draws implications for the Indian farming community and policy making. The study found that the conventional plant propagation knowledge developed within the community and its access to the members of the community, including workers, was open. Motivation for conventional plant breeding knowledge generation and its access found to be rooted in the social values of the community to a great extent rather than the commercial interests. However, PTC technology enabled codification of propagation procedure in terms of protocols and thus became inaccessible and secretive. Even the workers who are involved in the propagation process are not aware of the technical content of the inputs used in the process. The study raises two important policy concerns vis-a-vis Indian farming community involved in horticulture. One, would tissue culture technology, by enabling proprietary rights and greater control over technology, exclude the small and marginal farmers? Second, would tissue culture technology based horticultural

plantlets become another *seed*, similar to what had happened in agriculture? Policy measures should focus on the issues of access and affordability of the PTC technology based plantlets and integrating it with the conventional breeding techniques.

Introduction

Agriculture, even today, is the predominant occupation of a majority population in rural India. The social, cultural, economic, and political spheres of this population has been so intertwined with agriculture that every technological change in agriculture has had tremendous influence. One of the major fields of agriculture that provides livelihood to a considerable number of people is horticulture. Horticulture deals with breeding and cultivation of plants of flowers, fruits, vegetables, spices, ornamentals, etc. Historically, cultivation of fruit, flower and spices was practiced along with other food crops. However, after green revolution, horticulture undergone radical changes and evolved as a prominent field with commercial potential to generate income and employment. The trade of commercial propagation and sale of horticultural plantlets is one such field. Propagation of horticultural plantlets has been well-established in certain areas in the country. The commercial propagation units, known as nurseries, are spread all over India. Because of favourable climatic conditions majority of the nurseries are concentrated in certain states like Uttar Pradesh, Andhra Pradesh, Maharashtra, West Bengal, and Karnataka, thus providing employment to farmers (nurserymen), agricultural workers and traders. The most widely used methods of propagation by commercial nurseries are grafting, layering, budding, cutting and seed propagation methods.

However, with the application of plant tissue culture technology in horticulture the field of commercial horticulture has undergone radical changes. Proponents of plant tissue culture technology in propagation of horticultural plantlets claim that it holds several advantages such as mass production in a small area round the season, possibility of production of disease free plantlets, etc. It is considered superior over conventional plant breeding techniques used by the traditional nurseries. The expansion of plant tissue culture has been enthusiastically endorsed by state and federal governments with financial assistance and recognition of plant tissue culture units as industry. As a result, many big Indian industrial houses and technocrats-turned-entrepreneurs, with liberal credit assistance from financial bodies started commercial propagation of horticultural plantlets.

Objectives

Traditionally, various horticultural plant species in India are propagated by using conventional plant breeding methods. However, plant tissue culture is limited in its application to a few species. Vigorous research efforts of private and government research centers indicate that protocols for many more plant species will be developed in the near future. A situation is not far when a whole range of horticultural species will be propagated through tissue culture in the sophisticated laboratories replacing traditional nurseries. The entry of plant tissue culture industry into domestic market offering plantlets hitherto produced by farmers and nurserymen likely to lead to a wide ranging changes in the trade scenario as well as social and economic aspects of farmers, nurserymen and traders involved in commercial horticulture. The present paper makes an attempt at capturing the changes in the process of horticultural plant propagation as a result of introduction of tissue culture technology. The findings discussed here are based on a comparative study of production processes in conventional nursery and tissue culture industry. The paper brings out the changing forms of knowledge generation and its application vis-a-vis propagation technology and attempts to draw implications of such changes on the Indian farming community, particularly, the small and marginal farmers. The paper opens with a discussion on the implications of agricultural biotechnologies and presents the status of Indian agriculture and the status pf plant tissue culture industry India before presenting findings based on the comparative analysis of conventional and PTC production systems.

Implications of agriculture biotechnologies

The social consequences of biotechnology as projected by various studies are enormous and wide ranging. Biotechnology is considered as the most important technical force that will shape world agriculture over the coming decades (Otero, 1991). As green revolution can no longer sustain higher yields with minimal environmental damage, biotechnology is projected as the most reliable and environmentally acceptable way to secure world's food supplies. However, the improvement of the livelihood of small farmers and wage workers depend on the possibility of raising yields and reducing costs of production which is possible through biotechnology (Galhardi, 1996).

It is viewed that biotechnology is the brainchild of industrial countries. While green revolution was meant for third world countries, developed by the public funded research institution, biotechnology research has largely been confined to private domain. Biotechnology is a two edged sword which way it cuts depend largely upon who yields it and how (Kloppenberg, 1988). It is a technological innovation characterized as, in economists' terms, "technologies push", where the scientific research group develops an innovation where upon products and markets are subsequently bought, for example, lasers. In common with electricity a century ago, biotechnology is today a technology in search of applications (Krimsky and Wrubel 1996).

In the name of efficiency in food production, generic changes are designed to enhance a factory-like efficiency, thus promoting industrialization of agriculture. Environmentalists attack such developments aiming "to convert agriculture in to a branch of industry" (Levidow, 1998). This argument is further strengthened by the fact that biotechnologies do not function at village level. The investment required to sustain a viable biotechnological oriented industry sector is enormous, demanding both high levels of capital investment and also a highly skilled and trained work force (Ratledge, 1992).

Biotechnology can raise the possibility of an agricultural inversion. That means food production will take place to a greater extent outside the farm in enclosed continuous process bioreactors (Krimsky and Wrubel, 1996). Through plant tissue culture, which enables '*in vitro*' production, it is possible to overcome the spatial, temporal and climatic barriers to food, plant and fibre production. Since plant tissue culture technology is capital and knowledge intensive, it cannot be applied in the traditional production setup. Propagation and multiplication of plant material, once under the control of farmers, may begin to shift to industrial tissue culture farmers. Thus the scope for elimination of major aspects of the farming enterprise is enormous and could displace farmers and farm workers on a scale never before possible. This change alone is likely to bring with it substantial social upheavals as the location of production changes.

In industrializing agriculture, biotechnology attributes human qualities as properties of things, such as genes for 'efficiency' or 'value-added'. Nature and agriculture are recast in biotechnology images through metaphors of code, combat and commodities. These become literal investments in standardizing, ordering and capitalizing nature. In the search for genetic fixes, nature and agriculture are biotechnologised (Levidow, 1998).

Biotechnology as Buttel (1989) proposed will be more a substitutionsist technology to be applied in declining sectors (agriculture) of the economy (Otero, 1991). The argument is supported by the fact that technologies like tissue culture, cell culture are used to manufacture industrial substitutes for agricultural crops which otherwise have been imported from third world countries. Plant tissue culture can now offer plantlets which otherwise have been produced by farmers. Goodman, Sorj and Wilkinson (1987) have described this process as 'appropriationism' and 'substitutionism' where by the rural base of agriculture is being displaced by urban/ industrial base.

Biotechnologies will force many classical methods into obsolescence and will have profound effect on traditional goods which are produced and traded locally as well as internationally (Ventura, 1982). The kind of research carried out to improve current varieties using plant cell and tissue culture, tends to cater for the needs of the international markets rather than for domestic needs. Biotechnology is likely to affect the small farmer adversely. The adverse impact may arise because any technology which is technically scale neutral (i.e. divisibility of inputs which can be equally well applied to every tiny plots of land) but capital intensive is likely to remain outside the small farmer's reach. Benefits arising plant tissue culture such as for instance the selection of higher-yielding clones or *in vitro* vegetative propagation of cultivars of desirable agronomic characteristics would probably strengthen large agricultural estates rather than improve the standard of living of small land holders. This is because the large agricultural estates have access to operational skills, financial resources and market experience, all of which enable them to take full advantage of the latest know-how and technological application. Small landholders and land less farmers run the risk of being displaced by further expansion of large agricultural estates (Sasson, 1988).

Status of Indian Agriculture

Indian agriculture is inherently fragile in the sense that it is highly vulnerable to the changes in the domain of agricultural technologies as well as economic policies pursued at the national and global level. The frailty of Indian agriculture is attributed to the structural differentiation which is so skewed that majority of the operational holdings are less than one hectare of land (see Table 1). Horticulture, a key component of commercial agriculture, is an important field that provides employment to a considerable section of rural population in India. A wide section of rural population namely farmers as growers and nurserymen, wage labourers, marketing agents, post harvest workers, transport agents, etc. are involved in horticulture. The cultivation of horticulture plants whether fruit, flower, plantations, etc. is largely carried out under small holdings. The structural differentiation of land holdings in horticulture are similar to that of agriculture.

TABLE 1: STRUCTURAL DISTRIBUTION OF LAND HOLDINGS

Classification of holding	Size of the holding (in hectares)	% of the total operational land holdings
Marginal	Less than 1 ha	70
Small	1to < 2 ha	16
Semi-medium	2 to < 4 ha	9
Medium	4 to < 10 ha	4
Large	10 ha and above	1

Source: "Some Aspects of Operational Land Holdings in India, 2002–2003", NSSO Report No. 492, Ministry of Statistics and Programme Implementation, Government of India.

What is Plant Tissue Culture?

Plant tissue culture is the technique of growing plant cells, tissues and organs in an artificial nutrient medium static or liquid, under aseptic conditions. Based on the principle of 'totipotency' — ability of any plant part cell to grow into a full plant, parts of the plant, referred to as explants, such as buds, root tips, nodal segments, or germinating seeds are used for micropropagation. The selected explants are placed in suitable nutrient media where they are allowed to grow into an undifferentiated mass known as callus. The callus after disinfection is propagated indefinitely by subdivision. The whole process is carried out under completely controlled environment and independently of weather, season and climate.

Tissue Culture can ensure virus and disease free planting material of uniform yield potential. Although the tissue culture plantlets are more expensive than the conventionally propagated ones, the advantages tissue cultured plants offer to the farmer is that the yield is synchronized, uniform and true-to-type with the mother plant. Synchronized yield and uniformity in yield are important commercial advantages for the farmers. Another important advantage that Tissue culture technology offers is that it decouples the production process from land. In the entire tissue culture production process land relegated to the end stage. The tissue culture plantlets are acclimatized in the greenhouse before sending them to the farmer. And hence, tissue culture units can be set up anywhere as most of the tissue culture based production process takes place in laboratories. This is a significant departure from the agricultural technologies so far introduced. Tissue culture, one of the biotechnologies, by decoupling the production of plantlets from land raises important concerns for the farming community in the country.

The reason for growing interest in commercial applications of micropropagation in horticulture is due to the inherent limitations of conventional plant breeding methods. Conventional propagation methods are slow and require huge numbers of parent propagule material. Moreover, in conventional propagation quality of the plantlet is greatly dependent upon season, age of the parent tree, availability of disease-free mother plants, freedom from damage from fungi and insect pests during propagation and availability of moisture at the critical time of rooting.

Tissue culture technology ensures quality plantlet as it is possible to select the quality mother plant and can ensure the production of true-to-type plantlets. Hence, tissue culture techniques are now widely used for the production of disease-free plants, multiplication of vegetatively propagated plants and germplasm storage (Ahloowalia, 2000). Since 1970 many fruit species like banana, papaya, pineapple, grapevine, and rootstocks of peach, apple, pear, plum, cherry, etc. and ornamentals and foliage plants are produced in millions through micropropagation. The technology is also used for production of disease-free mother-stock cultures, which are then used as a source of conventional cuttings. The advances in micropropagation now allow routine regeneration of 15 major vegetables and some tropical root and tuber crops (e.g. cassava, yam, coco and sweet potato). During the past 30 years, an entirely new industry has developed based on micropropagation which has now grown into a multi-million dollar business.

Plant Tissue Culture in India

India became a destination for tissue culture laboratories as part of cost cutting strategy of the global tissue culture industry. As tissue culture technology facilitates the production of plantlets anywhere irrespective of weather and other climate parameters the tissue culture companies started production units in collaboration with Indian partners or outsourced the production to Indian companies. Also, India enjoys the advantage of vast pool of skilled manpower as well as cheap labour.

Realizing the potential of plant tissue culture technology in revolutionizing the commercial agriculture sector by enabling mass propagation of elite, high yielding and disease free plants throughout the year, the Department of Biotechnology (DBT) identified it as a priority area and initiated a number of programmes aimed at development and commercialization of the technology in an integrated manner. The formation of the Department of Biotechnology and subsequent Hi-Tech industry status given to plant tissue culture provided fillip to the emergence of plant tissue culture industry in India (Singhal, 1996). At the same time the government of India identified micropropagation of plants as an industrial activity under the Industries (Development & Regulation) Act of 1951 and offered several other incentives (Govil and Gupta, 1997).

Presently several horticulture plant species ranging from vegetable to plantation, fruit, flower and medicinal plants are being produced through micropropagation in Indian commercial tissue culture units. Table 2 shows the portfolio of plants produced through micropropagation in India.

TABLE 2: LIST OF TECHNOLOGIES WHICH HAVE BEEN PERFECTED FOR LARGE SCALE PROPAGATION

Plant category	Plants
Fruits	Banana, grapes, pineapple, strawberry, sapota
Cash crops	Sugarcane, potato
Spices	Turmeric, ginger, vanilla, large cardamom, small cardamom
Medicinal plants	Aloevera, geranium, stevia, patchouli, neem
Ornamentals	Gerbera, carnation, anthurium, lily, syngonium, cymbidium
Trees	Teak, white teak, bamboo, eucalyptus, populus

(Source: Summary Report on Market Survey on Tissue Cultured Plants — BCIL, 2005)

There are about 46 established commercial tissue culture units operating in India. Their production capacity ranges between 1 million to 5 million and above plants per annum with an aggregate production capacity of 180 million plantlets per year (BCIL, 2005). Initially, these companies were largely concentrating on the international markets. However, due to a number of constraints such as short shelf life, stringent quality norms and uncertainty many companies shifted focus to the domestic market. Traditionally, the plantlets for a variety of horticultural plants have been produced by nurserymen using conventional breeding techniques. Growers (farmers who cultivate horticultural plants in orchards), farmers (who cultivate seasonal, annual, biennial horticultural plants) largely depend on the nurserymen who produce the plantlets (planting material). The demand for the plantlets is high and there is also a demand from the growers for quality plan material. Table 3 shows the horticulture scenario in India. Considering the high rate of consumption of conventionally propagated plants in the domestic market and the perceived potential of tissue culture plants for improving overall productivity the tissue culture industry has started producing for the domestic market.

TABLE 3: AREA AND PRODUCTION UNDER HORTICULTURAL CROPS
[AREA IN 000 HA, PRODUCTION IN 000 MT]

Horticultural crops	2006-2007				2007-2008			
	Area	%	Production	%	Area	%	Production	%
Vegetables	7584	39.5	115011	60	7803	39	125887	61
Fruits	5554	28.9	59563	31	5775	29	63503	31
Plantation crops	3207	16.7	12007	6	3226	16	12045	6
Spices	2448	12.8	3953	2	2603	13	4103	2
Flowers	144	0.7	880	0.5	161	0.8	870	0.4
Aromatic and Medicinal plants	324	1.7	178	0.1	386	2	325	0.2
Total	19261		191592		19954		206733	

Source: Indian Horticulture Database, Ministry of Agriculture, Government of India, 2008.

Initially, production of tissue culture plantlets for the domestic market was largely been confined to a few plant varieties namely, banana, eucalyptus and other ornamentals. However, over a period, protocols were developed for plants that offer high volume sales. They include non-fruit crops as well. For example, potato and sugar cane. In banana suckers are being produced using tissue culture technology. Likewise potato and sugarcane planting materials are being offered by PTC companies. Farmers, who have been largely dependent on the nurserymen for the plantlets have started to consider the use of tissue culture plantlets. Added to the efforts of the tissue culture industry to capture the domestic market is the incentives offered by the federal and state governments to promote the use of tissue culture plantlets. Table 4 presents the increasing domestic consumption of tissue culture planting material in India.

TABLE 4: DOMESTIC CONSUMPTION OF TCPS

(Volume in thousand nos., Value in Rs. Lakhs)

Crop	Year									
	2003-04		2004-05		2005-06		2006-07		2007-08	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
Banana	21613	1945	27537	2478	35808	3223	47470	4272	64060	5765
Pineapple	4618	693	5080	762	5588	838	6147	922	6761	1014
Grapes	926	232	975	244	1026	257	1080	270	1137	284
Sugarcane	14791	592	16271	651	18709	748	22449	898	28055	1122
Potato	6		10		22		43		83	
Turmeric	634	44	698	49	767	54	844	59	929	65
Vanilla	1000	70	1245	87	1123	79	1123	79	1123	79
Large Cardamom	2000	140	2000	140	2000	140	2000	140	2000	140
Small Cardamom	200	18	300	27	400	36	500	45	600	54
Ginger	401	28	441	31	484	34	533	37	586	41
Medicinal and aromatic plants	2100	105	11510	576	11741	587	11995	600	12275	614
Ornamentals	20290	3044	18120	2718	18944	2842	19973	2996	21172	3176
Trees	3000	750	3380	845	3824	956	4342	1086	4951	1238
Total	**71579**	**7660**	**87567**	**8607**	**100436**	**9793**	**118499**	**11404**	**143731**	**13592**

Source: Summary Report on Market Survey on Tissue Cultured Plants — BCIL, 2005.

The federal government integrated the incentives of tissue culture plantlets as part of its larger policy of promoting horticulture in the country. For example, it provides financial assistance to set up tissue culture units, to purchase planting material under the area expansion programme for the crops like banana. States also have been providing financial assistance for setting up tissue culture laboratories under its agro-industrial policy. Apart from this, certain states also provide 50 percent subsidy to farmers to purchase tissue culture plantlets. For example, Andhra Pradesh state gives 50 percent subsidy to purchase tissue culture banana.

Findings and Discussion

Findings discussed here are based on an empirical study of plant tissue culture units and conventional nurseries located in the southern part of India. The study was carried out to examine the nature of production using tissue culture technology and to draw significant departures from the conventional practices. To map the differences in the production process a bench mark study was carried out in the nurseries where conventional propagation techniques are used. The findings are used to draw implications for the farming community in the country.

Traditionally, horticultural plantlets are produced in the nurseries using conventional plant breeding techniques like budding, grafting, layering, seed propagation, etc. The output of two kinds of production processes i.e. plant tissue culture technology based and conventional propagation techniques based, is similar. However, technologies employed in the production of horticultural plantlets are different. The conventional nurseries produce a wide variety of plantlets whereas the tissue culture units concentrate on a few horticultural plant varieties. The reasons for narrow plant range of tissue culture units are two-fold. One, protocols (a protocol specifies different components of media in the form of pre-assigned codes) for all plant varieties have not been developed. Protocols are available for high value and high volume plantlets that have huge market. Second, the commercial interests that guide the research and development efforts of the tissue culture units to develop protocols. In the case of Indian tissue culture units, they concentrate their research and development efforts on those plants that offer high volume sales.

Though the outputs are similar the production technologies employed are dissimilar. How the different production technologies operate and the implications for different communities like nurserymen, farmers and growers are discussed here. Both the production technologies and the social organization of production are discussed and in the conclusions implications for the communities are presented.

Conventional Nursery Production

Commercial propagation of horticultural plantlets has been carried out in the study area (the study was conducted in a coastal district of Andhra Pradesh, South India, where large number of nurseries are located) for the past seven decades. Prior to the emergence of nurseries farmers in the region were engaged in the cultivation of flowers like rose, marigold, chrysanthemum, jasmine, lily etc. Though the seeds of commercial nurseries where horticultural plantlets are propagated on commercial lines were sown in 1930s large scale propagation to the tune of exporting the plantlets across the country and to South East Asian nations began during the past three to four decades.

The first nursery was started in 1933 by an enterprising farmer in the region (Reddy, 2002). The individual farmer's curiosity to experiment with propagation based on the empirical knowledge that soil, climate and other natural elements in the region favour the propagation of plantlets on mass scale gave rise to the emergence of commercial nurseries in the region. The initiative of the farmer prompted others in the region to start propagation operations on commercial scale. Over the next few decades farmers in the region had shifted from cultivation of flowers to commercial propagation of horticultural plants.

Initially, the knowledge of propagation of various kinds of horticultural plants was not readily available to the farmers. In the quest to master the procedures of propagation many a farmers in the region attempted number of trials which were conducted though in unscientific manner but based on empirical knowledge derived from experience. Farmers neither had formal academic qualifications in plant sciences nor was there any institutional support in their effort. Even today majority farmers in the study area do not possess formal education beyond tenth standard. Despite these odds over a period few enterprising farmers succeeded in standardizing the propagation procedure/method for a variety of plant species. Each plant species is propagated in one method that is most efficient in terms of cost, time and money. The contribution of the community members constituting farmers, farm workers was immense in the process of standardizing the procedures of propagation. Such knowledge, i.e. the knowledge of the standard method of propagation was never appropriated for gain by the farmer who took the initiative and succeeded. However, it was freely shared with fellow farmers, workers and other members of the community. The most significant aspect of knowledge production and its dissemination was the community proprietorship of the knowledge of standard propagation procedures. Unlike biotechnologies, which are tied to intellectual property rights and control over knowledge, the conventional plant breeding knowledge was developed and owned collectively.

Generation of knowledge is neither linear nor spontaneous. It took several years to develop the presently used breeding techniques indigenously and standardize them. The inspiration to develop knowledge came from the farmers who initiated the nursery trade in the village. Community intervention in knowledge generation and dissemination may be found in three spheres of activity. First, development of appropriate breeding method for each plant species, second, adaption of an exotic plant variety to local conditions and third, constant search for augmenting the efficiency of the so called best propagation procedures and methods. Generally, the process begins when a farmer finds interesting plant species elsewhere and develops an interest to localize. With the help of their acquaintances plants are procured and through trial and error the appropriate propagation method is developed and acclimatization practices are created. Today one can find a number of exotic plant species successfully propagated by the nurserymen in the area. The innovative practice is shared with fellow farmers as innovations and new knowledge brings prestige and recognition in the community. The community value system places high emphasis on innovation and possession of rare or exotic plants is considered as a privilege which bestows high status. Thus, farmers try to gain recognition for their innovations rather than use it for commercial exploitation.

The knowledge thus acquired is passed on to the younger generations through oral and informal means. Such knowledge is open and freely accessible to all the farmers and workers. The continuous interaction with external sources had helped farmers in upgrading their knowledge further. Through the external sources of contacts such as farmers of other parts of the country involved in the same occupation, traders and the urge among farmers to propagate new plant species led to rapid advancement and indigenization of the propagation techniques.

Tissue Culture Technology based Production

Tissue culture technology has brought in several changes in the organization of production of horticultural plantlets. Core production operations involved in tissue culture production are carried out in closed concrete structures such as lab, growth rooms, etc. Also plantlets are raised and acclimatized under controlled climatic conditions. In contrast to the conventional nurseries that are spread over many acres the physical area used for tissue culture propagation is spread over few hundred square feet.

The norms of work and the content of work have been significantly altered with tissue culture technology due to decoupling of production operations from land. Work is essentially guided by the standard operating procedures. The pace and content of work is framed by the technological factors rather than climatic and other external factors as in the case of conventional nurseries. Tissue culture production process is complex, sequentially interdependent and multi-staged.

Technology, when tied to commercial interests and developed by private initiative involving substantial financial investment, becomes secretive and inaccessible. Commercial exploitation of technological innovations to their fullest potential tends to be the dominant objective of any privately funded research. To a great extent, plant tissue culture technology is the product of privately funded research institutes in developed countries. Such knowledge in plant tissue culture is codified in terms of protocols. A protocol specifies the proportionate contents of media for plant growth. Protocol varies from species to species. In the tissue culture industry protocols are tradable commodities. In order to produce plantlets through tissue culture technology the company must acquire the knowledge which is available in the form of protocols. The content of the protocol is related to the process of media preparation. Media contains essential nutrients which help the growth of shoots and roots of the tissues. In the tissue culture companies the protocol is secretly guarded and never disclosed in its original form. Even the technician who prepares the media is not aware of the content of the media as the contents are given in the form of codes. Almost all tissue culture companies also devout resources to research and development. Research and development basically aims at developing protocols for plants as a new protocol gives trade advantage to the company.

Proprietary control over knowledge is considered as a trade advantage over other companies. Hence, the tissue culture companies during lean period research oriented experimental projects such as development of protocols for new plant varieties, initiation of cultures in different nutrient and root media, etc. are carried out. In-house research and development, though at a low-level, is a common practice in all the tissue culture companies. In India the present scenario is that protocols are established only for a few varieties of fruit, ornamental and plantation plants. There are many commercially viable plant varieties for which protocols are yet to be established. Once a company gains knowledge of protocol of a particular plant variety through in-house R&D or by acquisition of protocols under various agreements, including outright purchase from outsiders, it tries to derive trade advantages over rival companies by introducing its products first in the market. It is also common to find tissue culture companies vie for patents.

Tissue culture technology has created a new feature in the field of horticultural plant production, i.e. proprietary knowledge. Apart from the issue of proprietary knowledge the tissue culture technology also brought several significant changes in the production process. They include routinization of tasks, control, dehumanization of work, etc.

Production process using tissue culture technology is carried out through schedules and standard operating procedures. The standard operating procedures dictate task performance to the minutest extent leaving no scope for technicians to use discretionary abilities. As a result a technician in a tissue culture unit is a human machine or a "cog in the wheel" expected to perform the given tasks repetitively. Tissue culture technology enabled management better control over workers. It not only enabled control over agro-climatic conditions in the production of horticultural plantlets by creating "second nature" but also helped management to discipline the workforce and controlling the quality of work.

Tissue culture technology, through standard operating procedures, resulted in routinization of tasks, particularly that of technicians thus leading to regimentation. The job of technicians is highly routinized owing to two reasons. One, the technicians' job is completely guided by the standard operating procedures. Second, the tasks assigned to them are repetitive in nature. Irrespective of the plant type, whether banana or sugarcane or teak, the steps involved in sub-culturing are more or less same. Repetitive tasks when guided by standard operating procedures become routinized. Since task variation consumes more time, management ensures that the tasks of the technician do not vary. Instead of using a variety of skills and working at their own pace, technicians perform specialized and repetitive tasks that are dictated by the tempo of the production process (Reddy, 2007).

Conclusion

Plantlet or sapling is the key component in horticulture. A plantlet or sapling in horticulture is similar to seed in the cultivation of food crops. Traditionally farmers and nurserymen have been producing the plantlets using conventional breeding techniques conventional propagation methods such as budding, grafting, layering, etc which are purchased by the horticulture farmers. Plant tissue culture technology is one of the successful commercial biotechnologies used to propagate horticultural plantlets. Tissue culture is considered as superior technology to produce high quality plantlets when compared to the conventional methods. Supported by state policies that encourage plant tissue culture technology through liberal financial assistance and subsidies many plant tissue culture units in India have been offering the plantlets. This has given rise to a situation where in two kinds of horticultural plantlets are available to the farmers. One kind of plantlets, produced through conventional breeding techniques, available to the growers at affordable prices. Another kind of plantlets produced using plant tissue culture technology, though available through state subsidies, unaffordable by small and marginal farmers.

Significantly, tissue culture technology decouples the production process from land. Land, a critical element in conventional horticulture plant propagation, is substituted with laboratory by tissue culture technology. This is a critical departure from the agricultural technologies so far introduced. Tissue culture technology by decoupling the production of plantlets from land raises important concerns for the farming community in the country as it may lead to agriculture inversion when the ambit of tissue culture technology enlarges.

Production takes place outside farm substituting land for lab operationalized by technocrats and production operations carried out by technicians replacing farmers and workers. The social organization of tissue culture technology production is similar to that of a manufacturing industry. Thus tissue culture technology has industrialized the production of horticultural plantlets (Reddy and Haribabu, 2002). Tissue culture technology not only industrialized the production process but it also commodified the knowledge of propagation. This further raises concerns of affordability, access and control. Conventional breeding technologies are affordable and access to knowledge has always been in the public domain. In fact, in the study area, breeding techniques were standardized with the active participation of community members. The knowledge thus generated has been open and accessible to all. Social value system plays an important role in the innovation as well as dissemination process. In contrast, plant tissue culture technology is tied to proprietary rights and commercial interests play important role. The knowledge generated is a tradable commodity.

Plant tissue culture industry has taken roots in India as part of the larger process of globalization. PTC technology which decoupled production process from land enabled production outsourcing. Liberalization policies of India promoted technological advancements in agriculture that lead to exports. Plant tissue culture industry has been recognized as a key industry potential to earn valuable export revenue providing employment as well. As part of liberalization process, the industry has been given incentives, permissions and liberal financial assistance. Research in the area has been vigorously pursued by public and private funded institutions and successful technologies have been promoted. However, technological options in agriculture have to be exercised keeping the interests of the primary stakeholders i.e. farmers in mind. Any agricultural production technology that operates above farm level leads to agricultural inversion. Moreover, any technology that is tied to proprietary rights invariably increases the cost of production and dependency on external sources.

In the process of promotion of PTC it is also important to understand its implications on wide sections of population. The policy initiatives focus on the promotion of PTC units and widening the ambit of PTC but not on integrating the PTC with conventional breeding methods at the conventional nursery level. Policies aiming at promotion of use of tissue culture plantlets in horticulture must focus on low-cost options in producing tissue culture plantlets (IAEA, 2004). Also, the policy measures must attempt at integrating the PTC technology with the conventional breeding techniques at the farm (nursery) level. State initiatives must aim, at the first instance, upgrading the institutional support to the nurserymen and farmers in terms of training in advanced technologies and materials used in conventional breeding thus enhancing the efficiency of nursery. At the next level, propagation of plantlets must be recognized as an industry and liberal financial assistance must be provided. For a long time, a nursery was neither recognized as part of agriculture nor industry thus hindering the access to policy incentives and financial assistance. For example, when a severe cyclone struck this part the only group of farmers that was not provided any financial relief was the nurserymen just because nursery was neither recognized as agriculture nor as industry. The group of nurserymen, marginal and small farmers is the important group to be kept in mind while proposing any policies that encourage application of agricultural biotechnologies. Agriculture for this section of farmers is not a commercial enterprise but a source of livelihood.

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Ejnavarzala Haribabu

Open Source Route to Innovations in Agricultural Biotechnology

Abstract:

The changes ushered in by the economic liberalization policy in India, facilitated the entry of private enterprise in many areas of the production of goods and provision of services in which the state was a major actor during the pre-liberalization period. The process of globalization facilitated by the WTO in the 1990s created an environment for the entry of foreign private enterprises to invest in India in the production of goods and provision of services. The WTO norms on Intellectual Property Rights (IPRs) institutionalized protection of inventions. In the context of agricultural biotechnology arguments in favour of proprietary technology are: that protection of knowledge is a compensation for the time, money and intellectual effort that is expended in bringing out the invention and also an incentive to the inventors. Arguments against the proprietary technology are: nobody invented genomes of crop plants and the proprietary technologies based on genomic knowledge restrict access to knowledge and products. In this context attempts are being made to explore the open source software development for innovations in agricultural biotechnology as an alternate model to proprietary technology development model. The model, based on free software model, has the potential to develop innovative technologies on the basis of the genomic knowledge that is available in the public domain. The paper reviews the reactions to the genetic engineering technology and examines the open source model in biology as an alternative to proprietary genetic engineering technology by illustrating the Marker-Assisted Selection (MAS) technology as an important route to pro-poor innovations in agricultural biotechnology.

Introduction

Reform process initiated in early 1990s in India, the principal element of which is economic liberalization. Economic liberalization meant opening up of the areas of the economy which were hitherto in the domain of the state. Globalization, characterised by flow of capital, technology, culture including knowledge across national borders is facilitated by the WTO, a multilateral institution. Internally liberalization policy provided opportunities to foreign players to enter the above areas of the Indian economy. These changes have begun influenced agriculture sector as well. In the following paragraphs we will see how production of seed, one of the crucial inputs in agriculture has become a proprietary product over time.

Historically human societies across the world succeeded in selecting the edible crop plants, fruit plants, vegetables, tubers and flower plants successfully conserved the germ plasm of these plants. The knowledge about selection of plant varieties and their breeding was on the basis of empirical observations and trial and error methods. Over time farming communities accumulated empirical knowledge about production of seed, storage of seed for reuse and conservation of the seed and the produce arising out of the practices. In other words, farmers acquired control over seed production and its conservation *in situ* or on the farms. The genetic property of the seed to multiply, and the control over the seed through *in situ* conservation made agriculture a recalcitrant sector for the entry of capitalist enterprise until the early 20th century. However, contributions of Gregor Mendel in the early 20th century in understanding of the laws of inheritance of traits led to scientific breeding of plants. During the 1930s, in the USA for the first time some entrepreneurs with the help of plant breeders employed in agricultural universities succeeded in producing hybrids on a commercial scale and demanded legal protection for the information on the parental lines that were used for obtaining the hybrids as trade secret. This was recognized by the state as breeders' rights (Kloppenburg 1989). Commercial production of hybrids marks the beginning of the entry of capitalist enterprise in seed production and the gradual decline of farmers' control over seed production. Breeders' rights are now protected by the provisions of the WTO.

The specialty of Social Studies of Science and Technology (SSST) attempts to understand the technology — society dynamics. The factors that shape technology development and its deployment and its influence on economy, polity and culture are significant themes in the specialty of social studies of science and technology. Historically conceptualization of the relations between science and technology on one hand and society has been undergoing change. Initially science was seen as a morally neutral act of knowing and technology was seen as the act of doing. Later the relations were conceptualized in terms of symbiosis (Price 1982). The terms — science and technology- are historically produced and their meaning, hence, is not static (Layton 1974). More recently with the convergence of science and technology in areas such as molecular biology, the relations are conceptualized in terms of techno-science, according to which the science and technology are interpenetrating systems of knowledge and practices and they are shaped by economic, political and cultural domains (Latour 1982, Ziman 1996, and Haraway 1999). Now the significant questions in the context of biotechnology in general and agricultural biotechnology in particular are: How do science and technology interact with economy polity and culture and the consequences for social groups, classes and communities and how the social, economic and cultural contexts shape technological innovations to address questions of poverty and environmental implications.

Modern biotechnology and innovations in agriculture:

The discovery of the double helical structure of the DNA by Watson and Crick (1953) opened up the possibility of understanding the life processes at molecular level and eventually opened up the possibilities of interventions in the life processes at molecular level. The technological breakthrough achieved in the mid 1970s made it possible to transfer genes from one organism to another, irrespective of the taxa to which of the organisms belonged. Thus, engineering genes from one organism to another acquired the label of recombinant DNA technology or genetic engineering technology. These developments ushered in what is now popularly known as gene revolution in contrast to the green revolution of the early 1960s based on high yielding varieties of seed and hybrid seed. The corporate sector became the locus of production of hybrid seed and other inputs such as chemical fertilizers, pesticides micro-nutrients etc.

Modern biology ushered in a body of techniques. Tissue culture is a technique based on the principle of totipotency, according to which any part of the plant has the potential to grow into a full plant. This technology does not involve transfer of genes from one organism to another. This has become a popular technique in horticulture in India (Raghava Reddy and Haribabu 2000). Cloning is another technique that is used to produce identical plants and animals from mother plant or animal. This technique has also become controversial from moral and human and animal rights perspectives.

Genetic engineering technology: Proprietary technology

Genetic engineering, as mentioned above, involves transfer of genes from one organism to another irrespective of the taxa to which the organisms belong. The innovation potential that the rDNA technology offered made the corporate sector enter the plant biotechnology research and development in a big way. As a consequence today the R&D based on molecular biology are concentrated in big business corporations. In other words, modern biology has become industrialized in a new way in the later part of the 20^{th} century.

An example of genetic engineering is the Bt cotton seed into which a toxin producing gene from Bacillus thuringiensis (Bt) has been transferred to confer resistance to the cotton plant against the bollworm, a major pest, that attacks the cotton plant. The Bt technology is a proprietary technology owned by Monsanto, a corporate company. Further, biotechnological innovations are now protected by the provisions of the Intellectual Property Rights (IPRs) of the WTO. In other words, science is no longer morally neutral study of nature and it has intimate links with industrial interests and has thus become an intellectual property (Ziman 1996). It is increasingly being realized that genetic engineering technology has some inherent limitations, set by nature and culture.

Regarding the constraints/limits set by nature, initially molecular biologists and biotechnologists believed that single gene controlled single trait. Based on this assumption single genes were transferred to organisms. It is now realized that a single trait is controlled by more than one gene and these genes have to be identified for transfer. The costs of identifying genes and transferring them into the plant genome are very high. Further, the foreign gene, once transferred into a plant remains permanently in the genome of the transgenic plant. As part of the natural process of gene flow, a foreign gene may flow into non-transgenic plants of the same species and some times other species.

Genetic engineering has also been questioned on moral and religious aesthetic grounds. Questions such as what moral right do we have in interfering with nature. Religious considerations arise from the belief that God created the world. Can human beings tamper with God's creation? In Europe there has been opposition to genetically modified crops due to unknown risks for human beings and environment. However, scientists argue that genomes of organisms are not static and several changes have been taking place in the genomes of organisms due to adaptation and mutations in the course of evolution of organisms. In terms of the environment, there are apprehensions that the genetically modified crops may harm useful organisms due to toxicity of the foreign genes in plant. In other words, different stakeholders view agricultural biotechnology from the vantage point of their interests and meanings (Haribabu 2004).

In terms of production and distribution of and control over seed, the green revolution technology, based on high yielding varieties of seed was developed in the public institutions, both national and international, and made available to farmers in India as in many other developing countries at affordable costs. In contrast, in the case of genetic engineering technology R&D and production of genetically modified seed as mentioned above, is concentrated in big industrial corporations which make use of provisions of the IPRs to protect the seed and thus maintain control over the seed. Further, the inventions based on molecular biology knowledge and tools are protected by the WTO provisions on IPRs. Public institutions especially in most of the developing countries have not been able to invest resources, both human and financial in knowledge intensive and capital intensive innovations based on molecular biology.

The Changing Agricultural R&D scenario in India:

In India, the Green Revolution was ushered in due to the R&D efforts of public institutions such as International Rice Research Institute, Manila and CYMMIT, the wheat research institute based in Mexico. The national institutions like the Indian Council for Agricultural Research (ICAR) and the Agricultural universities played an important role. With advances in molecular biology knowledge and tools the public institutions in India, in many developing countries as mentioned above, have not been able to compete with private corporations in terms of equipping themselves with knowledge and the necessary infrastructure to carry out research for crop improvement due to paucity of resources, both human and financial until the 1980s. However, the situation has started changing since the 1990s with the Rockefeller Foundation's support for the development of human resources and infrastructure for research in the area of molecular biology and application of molecular biology tools for crop improvement. The Rockefeller Foundation decided to support molecular biology research and application of molecular biology tools for improvement of rice under its International Rice Biotechnology Program as rice is the staple food in many countries in Asia. Many scientists were trained in advanced laboratories in the US and Europe as part of the program's projects and research fellowships for scientists at various levels. The Rockefeller Foundation's International Rice Biotechnology Program during 1988-2000 created a pool of scientists who were trained in advanced techniques in many Asian countries including India and China. The Indian scientists supported by the Rockefeller Foundation have developed several projects later on supported by the national funding bodies such as the Department of Biotechnology (DBT) and the ICAR through its in-house support to scientists. It should be mentioned here that the National Agricultural Research System (NARS) in India (ICAR institutions, Agricultural Universities) has produced some outstanding scientists specializing in plant breeding during the Green Revolution. However during the 1990s with the Rockefeller Foundation support scientists engaged in basic molecular biology located in Universities and the national laboratories of the Council for Scientific and Industrial Research (CSIR) began to focus on crop improvement. While the public institutions were equipping themselves to shift to research on molecular biology and molecular breeding, genetically modified Bt cotton seed, developed by a private company was permitted to be released to the farmers in 2003. Adoption of Genetically modified cotton generated a debate on genetically modified crops in India.

From the point of view of farmers, Bt cotton seed has resistance against one pest, that is bollworm on account of introduction of the toxin producing gene from Bacillus thuringiensis (Bt). The technology was transferred to farmers on the premise that its use will minimize pesticide use. The toxin produced by Bt cotton plant kills the pest when the pests consume the leaves of the plant. In other words, Bt technology is a crop protection technology. Studies (Shah 2005, Stone 2005) indicate that the Bt seed has been adopted by farmers in Gujarat in Western India and Andhra Pradesh in South India. It did indeed reduce pesticide use and the savings made on account of reduction in the expenditure on pesticide is tangible. However, farmers continue to use chemical pesticides against secondary pests. In some areas the secondary pest has become primary pest in Bt cotton fields. Scoones (2005) analysed the interplay among science technology and politics in the context of agricultural biotechnology. From the point of view of farmers, genetic engineering technology is knowledge-intensive and in societies where farmers are poor, illiterate and possess small size land holdings in the absence of effective regulatory system, surveillance and extension system the technology may not produce the same results as promised by the advocates of the technology. In countries like India the cattle are integral to the farming system. In such a situation the cattle which Bt cotton crop residues may be exposed to the toxin produced by Bt gene present in the crop residues. In India cotton oil is used either wholly or in combination with other edible oils as cooking oil. In other words, oil extracted from Bt cotton seed enters human food chain and cause health problems such as allergies. At another level the genetic engineering alters the system of meanings that farming communities attach to seed and several practices associated with agriculture. As mentioned earlier, over time farmers have lost control over seed production and have become dependent on private companies for the seed which earlier was in their control. In case of risk arising out of using the seed and the quality of the seed, in the absence of strict regulatory and surveillance mechanisms the resource-poor farmers will not able to legally engage with economically powerful companies. Further, patents may hamper innovations as some innovations make use of several patented products, devices, cloned genetic material etc. To commercially release the final product the inventor has to deal with all firms and individuals whose patented products were used as intermediaries in the innovation process. A case in point is the Golden rice that was developed by Ingo Potrykus and Peter Beyer in 1999 as the proof-of -concept. It was based on engineering vitamin-A producing gene into a rice variety to make the variety produce vitamin-A. The golden rice was produced by using over 70 patented products that were used as intermediaries. Ingo Portykus and Peter Beyer entered into an agreement with Zeneca company (now Syngenta company) in 2000. As part of the agreement the financial interests and legal negotiations with the patent holders of the intermediaries used in the invention and the humanitarian aspect were separated. Syngenta has licensed inventors for humanitarian uses with the right to sublicense public research institutes and low income farmers (with annual income of US $10,000 or less) and allows farmers to replant their seed and trade them locally (Mayer 2005). However, due to regulatory norms, general opposition to genetically modified food and argument regarding alternate ways of administering vitamin A the golden rice remains a proof-of-concept.

At the level of policy making, countries that are signatories to the WTO agreements, have rewritten their legislations that govern seed production and distribution in accordance with the WTO norms on IPRs. In India the Process Patent of 1970 has been recently replaced in 2005 by patent legislation that protects both the process and the product. There is move to introduce new seed legislation in India in conformity with the provisions of the WTO on breeders' rights. This is an instance where the technology and the institutional arrangements that it entails for its deployment influences the policy environment with in a country. Winner (1999) argues that technological artefacts have political dimension. According to him some technologies necessitate decisions regarding the institutional arrangements to oversee the deployment of new technologies while some other technologies such as atomic bomb are inherently political in nature. In the case of India the government has been negotiating, in collaboration with other developing countries, with the WTO to see that the provisions of the WTO do not undermine the interests of the farming communities in developing countries.

Argument made in favour of proprietary technology in agricultural biotechnology based on genomics is that the inventor should be duly compensated for the time, energy, intellectual effort and money expended by the inventor in creating the invention that leads to an innovation. The compensation hence is an incentive for the inventors so that they continue to produce inventions. Argument against the proprietary technology in agriculture is that nobody invented genomes of crop plants and further, the proprietary technologies based on genomic knowledge restrict access to knowledge and products to the farming communities that conserved the germ plasm of crop plants *in situ*. A firm may use patents to merely to prevent competitors to innovate in a given area that is of interest to the firm.

Civil Society Organizations (CSOs):

In the Indian context the civil society organizations which have been responding to the changes in agricultural technology may be categorized broadly into the following: a) CSOs that accord uncritical support to the genetic engineering technology; b) those which believe in the solutions based on genomics and insist on ensuring the safety of the technology through transparent, democratic and broad-based regulatory system, prioritization of crops and traits within crops that are relevant to the Indian context and insist on alternatives to transgenic approach and c) CSOs which oppose the genetic engineering technology and argue for alternate technologies such as organic farming and use of bio-control agents as alternatives to chemical fertilizers and pesticides. The CSOs that belong to category b and c above insist on participative R&D in agriculture which involves farmers in the process of innovations from the stage of identifying a problem to the stage of implementing the solution through solving the problem.

Open Source Innovations:

Given the controversies surrounding transgenic approach for crop improvement and the associated issues like the breeders' rights and the IPRs and control over seed and the consequent dependence of farmers on big companies for the proprietary technology, attempts are being made to look at the open source software development as a model for innovations in agricultural biotechnology. The open source software or free software model pioneered by Richard Stallman (*http://stallman.org/home.html*) is based on a new and democratic ethos. He argues: "Free" refers to freedom: we write and publish software that users are free to share and modify (*www.fsf.org/blogs/rms*). The software developer has to indicate the source code in which the software is written and the code has to be made available to other developers for further improvement of the software in contrast to proprietary software the source code of which is protected. The model offers a potential to develop innovative technologies in biology on the basis of the genomic knowledge that is available in the public domain. Already some R&D institutions have been exploring the potential of the mode. For example, Jefferson, a leading molecular biologist, inventor of GUS technology that has made an enormous impact on molecular biology research and CEO of Centre for Application of Molecular Biology for International Agriculture (CAMBIA), based in Australia, has initiated a movement called Biological Open Source (BiOS) to explore the open source model. He argues that the open source innovations also create wealth. Wealth is created not by producing the open source innovation but by using them (Jefferson 2006). In India there attempts are being made to explore drug discovery by adopting an open source model.

Marker-Assisted selection (MAS): An example of Open source bio-innovations in India:

In the following paragraphs we examine the development of Marker-Assisted Selection (MAS) technology for crop improvement as an open-source innovation that is pro-poor. It involves movement of genes within a crop gene pool, from one variety to another. The MAS, in other words, is based on tapping the variability in a crop gene pool. The MAS maintains the integrity of the genome of the crop plant. In contrast genetic engineering involves transfer of genes from one species to another and the genome with a foreign gene is seen as a new genome that did not exist earlier. The DNA markers — stretches of the DNA — are developed from the genome of a crop plant that is available in the public domain. The markers are used to find out whether or not a gene transferred from variety of a crop plant into another variety is getting expressed or not in the seed before it is sown in the field. This reduces the time required to detect the new gene. In contrast, in the case of morphological markers that were used earlier, to find out whether or not a gene is expressed at a phenotypic level one had to wait till a plant grows to a certain stage. Though the markers may be patented their use is not. They can be bought from a vendor like any other chemical preparation and can be used in the MAS. The MAS is not controversial as the genetic engineering technology and the MAS technology can be used to improve local varieties of food crops and crops that are grown in rain-fed areas.

In India already demonstrated the usefulness of the MAS for crop improvement. I will cite one project as an example. Scientists in public R&D institutions attempted to improve rice crop through the MAS technology by transferring genetic material of one variety of rice to another to protect the crop against Bacterial Leaf Blight (BLB) disease. This project involved collaboration between two public R&D institutions, namely the Centre for Cellular and Molecular Biology (CCMB), Hyderabad and the Directorate of Rice Research, Hyderabad. The former is a laboratory of the CSIR and the latter is an institute set up by the ICAR. The research group at the CCMB that was involved in the BLB project successfully introduced three genes (Xa5, Xa13 and Xa21) that conferred resistance against the BLB from a rice variety SS 113 into Samba Masuri, a popular rice cultivar in South India. Then the scientists at the DRR, trained in rice breeding carried out validation and field trials. This project indicates that the synergy between the two research groups having competence in complementary areas has led to an innovation that is relevant to the social context (Haribabu 1997 and Reece and Haribabu 2007). Recently attempts have been initiated to employ the MAS for improvement of millet crops such grown rain-fed areas through a collaborative project between International Crop Research Institute for Semi-Arid Tropics (ICRISAT), an international public institution located in Hyderabad and Haryana Agricultural University, Hissar. Millets are coarse grain referred to as poor man's crops. These crops, popularly called orphan crops, received not attention so far. The MAS as mentioned above are based on genomic data available in the public domain and the markers can be developed in a moderately equipped laboratory. The MAS is thus an example of open source bio-innovation. In India similar open source innovations are being explored in the area of drug discovery. Research on Tuberculosis is being carried out in the framework of open source innovation (see this volume)

To summarize we have seen how genomics may be used to either develop proprietary technologies in agricultural biotechnology or open source technologies. We conclude that open source innovations are based on a new ethos of sharing knowledge and democratic participation in the advancement of knowledge. In the context of genomics based innovations it is a way of ensuring that knowledge generated is bequeathed to the farming community that preserved the germ plasm of crop plants *in situ*. Open source innovations will go a long way in making knowledge accessible to the resource-poor farmers in most of the developing countries. Of course, the MAS has to travel a long distance before it is deployed to improve individual traits of different crops in different agro-climatic zones in different countries.

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Jyoti Yadav & OSDD Consortium

Open Source Drug Discovery — A CSIR-led Initiative with Global Partnership

Abstract:

The complete genome sequence of the causative pathogen *Mycobacterium tuberculosis* was published a decade ago and many years of painstaking efforts have been invested since then, yet we are still far from having a good, fast acting drug or vaccine which confers long lasting protection. Despite increasing investment, led by charities including the Gates Foundation, no novel drug for TB has entered the market in the past few decades.

The Council of Scientific and Industrial Research in India wishes to bring in the power of Open Source in finding cure for TB. The project has participation from scientists from various modern biological sciences, chemists, informatics, medical practitioners as well as social scientists. The project would involve an array of experimental methodologies, computational technologies with the participation of young and brilliant talent from Universities and Industrial partners with a strong inclination to apply a concerted effort to address this important scourge. Government of India has committed US $38 million towards this project. An equivalent amount of funding is expected to be raised from international agencies and philanthropists. Nearly US $10 million has already been released for the Phase 1 of the project. All researchers contribute data related to tuberculosis drug targets and active molecules through a copy left agreement; anyone who is prepared to keep to this may participate. All the data is Click wrap protected and credit sharing will be based on a novel and flexible micro-attribution system. This system is aimed at providing due credit through an active process. Various levels of investigators shall have appropriate levels of rights, recognition and responsibilities.

Another valuable aspect is the partnerships of Industry with belief in Open Source systems and models. This concerted effort to tackle this dreaded disease is the Open Source Drug Discovery for Tuberculosis.

Introduction:

Infectious diseases collectively cause immense mortality and morbidity worldwide. Among the many infectious diseases caused by various pathogens, Tuberculosis accounts for major proportion of these maladies. Tuberculosis (TB) continues to be one of the most important global public health threats. About one-third of the global population is infected with *Mycobacterium tuberculosis* and at risk of developing the disease. More than eight million people develop active TB annually with more than 90% of deaths occurring in the developing world (1). Early detection and proper treatment are critical measures for disease control.

Nearly one-third of the world's population is presently infected with tuberculosis with India being the highest TB burden country globally. In India, on an average, one person dies every 1.5min. This data alone glares at us and throws challenge for discovering new approaches to contain and eliminate the dreaded disease. Presently used drugs — Rifampicin, Isoniazid, Ethambutol, Pyrazinamide although very effective in curing the disease, require careful monitoring. Left unmonitored, drug resistance develops and other drugs are to be administered for cure. However, several constraints hinder successful completion of this therapy. First, the therapeutic duration itself takes 6-9 months and this is because the pathogen transits to persistence state that requires long time to be treated. In addition, the pathogen also goes into a state called Latent state, whereby it survives in host tissues for a very long time. Second is the rapid emergence and spread of drug resistant mutant strains. The Third deterring factor is that drugs are expensive and Tuberculosis is a widely ravaging disease among the poor. Another obstacle in controlling TB is the HIV pandemic and co-infection which has dramatically increased the incidence of TB and multi drug resistant form of TB in immune compromised patients. The situation has worsened by the emergence of XDR-TB which is characterized by resistance to at least two first-line drugs in addition to one or two second line drugs.

We desperately need new tools to fight TB and save millions of Life as well as the invaluable loss of man-months it causes as a result of morbidity. It is extremely unfortunate that most of the tools in the TB diagnosis and cure are age old. The most commonly used TB diagnostic, sputum microscopy is over a hundred years old and is insensitive to detect infection in world's half of the patients. This imparts huge economic burden on the country and people. In India, TB alone causes huge direct and indirect loses to the society. (Table -1)

Bringing a new drug to the market is an expensive affair. It takes about 12 yrs and approximately US$ 800-1200 million for a new drug to reach the market. The pharmaceutical companies are therefore often driven by the market size and countries of prevalence of diseases for investment decisions. Companies are interested either in the diseases of the rich nations or in the lifestyle diseases which have a potential of a good return. Analysis of the current drug pipeline has an estimated 399 candidate molecules for Cancer at some stage of clinical development on contrary to a mere 6 molecules for TB. Only one compound in twenty successfully emerges from a typical anti-infective drug discovery programme (2) which gives an estimate that theoretically, there would be no new molecule for TB in the coming years. About 178 pharmaceutical companies are involved in cancer research and only 12 for TB (3). These companies do not invest funds in diseases of poor world as it is well known that a sizeable portion of world's population, including 50% of Indians, do not have the capacity to pay for costly drugs although they need it the most.

The solution to these bottlenecks is to identify new drug targets and discover new drugs that will act fast and also be affordable. In order to develop a strategy to address these bottlenecks, it is necessary to develop a comprehensive programme for Drug Discovery. Drug Discovery has been in the closed sector protected by patent laws of different countries for many years. Because of this approach, drug development has been an expensive process. Further, availability and affordability has been very limited and beyond reach of poor sections of the population as pharmaceutical companies need to recover R&D expenditure and also make profit. In addition to this there are requirements of mutual agreements that usually are complex and time consuming involving multiple rules and regulations that vary from one country to another. Under these circumstances, there is a growing need for the academic institutions to participate in early drug discovery stages with identification of new druggable targets, followed by rigorous target validation and identification of new leads. Drug discovery at academia is limited because of the lack of access to critical information, pharmaceutical expertise, compounds, and research tools (4).

With the advent of successful open source models in IT (e.g., Web Technology, LINUX Operating System) and Biotechnology (For e.g., Human Genome Sequencing), inspiration is being drawn to experiment drug discovery in an open environment. Efforts are underway in exploring drug discovery in a shared and collaborative environment in a non-conventional drug discovery setup with efforts from academic experts together with industrial expertise. Some initiatives involved in the Tuberculosis drug discovery are Tropical disease Initiative (http://tropicaldisease.org) (5), TB alliance (*www.tballiance.org*).

Council of Scientific and Industrial Research, India has initiated a comprehensive Open source Drug Discovery programme (6). OSDD provides an open platform to "Collaborate, Share and Discover" and also provides tools for the same. OSDD contains a comprehensive TB database called MTB Sysborg, which provides extensive information related to the complex biology of the pathogen, drugs and their interaction with different proteins, protein-protein interactions etc. It also provides computational resources at one unique platform to aid the initial stages of target identification and drug discovery (http://crdd.osdd.net/). Open bookmarks and TB prints archive are other tools to share discussions, online resources as well as to provide published and unpublished data related to drug development against tuberculosis. Current developments in the project includes several active sub-proposals to identify drug targets, virtual screening and *in silico* toxicity work. The major innovative aspect of this programme is the wide participation of talented young students from the University System across the world. It is a project without geographical boundaries.

Implementation model:

The project has a unique implementation model where in experts from interdisciplinary fields and otherwise contrasting fields would work together in an open environment for the good cause of finding new and effective drugs for TB (Fig1). It is project where the young will get a chance to not only contribute by working for some one's idea but also by posting their own ideas. The entire project has been sectioned into different Work-Packages (WPs). This would enable to clearly specify the works to be carried out during the implementation of the project along with responsibilities for the respective WPs. In addition, the connections between the responsibilities are also planned. This also includes the wet lab experiments that not only provide valuable lead to start working with but are also required at each step to validate the output of computational methods. The open source community may tie up with a knowledge process outsourcing partner to develop strategy and planning and then tie up with a CRO to develop the molecule and may even go further to tie up with another CRO to test its efficacy.

The semantic inter-relation between work-packages is depicted in Figure 2. Failures and dead-ends may be posted that help to avoid re-inventing the wheel i.e., targets already failed by certain approaches may be re-checked by alternative methods.

Availability of funds is a crucial aspect behind the success of any initiative. India's federal government has committed $38 million for OSDD and the project expects to raise a third of the overall project from donations and charity.

In addition to this, India has been a world leader in the production of generics and a provider of affordable drugs the world over (7). India with its diverse knowledge pool in form of researchers and doctors working on tuberculosis, access to patients and experience to work with generic molecules is the best strategic location to launch such an interdisciplinary and innovative project. In the process, universities will be enabled to benefit students and Science Personnel. This serves to cultivate and propagate interest in science. Contract Research Organizations (CROs) will be involved for outsourcing services at various stages. An important focus of the project is to involve young and brilliant talent from Universities and institutes and to develop rational means for optimized drug therapy to ensure maximum efficacy with minimal side effects. This could involve voluntary participants from government and private sector research laboratories, universities, institutes and corporations working together with appropriate credit sharing/distribution mechanisms. This will provide an opportunity for scientists, doctors and technocrats with diverse expertise to work for a common cause. OSDD aims to circumvent the need for IPR in drug discovery. A sharing and collaborative environment is expected to grow and lead to increasingly potent discovery informatics environment. The OSDD model would exploit the system of monetary and non-monetary rewards that is already part of the scientific establishment — using the prospects of scientific progress, career advancement, and humanitarianism to engage biomedical researchers. OSDD will have a research environment delivered through web portal that aims to provide ready access to resources/technologies that enables researchers to perform drug-lead exploration in an efficient and inexpensive manner. The portal will provide facility for using the applications, databases, computation, storage, archival, etc using open source web based tools.

Components of OSDD platform:

Resources for drug discovery

The advent of high-throughput sequencing, microarray and proteomics technologies has lead to an explosion in the genetic and genomic data and a concomitant increase in informatics resources to store, access and analyze these data sets.

Drug discovery and development requires the integration of multiple data types from a multitude of scientific groups across prolonged time periods. Despite the efforts of researchers, the failure rate for compounds in drug discovery and development is still high because of either lack of efficacy or unacceptable toxicity. The availability of data across multiple datasets, and at the cross road of scientific disciplines, enables the evaluation of new questions and exploratory analyzes that can lead to novel insights and eventually to innovate new medicines. This availability of data further promotes collaboration among researchers from multiple disciplines, with well-documented scientific workflow providing a standardized form to orchestrate the steps of discovery (8). Availability of comprehensive and numerable types of chemical, biological and medical databases, newer software and powerful computing provides for increased possibility for researchers to identify promising protein targets and small sets of chemicals, including good lead compounds faster using computation alone.

For implementation of the portal, portlet technology will be used as these are reusable web components and will be beneficial in building new portals in the future. Various components of the portal are — search engine, digital library, e-learning, mailing lists, news, blog or chat, real time audio-video for lectures, etc. The search engine will index and cross-connect the content, tools and user contribution. Digital library is an archive of publications, reports, presentations, etc. OSDD portal will also post challenges for writing tutorials on various aspects ranging from submitting data using wiki to writing code for invoking R libraries using PERL, etc. This platform may also be used to provide up-to-date information through RSS new feeds. Furthermore, the OSDD discussion forum will provide a common platform for the user community to interact and collaborate in an open culture. In a nutshell, OSDD provides a web based open source resource sharing portal, which may be extended to procure chemical libraries for screening, purified protein, or outsource high throughput assay development. There are over 1100 registered participants (Fig. 3) with approx. 65 active projects involving target identification, expression and validation. OSDD has a micro attribution system for contribution, provision of submission IDs for submissions like dbSNP and information on periodic meeting of consortium members and other international collaborators, international collaboration/partnership annual meeting. The portal will provide a comprehensive systems biology platform for MTB. It will help the researchers in identifying from literature and pathway modeling, all possible drug targets.

Wiki model for data annotation

Drug discovery related data, information and knowledge mostly resides in the form or research articles or text and documents which are usually unstructured, hence data mining becomes a herculean task. The open source model clearly supports the idea of community driven science and discussion for which not only the data needs to be made available but also searchable at the same time. *Mycobacterium tuberculosis* data on the portal MTB SysBorg (http://sysborgtb.osdd.net/bin/view/Main/WebHome) has followed a structured wiki model for collaboratively synthesizing knowledge, commonly referred to as the “Long Tail”. The objective of this relatively open data model is to target small contributions from a large population of contributors. It is imperative to mention here that for such a system to work, standard tags for each data entry are mandatory and are being created and installed in the database. These tags will not only help in storing the data in an organized manner but will also help in semantically searching for biologically relevant information.

As mentioned above, the entire project has been sectioned into different Work-Packages (WPs). This would enable to clearly specify the works to be carried out during the implementation of the project along with responsibilities for the respective WPs. In addition, the connections between the responsibilities are also planned. Moreover, the connections between the work packages describe the conceptual connections and the timings. This is especially useful when large network projects are conceived. "Open Source Drug Discovery" project is a large network project emerging and going beyond CSIR and encompassing Universities and Industries in a collaborative mode, employing modern genomic, proteomic and informatics technologies.

Work Package 1 (Targets all non toxic sites**)** starts with a whole range of computational activities including Systems Biology Research, set up of facilities and networks, and the OSDD Portal. This package brings together the computational strengths and reinforces the concepts of open source movement by participation of industries with strong inclination to Open Source.

Work Package 2 (Expression of targets**)** deals with experimental expression of protein targets. Success of this work package is an important component and this work package brings in the true concept of sharing experimental reagents and chemicals in Open Source.

Work Package 3 (Screen development**)** involves screening of targets discovered using large chemical libraries in order to identify the inhibitors with potential to become drugs. This package implementation may call for the participation of other Contract Research Organizations as well. Some assays may be developed using smart innovative molecules.

Work Package 4 (Based *on in silico* docking, identify a library of chemicals for specific screen**)** can be viewed as another very important computational work with its aim focusing on filtering or forestalling molecules with potential toxicity.

Work Package 5 (Take best inhibitors and do micro array gene expression for human cells and tissues.**)** is one such package where in modern genomics technologies of microarray would be used to build transcript profile and link with Work Package 4 as an overlap to check the mechanisms of the best inhibitors on the host. (Fig. 2)

Work Package 6 (Lead optimization on the non-toxic Hits**)** is lead optimization, an essential module of the drug discovery program.

Work Package 7 (Medicinal chemistry). Synthesis of analogues which have nano-molecular binding to the target but do not alter the expression profile of host cell significantly compared to the native un-intervened state.

Work Package 8 Create a potent lead affinity column to check for Human Cellular protein binding using proteomics in order to pick up only the potent lead with minimum binding.

Work Package 9 Pre-Clinical Toxicity of the Lead Compounds-in order to develop a pharmacological profile of the investigational drug.

Work Package 10 Clinical Development of New Molecular Entities — would look into the evaluation of new molecules so as to establish its safety, tolerability and efficacy and would be aimed at faster and more cost-effective development of the new drugs.

All of these WPs taken together shall steer this endeavor firmly towards affordable drug development.

Summary:

This is an effort to bring in the power of genomics, computational technologies and participation of young and brilliant talent from Universities and Industrial partners with a strong inclination to apply a concerted effort to address this important scourge. All researchers contribute data on tuberculosis drug targets and active molecules through a copyleft agreement; anyone who is prepared to keep to this may participate. All the data is Clickwrap protected and credit sharing will be based on a novel and flexible micro-attribution system. This system is aimed at providing due credit through an active process. Various levels of investigators shall have appropriate levels of rights, recognition and responsibilities.

Another valuable aspect is the partnerships of Industry with belief in Open Source systems and models. This concerted effort to tackle this dreaded disease has been named as Open Source Drug Discovery for Tuberculosis.

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Table:1

Table -1Social and Economic Burden of TB in India*

Types of Loss	**Amount of Loss**
Indirect costs to the society	US$ 3 billion
Direct Costs to the society	US$ 300 billion
Productive workdays lost due to TB death	US$ 1.3 billion
Productive workdays lost due to TB illness	US$ 1.3 billion
School dropout due to parental TB	US$ 300,000
Women rejected by families due to TB	US$ 100,000

*Int. J. Tub.Lung Dis 1999, 3 869-877

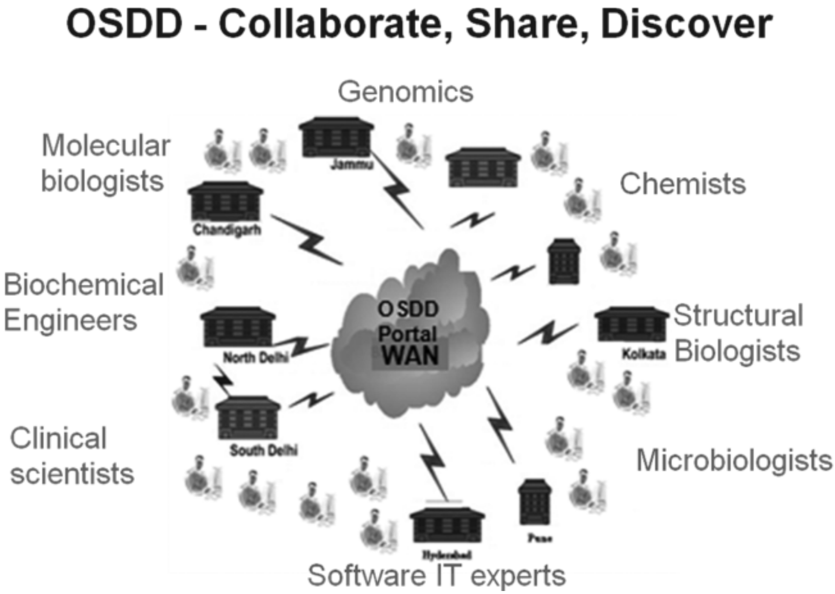
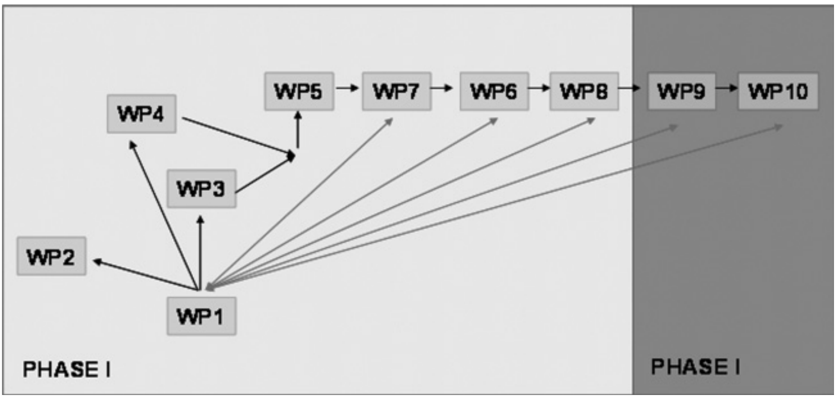

OSDD - Collaborate, Share, Discover
Genomics
Molecular biologists
Chemists
Jammu
Chandigarh
Biochemical Engineers
OSDD Portal WAN
Structural Biologists
Kolkata
North Delhi
South Delhi
Clinical scientists
Microbiologists
Pune
Software IT experts

Fig:1


WP1
WP2
WP3
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WP7
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PHASE I
PHASE I

Fig: 2

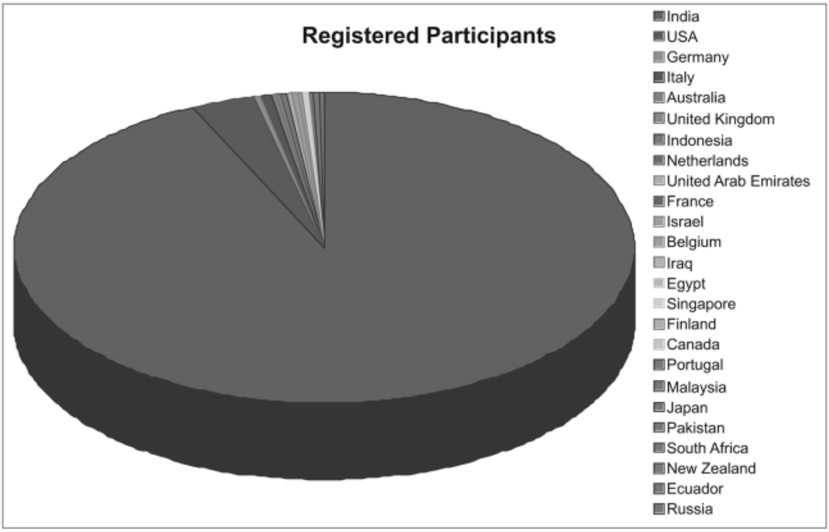

Fig. 3 Registered Participants

Judith Zubieta García

A Contribution from Industrialized Countries to the Developing World: Human Resources for R+D

A lot has been said and written regarding "Brain Drain", particularly during the 1970's. Different names and titles have been given to the analysis and discussion of this important topic, depending on the emphasis authors stress in their work; however, it is clear that migration of highly qualified human resources has attracted attention in central countries as well as in the periphery.[1] Although no one has argued there are no negative impacts attached, little governmental attention has been given to design and implement long-term policies to minimize them, either because it is not cost-effective to educate people who will later move abroad or because once they migrate, these individuals will no longer contribute to developing and consolidating National Science and Technology (S+T) in those regions.

In order to understand these migratory flows, several approaches have been developed. In the early seventies, the "push–pull" sociological theory used mainly by demographers to explain migration was considered useful. Usually, flows from a "less developed" country to a "developed" one were solely explained by considering the prevailing poor conditions in the former (the so called "push") and the attraction the latter exerted (i.e. the "pull" force). Such a simplistic interpretation of a complex phenomenon resulted in short-term policies implemented by governments of the less developed countries which proved futile in their attempt to stop this sort of human leakage. They mostly consisted of weak retention

1 The binomial expression North-South has many limitations provided that the brain drain also takes place among Northern countries. Regardless of the direction of this social movement, we will refer mainly to migration from non-developed to developed countries, or center-periphery movements, unless otherwise indicated.

strategies focused on a naive perception of what was thought to be politically correct, ignoring all other factors at stake like prevailing disparities between talent-export nations and those who attract them.

A second way to deal with this problem was inspired in neo-liberal social theories or, even more appropriately, in a laissez-faire approach. While recognizing that scientists of the so-called "emerging economies" should be granted the right to migrate wherever and whenever they want, it is hoped that they will sooner or later impact positively on their countries of origin, once they have settled in and started generating new knowledge and development. Multiple critiques to this approach were formulated, emphasizing shortcomings from economic developmental theories where a trickle-down effect was expected to pave disparities between regions. Indeed, no benefits can be taken for granted from migration towards more advanced societies, nor does knowledge ever spread evenly or freely among nations. Any laissez faire policy derived from this kind of interpretation will always undervalue the way markets operate without ever paying for the costs they impose upon less developed nations when promoting the emigration of scientists.

In the following paragraphs we will deal with brain-drain movements from different perspectives which we consider essential if a country is to overcome its negative impacts. It is clear that talent migration will take place despite the ethical consequences it encompasses and ignoring international calls for compensation. Therefore, exporting regions must design strategies if their S+T system is to subsist. Without pretending to advance a new holistic approach, we will review three perspectives and concentrate on those which can be easily instrumented in less developed countries: 1) from the source or origin (e.g. departure nations); 2) from the sink or destination (e.g. receiving nations); and 3) from the individuals (e.g. S&T human resources). We shall demonstrate that there are many coexisting forces and that it is common to find situations in which those three perspectives are closely interrelated.

a. Brain Drain from the Perspective of Departure Countries

Most less developed countries do not have strong scientific communities, their graduate and postgraduate programs have low enrollment and graduation rates, not to mention the uneven quality of their programs. Nonetheless, some students manage to get S&T degrees but not all of them find jobs related to their field of study.

The construction of scientific and technological capability in developing countries is a task that frequently brings to mind the mythical figure of Sisyphus, inasmuch as it requires great effort to push upwards and then, after considerable ado, the task becomes futile. In effect, many of the talent-producing nations which have invested time and a wide range of resources, have provided the conditions necessary in creating highly trained human resources. They have likewise built or strengthened institutions and designed and implemented diverse S+T policies. Yet after a time many of these efforts wane. It would seem as if the Sisyphean task to push the legendary stone was truly unavoidable.[1]

At the end of a six-year period characterized by a total lack of recognition of the importance of investing in research and development (R+D), it would seem that the problem of the brain drain will intensify in the near future, which endangers our sovereignty and reduces the possibilities of taking part in competitive conditions within the global economy.

Several authors have pointed to the urgency of including in our S+T policies certain social programs, traditionally associated with migratory flows generally. Among these are the well-known "Three R's": Retention, Reorientation and Relocation, which formed an essential part of Mexican demographic policy in the last years of the 1970's.[2] To these programs it is possible to add another three R's suggested by the relevant literature, so as to have a more complete and updated panorama: Restrict emigration, Recruit via replacement, and Repair the loss of human capital (Lowell and Findlay, 2001). Undoubtedly, the condition required so that these last three generate the impacts expected stems from the support and observance obtained in the receiver countries.

When reviewing the bibliography employed to write this paper, worthy of note were the numerous references made when contrasting the attention given to the retention, relocation or recruitment of a footballer compared with that of a scientist.

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[1] *See* Alcántara, A. *Entre Prometeo y Sìsifo. Ciencia, Tecnología y universidad en México y Argentina*. Barcelona, 2005.

[2] *Cf.* Consejo Nacional de Población, *México Demográfico*, 1982.

In the last decade reference has been made, with growing frequency, to a new approach called "Diaspora Networks". The virtue of these networks is rooted in the fact that they all emerge from the periphery and seek to make use of the scientists who have emigrated, in an organized and systematic fashion, to such a degree that exchange and the creation of more favorable conditions for the countries of origin are promoted.

The conceptualization of these diasporas in matters of S+T is effectively new in that they recover the importance of cooperation, the result of which can be beneficial, as much for the central nations as for those of the periphery.

In frank recognition of the need to incorporate a systematic approach to the relevant subject policies, an approach in which the structuring of this kind of network plays a predominant role, the Mexican government has just announced the putting into operation of a network to "combat" the brain drain". On October 14th last, in a meeting at the Institute of Mexicans Abroad, it was announced that this network would avail of the capacity and motivation of 75 Mexicans located in the USA and working in high technology companies "to contribute to the technological development of our country".[3] Undoubtedly, the initiative would seek to be opportune and pertinent, while alertness would be required as to the forms in which it was constructed, the conditions in which they would operate and the resources which they would be allocated.

b. Brain Drain from the Perspective of Host Countries

Since classical Greek times till the present day, the problem of the migration of scientists from less developed countries to other nations offering better opportunities has constituted a critical problem for emigrants and a benefit for those receiving them. Nevertheless, the conditions which a global economy based on knowledge currently imposes, are responsible for the fact that science and technology acquire special relevance as do the human resources which generate it.

It is by no means hazardous to affirm that in the near future the Southern countries will not find the conditions that will allow them to compete with the countries of the North, either in terms

[3] Note appearing on October 14th in the section "Noticias" of the network *Science and Development Network* (SciDev), available at:

http://www.scidev.net/gateways/index.cfm?fuseaction=readitem&item=News&itemid=3155&language=2&rgwid=1

of institutions and infrastructure for R+D activities, or in the many attractions on offer for highly qualified human resources in charge of carrying out such activities. With the situation as such, it would seem pointless to think that the countries which benefit in a solidarity fashion from these differentials will cease to import the human capital they require, or absorb the indirect costs which their absence or scarcity generates in the countries of origin.

The policy of compensations amassed by many in the first decades of the second half of the last century, never enjoyed viability[4], and the aid directed at talent-producing countries has neither been systematic nor generous. Subsequently, the importance of implementing policies and "ethically correct" programs has gradually been recognized.

Among such programs, those geared to providing norms for the processes of recruitment of personnel are endowed with the highest degree of relevance, particularly if it is a question of the health sector of underdeveloped countries. In this specific point it is worthwhile pointing to the efforts, which the OECD has made so that these programs respond to policies conceived from a global perspective.[5] Thus, only recently countries have been recommended to recruit qualified personnel to increase the aid intended for the development of human resources in the health sector of the countries of the periphery, where most of imported talent comes from.

While it is far too premature to affirm that these initiatives have been successful, particularly for the health sector in African countries of the South Sahara, it should be recognized that they have effectively shown at the international level the lack of ethics of the host countries who, aware of the negative impact that such recruitment will have, continue to pursue the same avenues.[6]

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[4] *See* Bhagwati y Humada, 1974.

[5] As far as agreements are concerned, the observance of this type of agreement is not obligatory. While it is true that certain types of campaigns designed to recruit highly trained human resources have been prohibited, these continue to be executed via new routes (OECD, 2004).

[6] In accordance with the points raised in OECD's report *Trends in International Migration 2003* (2004), the case of South Africa calls one's attention, not only because it has lost close to a billion dollars invested in the formation of health professionals who actually work abroad, but also because the country has suffered from the scarcity of human resources in circumstances currently experienced and associated with serious migratory problems, poor working conditions and VIH/SIDA epidemics.

It cannot be denied that, for these initiatives to prosper, relying on the support of the host countries is unavoidable. The example of South Africa is highly illustrative. This country has partially been able to contain the emigration of its intellectual capital via the signing of agreements with other countries (among these, the G77 group as well as those of the Community of Nations or *Commonwealth*) in which the prohibition or conditions employed to govern the contracting of South African doctors and nurses is imposed.

In spite of these results, voices from the First World can be heard, their argument being that these talents should be seen as "exportable goods" for periphery countries with low incomes, in virtue of the assignments of emigrants dispatched to their new location, which, at some time or other, will surpass the costs associated with their formation and training.[7] In the hypothetical case in which the abovementioned were true, the debt, which First World countries have with those of the Third World, would not diminish, even if consideration were given merely to the emigration of talented personnel.

c. Brain Drain from the Individual's Point of View.

According to the description outlined by Dr. Ruy Pérez Tamayo in his book "Acerca de Minerva", the scientific brain drain takes place via three different aspects: 1) "premature death"; 2) "internal drain"; and 3) "external drain".[8] Below we sketch the peculiarities of each, with reference to certain ethical considerations, which are unavoidable.

1. Premature Death. — With this term Pérez Tamayo alludes to "all those students, which at some time or other included science among their options for the future, but cancelled the idea ... ". I will go back a little in the formative process of a student to include those who, in spite of possessing the talent, were never able to develop their interest in science, be it for lack of information, stimulus, models to imitate, or rather because the values of our consumer society continue to favor the "how much you possess" over the "how much you know".

[7] *Cf.* "Brain Drain or Ethical recruitment" by Scott, ML *et al (en) MJA,* Vol. 180, February 2004. p. 174.

[8] Pérez Tamayo, R. (2002). "Acerca de Minerva". Col. *La Ciencia para todos*. Fondo de Cultura Económica. México.

In this sense, it is pertinent to mention the actions that the Mexican Academy of Sciences has undertaken for some years, in that it brings children and young people closer to science, independently of the many actions carried out in matters of diffusion. Programs such as “Science in Your School” and the “Summer of Scientific Research” have clearly revealed the virtues of their application and impact. Nevertheless, neither of the two programs has been able to grow due to lack of funds.

As long as a lack of funds continues to exist it will be impossible to justify a vigorous development of scientific research and technological development in our country. Such funds would simultaneously facilitate the widespread and appropriate diffusion of the benefits of investing in S+T, and, on the other hand, a labor market in which young people see real possibilities of personal and professional growth and development. In the meantime, little can we do to mitigate the effects of this premature death.

2. The ethical considerations of this aspect of the brain drain are directly associated with each country’s institutional and governmental responsibilities, particularly those known as “emerging” nations. To annul the possibility of young people from both sexes dedicating themselves to R+D and subsequently developing their intellectual potential not only restricts the professional fan to which every individual with studies should have access, but also reduces the possibilities of a nation’s progress and sovereignty.

3. The internal drain. — This loss or waste of talent (“brain loss”) takes place mainly when, without abandoning their country of origin, members of the academic community leave their R+D work in order to dedicate themselves to another kind of activity.[9]

Many are the factors that can motivate such decisions, from those of an institutional kind to those at the political, social and economic levels. As Pérez Tamayo so rightly points out, if this drain occurs when scientists are already consolidated, have formed

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[9] In the book *La Migraciyn de Talentos en México*, the concept of “internal drain” refers to the “phenomenon which consists of the fact that ex-grant holders returning to Mexico after graduating in a foreign university seek employment outside the Mexican academic institution which supported them in obtaining such grants, and to whom they had originally committed themselves on their return” (*Cf.* Castacos-Lomnitz *et al* (2004; 12). In spite of the moral implications of this interpretation, we consider less restrictive the meaning which Pérez Tamayo employs (2002; 95).

human resources and disseminated the products of their research, the loss is relatively less than when this takes place in the first stages of their academic career.

This phenonomen takes on particular importance in the case of women. In effect, for our societies it would seem that it is not sufficient that women have not experienced conditions of equity in accessing education, science and technology, even at the postgraduate level; now, those successful in attaining higher education levels, are obliged to confront a labor market which, in many different ways, discourages their progress and professional consolidation.

Unfortunately, it continues to be commonplace to find researchers who, having fulfilled all the requirements to gain entry into an institution, are unable to continue their academic careers. Factors of an institutional nature, added to those stemming from the responsibilities involved in bringing up children, as well as others of a family nature, keep women in the lower rungs of the academic hierarchies, limiting their development and neutralizing their potential.

A lot has been written on the so called “glass ceiling” phenomenon through which an explanation is provided of the impossibility which many women face when seeking to have access to more prestigious appointments, as well as higher salaries and greater responsibilities. The “sticky floor” phenomenon has also begun to be recognized, recognition being granted to the personal decision of women who, while holding a doctorate and in a position to become distinguished scientists, prefer to go unnoticed and remain in the lower categories and levels, where family obligations do not clash with labor commitment.

It would be pointless to stress the little done in this respect.

The external drain. – This is the phenomenon to which we referred previously when speaking of migratory movements of scientists of a country of origin, normally located in the South or Periphery, towards another whose destiny is generally central and located in the Northern Hemisphere.

To conclude, we should not ignore an aspect that frequently goes unnoticed in the literature on the theme: the so-called “interior exile”. This phenomenon is directly linked with the attitude of the scientists who, having been educated and trained in the North, work in the South totally alienated by a kind of intellectual colonialism: their work is disconnected from their reality and from the work of their colleagues, with whom they frequently share equipment, installations and even students. This form of exile has become more common as the countries hosting talented personnel have put into practice selective immigration favoring certain disciplines over others.

While it is true that in the South we continue to admire many aspects of life in the North, and with that their institutions and parameters of quality, it can also be affirmed that many of the efforts made to improve the quality of postgraduate life in the South, not to mention scientific production and the means by which this is diffused, are generally evaluated within the framework of the Northern mirror. Thus, for example, the only indicators which end up being valid are those built on the logic of the countries of the First World, with which it is much easier to alienate work on an everyday work basis in order to resemble it to that carried out in other latitudes, were migration possible.

Emerging from this previous phenomenon is a function which our Mexican Academy of Sciences would do well to assume: that of contributing in the design of indicators and mechanism which reflect with greater precision the conditions that prevail in the national institutions in which higher education is provided and in which Mexican R+D is carried out, in addition to promoting the execution of rigorous studies on this problem which receives scarce attention in our country, as much from the authorities responsible for boosting science and technology, as from our own scientific community.

As Dr. Pérez Tamayo already said in the book referred to earlier, “the crisis is making the life and work of Mexican scientists more and more difficult”. The most serious aspect is that 20 years later, and in spite of the fact that we no longer talk of crisis, this affirmation continues to have validity and support.

The brain drain has generated communities of foreign researchers in those countries offering greater attractions and these communities maintain links of different kinds with their countries of origin. The proposal to build “Diaspora networks” to compensate for the different prevailing structures is, in effect, a magnificent idea. It goes without saying that the attraction which scientists in training find in the more developed countries will not be eliminated by these; what we are dealing with is the commitment of already established communities to take part in its nations of origin in which the circulation of knowledge plays a key role.

It is enough to emphasize that we are currently living moments in which the differentials between North and South are becoming more and more serious, moments in which the different countries, the USA included, have been gradually putting into practice highly restrictive policies for migration, which can slowly convert themselves into less attractive propositions.

With or without a wall on the border, with xenophobic practices or with restrictive immigration policies, the industrialized countries will continue to recruit highly qualified human resources, trained in other latitudes, without assuming the corresponding costs. As Enrique Oteiza rightly points out "let us not fall into the trap that the existence of networks neutralizes the negative effect of the brain drain".[10]

Finally, allow me to add that we should not give up insisting on the fact that our countries ought to adopt S+T policies which will allow our scientific community to grow and enjoy better working conditions.

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Nadia Asheulova

Scientist's Mobility as a Mechanism for Russia's Integration into the World Scientific Community[1]

Nowadays, the problems of international mobility as a factor in the emergence of the joint scientist space, in internationalization of science and scientific activity have become ever more significant.

Mobility leads to a constant reconstruction of the research front which supplies scientists to the advanced research fields. Mobility helps to fill research positions in the new science areas and encourages interactions between scientists from various disciplines and different regions and countries. Its importance for innovation stems from its contribution to creating and diffusing knowledge (The Global Competition for Talent, 2009).

Mobility makes provisions for creating efficient multinational teams and networks which enhances competitiveness of various countries and encourages application of the results in future. Mobility plays an important role in optimization of research findings.

Mobility as a mechanism for science globalization is used in one of the most ambitious projects in the history of science — establishment of the European scientific space, integration of science potential of dozens of countries that differ greatly in their history, culture, political and academic traditions, the level of development of science and technologies.

Multipolarity of modern science is confirmed by active participation in the global division of labor of the countries like China, India, Brazil, Mexico and others.

Today, Russia is lagging behind in indicators that reflect the level of a country's integration into the global science. Insignificant involvement of Russian scientists in joint projects, international scientific conferences, symposiums, a small number of joint

[1] The paper was prepared in the framework of the project «Scientist's Mobility as a Mechanism for Integration of Country into the World Scientific Community: experience of India, Mexico, Russia», supported by Russian Foundation for Humanities, № 10-03-00329a

publications with foreign colleagues and international grants and awards, a low citation index — all this may be explained by a weak mobility of Russian scientists.

Scientist mobility: definition of the concept and types

The scientist mobility has various forms: a common, social form involves moving along the career ladder (upward and downward), moving between generations (inter-generational) and within a generation (intra-generational). The occupational aspect is a transition from one scientific discipline to another, from one scientific field to another, transition from one research institution to another, or in a pathological form it is when scientists leave science for other jobs, or in a geographical form (as P. Sorokin called it) it means territorial movements of scientists.

Our study is concerned with territorial movements of scientists in Russia at various historical stages as well as finding out how the territorial mobility influences Russia's integration into the global scientist community.

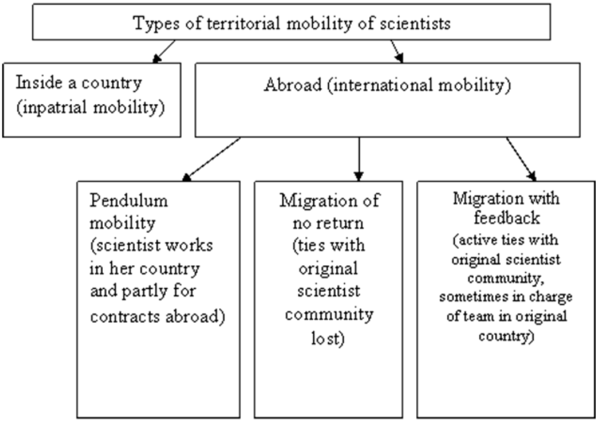
In the present-day Russian scientific papers you can find a wide range of perspectives on systematization and classification of scientist mobility, and there is a lot of terms for territorial movements of scientists, most used are geographical mobility, territorial mobility, migration mobility, migration, international migration, emigration, brain drain etc.

First of all, look at basic notions that are used in our study. We are inclined to call territorial movements of scientists or research teams a territorial mobility. When mobility involves a change in a place of living it is worth using the term of migration.

Let us try and identify types of the territorial mobility taking into account the latest trends in science. The territorial mobility includes movements of a scientist/scientist team both inside and outside a country.

When a scientist moves within her country from some research institutions to others, from one city to another, we call this type of territorial mobility "inpatrial" or within a country.

Any territorial movements of scientists that involve other countries are called international mobility which is divided into three basic types: pendulum mobility, irreversible migration, and migration with a feedback.



If a scientist has not emigrated, but works constantly in her country and works heavily for temporary contracts abroad, this type of territorial mobility may be called pendulum[2].

If a scientist emigrated from her country and lost all ties with the original scientist community, this type can be called an irreversible migration, but when a scientist has preserved the ties, it is a migration with feedback.

Scientists can just cooperate extensively with their colleagues in their original country through joint publications, exchange of literature, holding teleconferences, etc. They can be as well in charge of a laboratory in their country and from a distance of many thousands of kilometers coordinate team researches with the help of new information technologies paying several visits a year. (There are cases when, for example, a Chinese scientist working in the USA is in charge of twenty people in a Beijing research institute. He visits Beijing up to 10 times a year and is in constant contact with the team researchers working in China, through Skype or Googletalk and e-mail) (Mironin S.). This type of mobility encourages scientists to come back home and is a channel through which the latest scientific information can be brought into developing countries.

The present-day science introduces many corrections to definitions of the mobility concept. If a scientist emigration becomes huge,

[2] Term introduced by S. A. Kugel in 1974

experts use the term brain drain. For the first time, the term was used in a report by the British Royal Society in 1962 to describe emigration of scientists, engineers and technicians from Great Britain to the USA (Ikonnikov O., 1993).

This type of mobility becomes a negative factor in the development of national science, because the ever growing volume of emigration threatens the very existence of either particular scientific field or science in general, in a region or country.

Historical stages of the Russian scientists' migration flows outside the country

Using historical and comparative analysis, the basic stages of international mobility of Russian scientists were identified, starting from the second half of the XIX century to present days.

Up to the beginning of the XXth century scientists continued to consider themselves members of the global scientist community, the norms and values of which were more important to them than loyalty to national traditions and state interests. When studying and preparing for scientific work, a prospective researcher, as a rule, tried to learn, as much as possible, a wide range of scientific concepts, methods and methodologies, easily moving between universities and laboratories of different countries (Kolchinsky E. I., 2003:202–216).

Scientists, when expressing their findings in the universal language and neglecting, to a certain extent, the state frontiers, tried to find the most favorable conditions for their researches. Specialists were not afraid of changing their usual social and cultural environment and went to other countries to work. This fact was crucial for the emergence of Russia's scientist community in the first part of the 18th century. Both emigration and immigration were common for the world professional community. The vigorous Russian-German cooperation in science was brought about for many years by the massive arrival at that time of young researchers from Western Europe to Russia, mostly from German speaking states. The Enlightenment saw sort of competition between European monarchs in attracting famous scientists. So, Catherine II managed to invite Leonhard Euler to St Petersburg, one of the leading mathematicians of that time, member of the Berlin Academy of Sciences under sponsorship of Friedrich the Great.

1. The freedom of movement for Russian scientists.

Beginning from the second half of the 19th century, Russian scientists started to go outside the country quite often to found there their own schools of thought. They were, just to mention a few of them, the 1908 Nobel prize winner Ilya Mechnikov, microbiologist S.N. Vinogradsky, sociologist and economist M. M. Kovalevsky, geographer P.A. Chikhayev, mathematician S.V. Kovalevsky etc. Nobody was going to call them traitors of their Fatherland, and the scientists were able to come back if necessary at any time.

2. Civil war and the first mass wave of emigration.

The World War I put an end to the International of scientists, caused an outburst of patriotism and chauvinism in all countries. From now on, international scientific contacts were more and more conditioned by military and political considerations even in the time of peace. Russia's scientists experienced lives full of tragedies. Almost each Russian scientist faced a painful choice in 1918: to stay in the country devastated by the civil war or emigrate. Those who stayed felt all troubles of that time: persecutions, hunger, cold homes, infectious diseases, horrible working conditions. Some of them were executed during the pogroms or the years of the Red Terror.

3. First years of the Soviet government and the forced emigration of "anti-Soviet intelligentsia".

After the civil war, Russia's scientist community had to adapt their priorities to the interests of government to get more funding for science. In the 1920s, many of them got a feeling that the authorities understood them and were ready for cooperation. However, a lot of scientists, who did not want to bow to the Soviet power, emigrated. In the autumn of 1922, the Soviet government deported from the country more than 200 people with members of their families. They were mainly higher education professors from various Russian towns. Among the intellectuals, declared dangerous for the regime, were sociologist P. Sorokin (he was number 1 on the list for the city of Petrograd), professor of mathematics D.F. Selivanov (head of Petrograd University), professor of biology M.M. Novikov (head of Moscow University), professor V.V. Stratonov (dean, mathematics department, Moscow University), B.P. Babkin (head of physiology department, Novorossiysk University) and others.

It should be remembered that the mass emigration of scientists from Russia in the post-revolutionary decade provided science of other countries with outstanding discoveries and inventions. Russian scientists abroad tried for a long time to maintain scientific ties with their colleagues at home, they started even to create a special Russian science in emigration (specialized organizations, philosophy clubs, etc).

4. The Soviet period of Russian science, total control over international contacts, few trips abroad.

The Soviet period of Russian science, starting from 1930, changed radically the international mobility of scientists. During the Great Terror, international scientific communication was almost forbidden, the renowned scientists, including the founders of the social history of science N.I. Bukharin and B.N. Gessen were executed. During Khrushev's 'thaw' period, cooperation involved mainly scientists from socialist countries (German Democratic Republic, Poland, Czechoslovakia). Until the end of the 1980s, there was a total control, exercised by the regime as well by the Academy bureaucracy. A comprehensive cooperation was impossible, most scientists in Leningrad did not even expect to go abroad or to be published there. Their contacts were reduced to correspondence, exchange of literature and occasional meetings at international conferences in the USSR.

It should be stressed that Soviet sociologists of science (S.A. Kugel, V.Zh. Kelle) studied only social and occupational mobility of Soviet scientists, dealing a little with the territorial migration inside the country, designed to raise efficiency and productivity of scientific knowledge in the USSR (Kugel S.A., 1991:155–158).

By the way, internal (inpatrial) territorial migration in the USSR was often forced. The entire teams of leading scientists from scientific centers were sent to various Soviet towns in order to balance the brain drain from underdeveloped regions. As to the vertical mobility, it existed in science institutions. It was mostly upward, which did not exclude the downward trend (owing to the wide-spread system of complaining and reporting). In the Soviet era, the occupational mobility manifested itself as transitions between subjects and roles (for instance, from a researcher to a lecturer and vice versa).

5. The post-Soviet stage: liberalization of science policy, mass emigration of Russian scientists.

The post-Soviet period of the early 1990s saw a new mass wave of scientist emigration. It was caused by a number of common factors: economic, political, occupational, ethnical, psychological, as well as particular factors: falling prestige of scientist work, isolation from world science, lack of information, miserable working conditions and impossibility to implement their projects, limited opportunities of the professional career (Nekipelova E.F., Gohberg L..M., Mindeli L.E., 1994:16). Emergence of foreign foundations that provided support inside Russia during the crisis of Russian science became instrumental in preserving Russia's scientist community on the one hand, but on the other hand, they generated growing migration flows turning them into a mass phenomenon.

The scale of the post-Soviet brain drain has remained a matter for discussion. The lack of reliable data from state agencies and imperfection of expert opinions on this issue leads to big difference of opinions over the scale of emigration.

The passport and visa agency of Russia's ministry of internal affairs says that 4,576 scientists and higher education teachers emigrated in 1992, their number in 1993 was 5,876 (Tsapenko I.P., Yurevich A.V., 1995:17–25). Assessments done using the State statistics committee data for 1992–1993 suggested that the contract-based emigration was 3 to 5 times higher than the number of scientists who left the country for ever. In the early 1990s, about 20,000 to 30,000 scientists went to live permanently in other countries. It is more difficult to count those who lived abroad for years, but on papers they kept working in Russia's institutions, and finally they preferred to stay forever in foreign countries. Some analysts estimated the total number of emigrants in the first half of the 1990s as 5% of the overall reduction in the number of researchers (Kitova G. A., Kuznetsova I.E., Kuznetsov B.V., 1995:41–56).

The most emigrating scientists were physicists and mathematicians, with biologists, chemists and Earth scientists half as many. Humanitarians and social scientists were least of all among emigrants. Geographically, the largest flows were from the main scientific centers: Moscow, St Petersburg and Novosibirsk (Dezhina I.G., 2007:140).

At that stage, the pendulum mobility intensified: lengthy trips to work abroad helped to survive hard times. Some expert assessments suggest that about 30% of all scientists chose the way of occasional trips in order to work abroad.

It is more difficult to evaluate emigration of Russian scientists in terms of how strong remained the connection with scientist community at home. Very often there were no ties any longer and the migration was without return.

6. The early 21st century. Russia's participation in Bologna process.

The territorial mobility of Russian scientists saw changes in the early 21st century. The scale of the irreversible migration went down. This is how the directors of Academy institutions see emigration: "Who wanted to go, they have done it already". The survey in 2008 based on Academy scientists' responses reveals positive changes. One of the questions was: Do you contemplate the possibility of emigration to work in science or higher education in a foreign country? 71.4% of respondents were going to continue working in Russia's science or higher education.

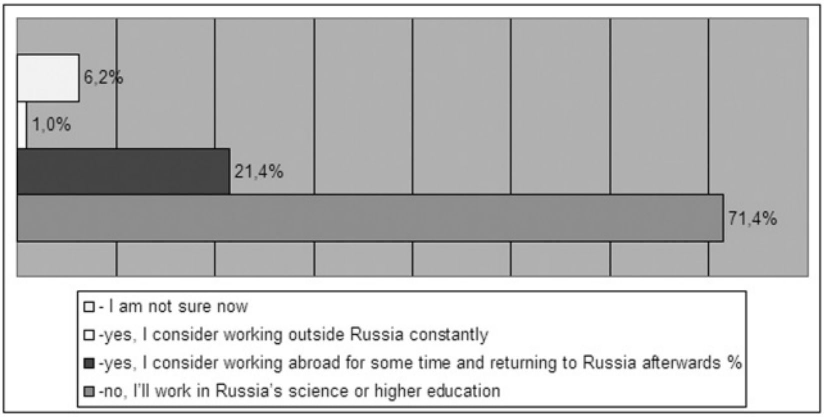


Figure 1.

Distribution of answers to the question: Do you consider emigrating to continue your work in science or higher education abroad? (%)

A declining number of emigrating young scientists may be misleading because there were few young people in the Academy institutions and the number of incoming fresh graduates is also very low. Only those who have not emigrated, are coming to work as scientists. Russia's joining the Bologna process in 2003 became a factor of increasing the extent of emigration among gifted graduates. In the Soviet times, the reproduction mechanism for scientist elite involved the following chain: an elite Soviet school — elite Soviet institute or university — a leading research institution in the USSR or department in higher education — membership in the Academy. Almost all links of this chain have changed nowadays. Russian universities share the goal of training the scientific elite with the leading foreign universities. More and more students go to study at Western universities owing partly to the system of grants for Russian students.

So, today the territorial mobility of scientists, especially young scientists in Russia, demonstrates its pronounced emigration trend and is often irreversible. The pendulum mobility in the Academy institutions is low. The period of 2006 to 2008 saw implementation of the Pilot project of reforming the Russian Academy of Sciences which led to firing a lot of researchers who worked for contracts abroad but still were counted as working in Russia.

A 2008 survey of the Academy researchers in St Petersburg revealed that their professional ties were narrow, concentrated mainly in Russia (Fig. 2). It has a negative influence on integration of Russian scientists into the world scientist community and reproduction in science.

Figure 2.

Distribution of answers to the question: How could you evaluate the network of your professional contacts?

The mobility of scientists inside the country (inpatrial) is weak and unilinear. The scientist migration flows in one direction: the most gifted and experienced Russian scientist move from the periphery to the capital cities of Moscow and St Petersburg. There are no flows from the centers to the periphery; usually scientists from the centers want to go to Europe, the USA and other countries. The ties with the scientists who went abroad are weak because a proper science policy is lacking and Russian scientists cannot use efficiently modern information technologies.

Nowadays both the Russian government and the scientist society have taken measures to correct scientist mobility.

The international seminar “Supporting the development of a scientist career and academic mobility between the Russian Federation and the European Union” was held in November, 2004. It was organized by the European Commission Office in Russia and the State University-Higher School of Economics. The team that included members from the Eurocommission, INTAS, the British Council, the German Service for Academic Exchange, other foreign organizations and specialists from the Russian national contact center 6RP for Marie Curie Actions program held, during a week, a number of presentations of the program Marie Curie Actions “Human resources and mobility” in Moscow, Novosibirsk, Tomsk, and St Petersburg. The representatives of Russian science and higher education were informed in detail on the latest European initiatives in promoting careers and international mobility of scientists. Moreover, practical advice was given on participation of Russian teams in European scientific programs, in particular, TEMPUS, Erasmus Mundus; young scientists’ grants program INTAS.

In January, 2007 the interdepartmental working group for reproduction in science and education had a meeting in the Russian Ministry of science and education. They discussed the draft federal target program “Scientific and educational personnel of the innovative Russia” that is to be implemented in 20008 to 2012.

An international conference “Cooperation Russia — European Union: priorities in the development of science and technologies for 2007–2013” was held in February, 2007. The aim of this conference was to present to the Russian scientist community those tools available to promote development of science and technologies within international cooperation. This can raise efficiency of Russian science, help to understand what standards exist in the global high tech market, how to commercialize their products globally. Now general considerations have been worked out as to how to assess submitted applications and projects. The idea is for them to get support from both the Russian Federal target program and the European program.

A meeting of experts was held in Berlin in March, 2007 on the Russian-German exchange of scientists "The scientist mobility in Europe: German-Russian scientific cooperation" which was organized by the German Research Society (DFG) and the Humboldt Foundation. Apart from briefing on exchange of scientists from the Russian Academy of Sciences and Higher Education, there was a lively discussion about the best ways of cooperation. A decision was taken to hold the next meeting of experts in Moscow.

In 2007, The Russian Humanities Foundation and The Russian Basic Research Foundation launched programs to support mobility of young scientists. Young scientists can get, through competition, internships in Russia's leading centers, as well as short trips abroad to participate in conferences, symposiums etc.

Findings of the study. Conclusions.

1. Science is international. In the modern world, science is more and more globalized, more and more international. The world science is understood as the system of knowledge production and relations between scientists in the world that includes national scientist communities, which in turn consist of regional scientist communities, teams of scientists and individual scientists. What is important is integration of each particular country into the world scientist community.

In our opinion, the following are indicators of the integration of a country into the world scientist community:

-participation in joint projects (including internships, practice, etc)

-joint publications as a result of joint researches and projects

-participation in international conferences, symposiums etc (both at home and abroad)

-citation index
-getting international grants and awards
-teaching at foreign universities.

All these indicators are influenced by the territorial mobility of scientists in a particular country.

2. The analysis of the historical stages shows that the territorial mobility of scientists hardly existed in the Soviet times with isolation from the world and total control of international contacts. Even inside the country it was forced (graduates were sent to work by the choice of government). Geography of international contacts was limited, mainly within the socialist bloc. The analysis of the literature on sociology and science studies suggests that the sociology of science in the Soviet times examined only professional and social mobility of scientists.

In the post-Soviet period, mobility took quite the opposite forms. The mass irreversible migration of scientists weakened Russian science and was one of the factors that generated a deep crisis in science. More liberal international cooperation increased tenfold the pendulum mobility, geography of scientific cooperation was extended thanks to ties with scientists from the USA, Japan, Great Britain, Finland, China, Serbia, Poland, Mexico, India and other countries.

3. In general, the territorial mobility of scientists in Russia is much lower than in the West (especially inside the country). The mobility of scientists in Russia is of markedly emigrational nature, it is often irreversible. There are no strong ties with scientists who emigrated to work abroad and there are no mechanisms to get those scientists back home. The pendulum mobility of scientists is also low. Most Russian scientists maintain relationship with colleagues mainly in Russia. Weak participation of Russian scientists in joint projects, international scientific conferences, symposiums, an insignificant number of joint publications with foreign authors, a low citation index are a result of the low three types of mobility: inpatrial (inside the country), pendulum and a migration with a feedback. The irreversible migration (without a feedback) is a barrier to Russia's integration into the world division of labor.

Exclusion of the Russian science from the world division of labor can result in its permanent falling behind. Scientists of all countries need to have close ties with each other, international research centers provide good opportunities for fruitful cooperation. Nowadays, some measures have been taken in the science policy to keep scientist elite in the country and to correct the mobility; however it remains to see how these changes will reveal themselves in future.

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Alexander G. Allakhverdyan

Manpower Collapse During the Crisis of Russian S&T and (1989–2006)

The success of the scientific activities in every country, including Russia, depends upon a conjunction of many factors. The most important factors are the following: 1) scientific personnel, 2) scientific equipment, 3) scientific information, 4) funding science.

In Russia, the effectiveness of the work of each scientist, of a scientific organization, and of scientific community to this or that degree depends upon these factors. We will discuss one of them — the scientific personnel, or, as it is often called, the human factor in the development of science. Scientific personnel is the main treasure of Russian science and its investigation is one of the most important dimensions of Russian Science studies.

The main purpose of this paper is to clarify the point of how the scientific manpower in Russia has changed during the years of Perestroika and after the disintegration of the USSR, so we will discuss the dynamics of the transformation of scientific personnel in Russia during the last 15–20 years.

To a considerable degree the situation in Russian science during the last two decades was determined by the economical crisis of the late 1990. It was the time of transition from Soviet to post-Soviet science. This crisis was accompanied by the urgent internal problems of scientific community and science, these problems were clearly understood but not solved. The problems included:

- the ineffective policy of managing the scientific potential of the country
- the structure of scientific potential was inadequate for the modern needs
- low state demand for the scientific results;
- strict division of science into civil and military parts;
- isolation of Russian science from the world one,
- poor organization of the information supply (Nekipelova, Gokhberg, Mindeli, 1994:7)

The above mentioned problems accelerated the decline of the prestige of scientific labour, lowed the status of scientific researcher in the society and contributed to that the scientific activities nearly lost their attraction for the youth. As a result, a stable trend for the reduction of the number of research personnel took place.

The investigation of scientific manpower has many sides, it includes the analysis of many different aspects of this problem based on consideration of the data of the official statistics and results of sociological research. This problem has interdisciplinary character and is located in the intersection of professional interests of sociologists, economists, and historians of science. In this presentation we will consider only the evolution of the following aspects of the many aspect problem. We will look at: 1) how the number of the scientific personal has changed starting from Perestroika and the time of the disintegration of the USSR; 2) how the proportion of female scientists to male scientists has changed in Russian science and what are the causes of this change; 3) how the age of scientists in Russia has changed; 4) what is scale of the brain drain from Russia.

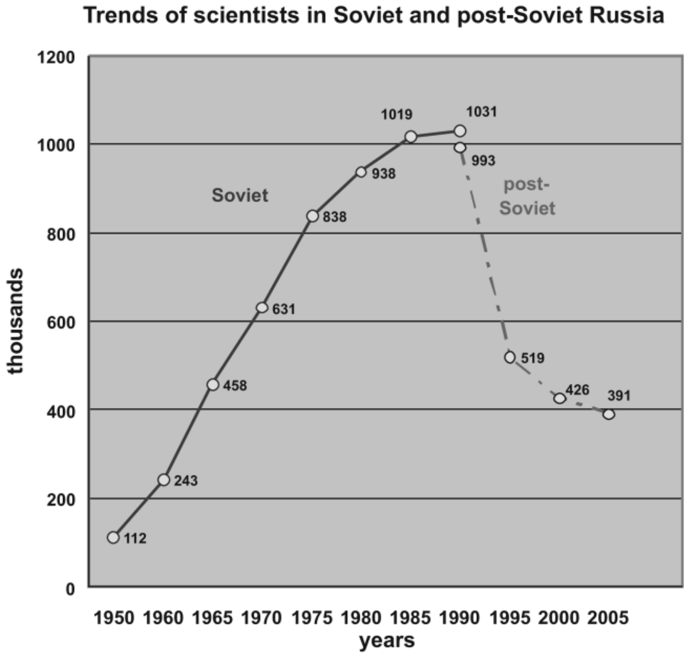
The number of the scientific personnel of the country is one of the most important quantitative indexes of not only the dynamics of scientific field but of the economy as a whole. The post Soviet period is characterized by steady decline in the number of researchers in Russian science. During the years of 1989–2006 the fluctuation of the personnel in science was mostly of spontaneous, uncontrolled character. In 1995, for example, 63% of workers who left the scientific organizations did it by their own free will, and only 13% were made redundant because of the staff reduction.

During the 18-year period (from 1989 till 2006) the number of researchers (researchers are professional engaged in R&D and immediately performing the creation of new knowledge, products, processes, methods, and systems, as well as in the management of these as well as private non profit institutions serving the above-mentioned organisations) in Russian science went down dramatically: from 1 118 812 researchers in 1989 to 388 939 in 2006, so the loss amounted to 729 873 researchers (Nayka v Rossijscoj Federachii, 2005:103; Indicatori nayki: 2008, 2008:28). However, in deferent parts of this 18-year period, the decline of the number was of very irregular character. During the first period, that is first 6 years (from 1989 till 1994), the number of researchers went down more then in half (53%). The maximum of this decline was reached in 1993, when during only one year Russian science lost 160 000 researchers. That situation was in number equal to that as if two states — Canada and Italy — lost all their scientific researchers in one year.

It is important to underline that nearly 90% of the researchers who left Russian science not only left the organizations they had worked for, but completely left the field of science. And this is not surprising, because Russia had turned very sharply to a market economy. The new sectors of Russian economy connected mostly with private business, banks and finances, started to form rapidly and many attractive well-paid working places appeared. The so-called internal brain drain became inevitable. It was a sizeable process, because it counted thousands of scientific workers (Qualified Manpower in Russia, 2000:137).

This process was absolutely inevitable because only from the sphere of science it was possible to borrow the well-prepared, well-motivated and well-educated specialists for the new sectors of economy. If we look at top management of banks and investment companies, we will see a lot of Doctors of Science and professors. For science itself this process meant the loss of highly qualified personnel.

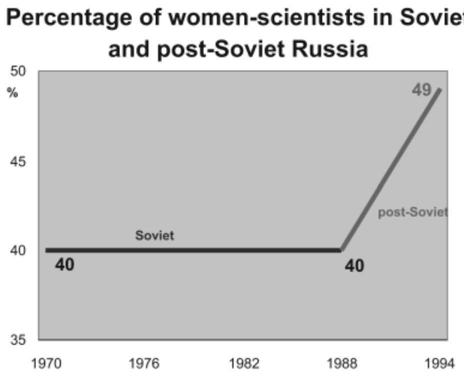
So, the steady reduction of the research personnel became the characteristic trend for the post-Soviet period. In total, during 18 years (1989–2006), the number of Russian scientists reduced almost 3 times. This is a unique case in the history of world science, when a country during such a short period lost that great number of scientists. By contrast with the post-Soviet period, during the Soviet period the number of scientific personnel has steadily and annually increased. The two diametrically opposite trends are reflected in the diagram



It should be emphasized here that the traditional notion of «scientific worker», has long existed in the Soviet science, changed in 1989, the notion of «researcher», which in terms of content differs from previous notions of « scientific worker». Thus, the graph of the figure in 1031 thousands of « scientific worker » matches in 1990, according to a new international personnel statistics, 993 thousand «researchers» (on the right, descending part of the schedule numbers 519 thousand in 1995, 426 thousand — 2000 and 391 thousand — in 2005 also reflect the number of «researchers»). However, in this particular case (1990), the numerical expression of the difference between «scientific worker» and «researcher» (1031–993 = 38) was small and there is no significant effect on the steepness of the graph, which was the main determinant of its construction and interpretations

One of the specifics of the development of post-Soviet science in 1990 is that, against the background of the reduction of the quantity of scientific personnel, one can see the relative increase of the proportion of female scientists in the total number of scientists in Russia. By contrast with the USA and other western countries, where during some historical periods the number of female scientists decreased substantially, in Soviet Russia the process of feminization of science had a steady increasing character. The statistic data show that this tendency went through the whole history of the Soviet science, and in some periods the speed of the corresponding indexes for women was higher than that for men.

Let us compare. If during the 18-year period (from 1970 to 1988) the per cent of female R&D personnel remained at the level of 40%, in 1994 (in 6 years) in accordance to statistics the female part went up 9% and made up 49%.



This happened not because more women began to join Russian science, but because the speed of the drain of men from science was much higher than that of women. The transition to other, more prestige and well-paid spheres of social activity, mostly to business, as we had already mentioned, was typical for man first of all. In this connection, Russian specialists in the Science studies E.Z. Mirskaya and E.A. Martynova: «The relatively low professional and aerial mobility of women is well known. Following inertia, women remain on their working places and agree to a small salary (wage) and not intensive work in scientific institutions. Because the reduction of research personnel goes haphazardly, without any considered scientific policy, the contemporary change in the structure of scientific personnel in Russia is going for the benefit of the least productive scientific researchers, including women" (Mirskaya, Martynova, 1993:693–700)

Another specific of post-Soviet science is the substantial change of the age structure of R&D personnel. The process of aging of R&D personnel depends on two mutually supplemental processes: small intake of the youth into science because of low salary, and slow retirement of aged scientists caused by very low pension. In 2006 only 1% of the total number of students graduated from Russian universities and colleges decided to become scientists and researchers.

Approximately every forth Russian researcher (23%) is older than 60, and about a half (51%) of R&D personnel is over 50 years old. The average age of a Russian researcher is 49 years, for Doctors of Science it is 53 years, for full professors it is 61.

One more specific of post-Soviet science which contrasts to the Soviet period is the possibility of easy travelling abroad. From the beginning of Perestroika and liberalization of emigration policy, the scale of brain drain measures by many thousands of scientists gone abroad. In accordance to the data of the Emigration Division of the Ministry of Internal Affairs of the Russian Federation, during 10 years (from 1992 to 2001), 45 544 people employed in the field of "Science and Education" left the country. We have no statistics of the following years, but the sociological investigations show that brain drain, although in a smaller extent, has been taking place up to now. The brain drain is not only the problem of Russia, but of many other countries, too. So I believe that the elaboration of a sociological programme and conduction of an international comparative research of brain drain is a pressing question.

Conclusions

- During 18 years, from 1989 till 2006, the number of researchers in Russian science has reduced by 730 thousands. The decline reached the top in 1994, when during one year Russian science lost 160 thousands researchers (this number is equal to the total amount of scientists in Italy and Canada in the same year).
- This fall of research personnel affected negatively the rating of Russian science when compared with the countries of Organization for Economic Co-operation and Development. If, by its number of research personnel (counted in proportion to every 10 000 employ-

ees), in the year 2002 Russian Science was on the 7th place , in 4 years (2006) it went down to the 18th place.

• More sensitive to this change are qualitative and not quantitative indexes of the development of science, especially the age index. In 2006, approximately every fourth Russian scientist (23%} was over 60 years old, and every second was older than 50. The average age of Russian scientists was 49 years.

• In accordance to the data of the Russia Ministry of Internal Affairs, during 10 years (from 1992 till 2001) brain drain to other countries was 45 544 persons.

• Being preoccupied with the negative personnel situation in research institutes and higher education institutions, Russian government stimulated the elaboration of the federal programme, "Scientific and Scientific- pedagogical Personnel of the Innovative Russia", for the years 2009-2013. The statistical analysis of the realization of the programme will allow evaluating effectiveness of its main points.

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Y. Madhavi

Liberalization: Its impact on Indian Vaccine S & T and Implications for National Vaccine Policy

Introduction

Vaccines are one of the important preventive medicines in primary health care. From public health point of view, vaccines are preferred and considered economical as short-term strategy to control infectious diseases, though, providing sanitation and safe drinking water is a better option to gain long-term health benefits. United Nations Development Programme estimated that it would cost at least $1260 and $20 000 per life saved to provide safe-drinking water and sanitation to rural and urban populations respectively, whereas, six vaccines and their delivery cost amount to $10 per child (Robbins, 1990). Moreover, several cost-benefit studies in the literature reported that preventive medicine (vaccines) is economical when compared to the costs of curing a disease. All over the world regular vaccination has been opted and practiced for the last several decades to control childhood diseases besides practicing sanitation. In addition, discovery of new vaccines and their availability since late 1980s created new demands in the market as well as in the public health programmes of many countries.

India adopted mixed economy after independence and to a large extent government supported public health programmes. Vaccines covered under Indian Expanded programme on Immunization (EPI) were produced and supplied by public sector units (PSUs) and were vaccinated free of cost at primary health care centers. In 1990s India introduced structural adjustments in its economy where public funding is slowly being withdrawn, and some of the public sector units were even declared sick. In this context, this paper assess the future availability of vaccines in public health programme and examines whether the increasing participation of private sector in the area of vaccines in the post-liberalization era imposes new pressures and additional costs on the government rather than relieving from them.

Vaccine Industry in Post-Liberalization Period

In 1990s at the behest of IMF, World Bank and WTO, Indian government introduced economic structural adjustments. The salient features of Liberalization introduced by the government of India include Privatization of public sector; cut in subsidy in social sector; increase in administered prices; increase in tariff rates by providing incentives for foreign investments; equating foreign companies with Indian companies; de-regulation of the labour market, customs duties and corporate taxes have been lowered. Accordingly, new drug policy was introduced in 1995 with changes in drug price control order (DPCO) that mostly favoured the growth of the private pharmaceutical sector. For instance, it introduced a single list of price control drugs with MAPE of 100%; the price fixing of drugs was based on certain limit of turnover; a drug with monopoly market would be under price control; a drug would be beyond price control if 60% of the market of that particular drug is controlled by several manufacturers; and the genetically engineered drugs produced by recombinant DNA technology and specific cell/ tissue culture targeted drug formulations will not be under price control for five years from the date of manufacturing in India. That means vaccines that are developed through genetic engineering may not be under price control. With public sector failing to meet the expected advancement in technology and production, the lifting of price control aims at attracting private sector to invest in these areas. Several authors have reported that these policies promoted the growth of the drug industry where the prices of many drugs have increased exorbitantly and the production of non-essential drugs has increased while the production of essential drugs has decreased (Sharma 1995; Madhavi and Raghuram 1995; Rane 1998; Rane 1999; and Dubey 1999). However, since primary vaccines are under price control their availability for common public is not affected so far. However, the availability of new vaccines might be influenced by structural adjustment policies are discussed in the following sections.

Transformation of Vaccine Industry under Liberalized Economy:

Vaccine industry all over the world had never been a lucrative business as long as conventional techniques of production were used and private industry was hardly motivated. In general the public funded organisations have been catering to the needs of national immunization programmes all over the world. However, the technological advancements in late 1970s and 1980s promised high-tech, expensive, high-profit oriented vaccines. During the same period several new biopharmaceutical molecules and vaccines were discovered, prepared on pilot scale and clinical trials were conducted extensively in various parts of the world, waiting to be released in the market.

When India introduced liberalization in 1990, there were around 15 vaccine manufacturing/marketing units in the private sector and around 23 government supported vaccine institutes/enterprises. In other words, mainly public sector catered to immunization programmes and private sector's participation was largely limited to the marketing of imported vaccines (anti-rabies, OPV, measles, single dose TT, oral typhoid, etc.) and veterinary vaccines that are sold in the open market. However, in post 1990s the following trends were observed in India.

(i) The slow phasing out of public sector units (Fig 1)

(ii) The public sector units set up by DBT in mid 1980s shifted away from their original objectives of achieving self-sufficiency and self-reliance in EPI vaccines

(iii) The expansion of private sector in the Indian vaccine market (Table 1) could not fill the demand supply gap for EPI vaccines (Fig 1 & 2).

(iv) Current vaccine market is flooded with expensive new vaccines and their combinations whose need, protection efficacy, safety is not established conclusively in Indian population and their introduction in UIP is contentious.

(v) India presents simultaneous co-existence of short supply of EPI vaccines with abundant expensive new and combination vaccines indicates 'supply push' drives the vaccine policy rather the 'demand pull' based on disease burden in India. In other words, market priorities take over the public health needs/immunization priorities in the liberalization era.

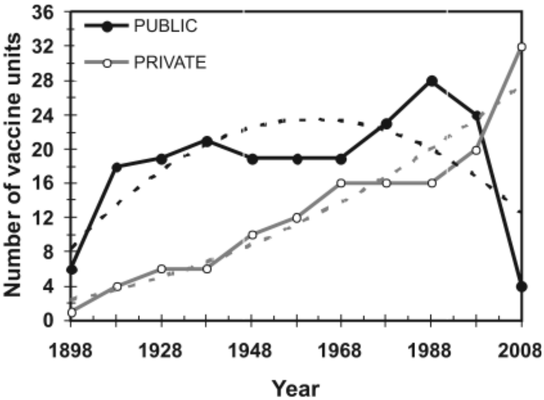

Fig 1: Growth dynamics of PSUs and private vaccine firms
Source: Compiled from Annual Reports of Health information of India and National Health Profile 2008, DGHS, India.

Table 1: NEW VACCINES IN INDIAN MARKET IN POST 1990

Vaccine	Developed by	Marketed by	**Year of introduction in the Indian market**
Rubella	Dr. Stanley Plotkin, London	Serum Inst. of India, Pune	2000
Japanese encephalitis	Natl. Inst. of Virology, Pune	Central Res. Institute, Kasauli	1990
Abhyarab (anti-rabies)	Human Biological Inst. Hyderabad	Abhay clinics	14th 2000
Anti-rabies serum	Pasteur Merieux Connaught	Pasteur Merieux Connaught	1999
Typhim-VI (single shot typhoid)			1997
Typhoid (capsule)	Hoecst India	Hoecst India	1994
Oral typhiod vaccine		Bharat Serums & vaccines Pvt. Ltd.	1990

Anti-typhoid (Cuban)	Klugman, South Africa	Cadila	1994
Leprosy vaccine	Natl Inst. of Immunology, New Delhi	Cadila	1998

Source: compiled from various news paper reports and company websites

Decreased Role of Public Sector:

With the introduction of liberalization, slowly public sector units were being phased out (Table 2 & 3). It is interesting to note that the three Public sector enterprises, Bengal Chemicals and Pharmaceuticals Ltd. (BCPL), Smith Strain street Pharmaceutical Ltd. (SSPL), and Bengal Immunity Ltd. (BI) which were set up as private enterprises during British India (in 1900s) were taken over by the government in 1980s and declared as public sector units to meet the demands of EPI vaccine requirement. However, it is ironical to note that the very same public sector units that were meeting most of the EPI vaccine requirements of the country were declared sick, while Indian Drugs and Pharmaceutical Ltd. (IDPL) were closed down in 1996 for want of financial assistance from government and some of the plants (Penicillin and streptomycin Plants) of Hindustan Antibiotics Ltd. (HAL) were handed over to private companies (Dubey, 1999). Thus, indigenous production capacities for vaccines as well for antibiotics (IDPL and HAL) were badly affected by the changing economic policies of Indian government, in turn affecting the access to affordable preventive and curative medicines.

TABLE 2: IDENTIFIED CENTRAL SICK PUBLIC SECTOR ENTERPRISES (1994–95)

Company	Paid-up capital	Accumulated losses	No. of workers	**Cash loss**	**Cost of revival**	**Cost of closure**
BCPL	12.8	53.44	1454	417	94.48	83
BI	15.74	32.79	1431	376	77.5	49
SSPL	5.93	18.85	800	487	25	22
Indian Drugs	111.91	434.08	9516	87	129	753

MAP	1.24	6.64	158	54	3.5	12.47
Orissa Drugs & Chemicals	0.54	1.71	69	0.48	1.2	6.24

Source: CIER's Industrial data Book, 1998, Sage Publication, New Delhi.
BCPL: Bengal chemicals and pharmaceuticals ltd., BI: Bengal Immunity Ltd., SSPL: Smith Srainstreet Pharmaceuticals Ltd.

TABLE 3: PERFORMANCE OF PUBLIC SECTOR COMPANIES (IN RS. CRORES)

Company	1989–90		1992–93		1993–94		1994–95	
	Capital employed	Net Profit after tax	Capital employed	Net Profit after tax	Capital employed	Net Profit after tax	**Capital employed**	**Net Profit after tax**
BI	17	−5.9	−11	−7	ed	−8	4	2
SSPL	−119	−4.2	−3	−7	−11	−8	0.3	−4
KAL	12	0.3	10	1	12	2	12	2
IDPL	235	−42.7	−173	−83	−44	−70	−92	−70
HAL	NA	NA	145	2	144	−13	118	−22

Source: CIER's Industrial data Book, 1998, Sage Publication, New Delhi.
BCPL: Bengal chemicals and pharmaceuticals ltd., BI: Bengal Immunity Ltd., SSPL: Smith Srainstreet Pharmaceuticals Ltd.

Several state sponsored public sector units (PSUs) that have been supplying EPI vaccines to respective states have been closed down slowly owing to the withdrawal of support from the respective state governments (Fig 1). The number of private vaccine manufacturers increased with new entrants in India in post 1990s, in contrast to the shrinking number of global vaccine manufacturers. Currently, global vaccine industry is dominated by a few large multinational companies such as, Aventis Pasteur, Biocine Sclavo, GlaxoSmithKline Beecham, Chiron Behringer, Merck, Wyeth-Ledrle etc., and many are a part of the global WHO-UNICEF vaccination programme (www.immunize.org). In India, all of the existing PSUs including those who were over century old have been closed down by 2008 except for two, and at the same time the growth of vaccine private sector accounts for 30 companies (Fig 1). In 1980s around 5 PSUs were closed down and between 2000 and 2008 around 14 Vaccine PSUs were closed down in India. Private manufacturers worldwide have shifted to the production of more new vaccines, leading to demand supply gap in primary vaccines. Most of the existing Indian vaccine production units were using only conventional technologies of production till now and the lack of resources is not allowing them to use new technologies of production. Public sector is a late entrant to use new technologies (Haffkine Institute producing OPV since 1997) while private companies like Serum Institute of India, Pune are ahead using new technologies (Measles, OPV, IPV, DPTP) of production in early 1990s with the technology transferred from elsewhere.

The Fate of public sector units set up after 1990 by Department of Biotechnology (DBT)

In 1989 DBT setup two public sector units, Bharat Immunologicals and Biologicals Ltd. (BIBCOL), Bulandhshar and Indian Vaccine Corporation Ltd. (IVCOL), Gurgaon) to achieve self-sufficiency and self-reliance in vaccines by the year 1992 using modern methods (genetic engineering, tissue culture method) of technologies. However, they have failed to achieve the objective in post 1990s. IVCOL is aimed to produce 20 million doses of measles vaccine, 50 million doses of IPV and 40 million doses of DPTP. However, it was closed down in 1997 due to non-availability of technology for measles vaccine production (Madhavi, 1997). BIBCOL is aimed to produce OPV and plasma derived Hepatitis B indigenously by 1992. However, the company is only concentrating on the finalization of procurement of OPV vaccine from reputed companies and plasma derived Hepatitis B production has yet to begin, while negations were going on to produce recombinant Hepatitis B vaccine (DBT Annual Report, 1997-98). It is interesting to note that while recombinant Hepatitis B vaccine has been considered safer, BIBCOL is still collecting plasma for its (plasma derived Hepatitis B Vaccine) production, whereas new private companies are manufacturing recombinant Hepatitis B vaccine indigenously. BIBCOL was been declared as sick company and IDBI was appointed to prepare a revival package in 2000. Under bilateral S&T cooperation Programme between Russia and India, the company was planning to produce OPV and BCG (DBT Annual Report, 1999–2000).

TABLE 4: ANNUAL BUDGET ALLOCATED TO IVCOL AND BIBCOL BY DBT (IN RS. LAKHS)

Compa–ny	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1994–95	1995–96	1996–97	1997–98	98–99	99–2000	**2004–2005**
BIBCOL	10 (For both)	550 (For both)	453 (For both)	4.09	0.2	0.0	0.0	0.0	3.0	5.31	0.05	0.05	0.00
IVCOL				0.91	0.0	0.0	0.0	0.0	1.5	0.0	0.00	0.00	0.00

Source: Compiled from DBT Annual reports.

Though these units were set up to meet the policy objective, the gradual decline of annual budgets allocated in post 1990s is a reflection of implementation of liberalization policy, where deliberate disinvestments in public sector is evident from the above table (Table 4). The budget allocated in the previous years since their inception reflects that during the period 1992–93 to 1995–96 no funding was given to both the manufacturing units. However, during the financial year 1996-97 the funding for BIBCOL has increased probably because plasma derived Hepatitis B production was initiated in collaboration with Centre for Disease Control (CDC), Atlanta, but the budget allocation for BIBCOL had decreased in the following financial year and in 2000-2001 no budget was allocated. Recently BIBCOL became debt free and continue to repackage from bulk OPV to Indian EPI programmes and to UNICEF. BIBCOL is planning to change its product folio into other pharmaceutical products through public private partnerships (DBT annual Reports 2004–05 to 2007–08). IVCOL was closed down in 1992 as technology for the production of measles was not available from Pasteur Merieux Serum & Vaccines (PMSV), France, as it became private company and India was viewed as potential future market for measles vaccine (DBT annual Report 2007–08). Thus, in post 1990s, though two public sector units were set up to meet the objective of vaccine self-sufficiency and self-reliance by DBT got diluted due to liberalization, globalization and the resultant open competition among vaccine companies.

Increased Role of Private Sector:

Technological advancements created bigger markets for vaccines, and the liberalization in India facilitated market for new vaccines beginning with Hepatitis B vaccine. It is evident from the market trends that even if there is no liberalization Indian companies would have any way imported the vaccines and sold them in the domestic market. However, low import duties in the liberalized policy certainly facilitated Indian companies to import and sell vaccines in the private market and/or to the private medical practitioners/ doctors through medical dealers, whose target is mainly middle class, upper middle class and rich class. According to "HAI News (1999) the pharmaceutical market in India is expected to grow around 10 billion US dollars by 2010 maintaining a compound annual growth rate of 15% with the increasing buying power of Indian consumers (middle and upper middle class people more than 200 million growing at a rate of 5–10% per year)" (Madhavi 2007). In that case Indian domestic market has to be prepared for the tough competition in future.

Indian vaccine market was very negligible (0.1%) when compared to total pharmaceutical market in pre 1970s as well as in post 1980s. However, the vaccine market is growing in post biotechnology period due to high profit margins and the large market size, and if they are included in national immunization programmes the rate of returns on the new vaccines would be ensured for many years to come. Currently global vaccine market constitutes 2% of world pharmaceutical industry, growing rapidly at the rate 22% per anum according to a market survey and it is estimated to be US$10 billion currently and expected to grow US$23 billion by 2012 (Terradaily, 8^{th} Feb 2007, http://www.terradaily.com/reports/Global_Vaccine_Market_To_Top_23_Billion_Dollars_999.html). Indian vaccine market is around US$150 million currently and expected to grow to US$900 million by 2012. In 2002-2003, vaccines accounted for 57 per cent of the total Indian biopharmaceutical market with an estimated growth rate of 27 per cent in 2004 (Pharma 2001). The global vaccine business is currently concentrated in 5 major MNC's such as sanofi-Pasteur (Sanofi-Aventis group), Wyeth Ledrle, Merck, Chiron Behringer, GSK, Biocine Sclavo etc. Multinational and national manufacturing companies view Indian market as gold mine. Unlike in pre 1990s Indian vaccine market is growing at a rate of 22–27% per annum, but the country is still spending US$ 12 million on imports of primary vaccines. In 1993, the total turnover of Indian production of human vaccines at manufacturers level was around US$ 33 million (Chaturvedi and Pandey, 1995).

The growth of vaccine industry in India is attributed to the increasingly growing participation of private sector, which has focused on high-priced new/improved vaccines (Table 1). Private companies imported and resold them (new typhoid oral vaccine, hepatitis b vaccine, single dose TT vaccine, MMR etc.) in the Indian market, because this short route is more profitable than to invest in manufacturing. Glaxo, Biological Evans Ltd., and Serum Institute of India account for a large share of Indian DTP production (Chaturvedi and Pandey, 1995). In addition, new entrants like Shanta Biotech, Bharat Biotech, Hyderabad, also ventured into the Hepatitis B vaccine domestic market to compete with Smithkline Beecham (SKB), one of the largest producers of the Hepatitis B in the world. Existing companies like Panacea biotech, Biological E Private limited, and Serum Institute of India also expanded their business into new vaccine marketing as well as indigenous production. Moreover, Technology Development Board (TDB) under Department of Science and Technology, ministry of science and technology of Government of India boosted commercialization of indigenous vaccines by providing soft loans. TDB soft loans facilitated private companies like Shantha biotech and Serum Institute of India to produce those vaccines (eg. Hepatitis B, Hib and their combinations with DTP) indigenously, which are off the patents. A large demand for Hepatitis B market was created across nations by the industry by campaigns and lobbying World health Organization (WHO) to include it in national immunization programmes of its member countries. The early entry of indigenous Hepatitis B vaccine production in India could be due to policy support, where the basic technology is known and the vaccine is considered to be relatively safe and stable. Moreover, SKB's patent for this vaccine has expired in 1998, and hence the race among many companies to enter the market and to get EPI orders for Hepatitis B vaccine since early 1990s (Madhavi 2003). In response to globalization and liberalization, the vaccine companies were waiting for an opportunity to compete in the market, like the other drug companies looking for future market in generic drugs as many of the patents on bulk drugs would expire around 2000-2005 (Surendar, 2000). Other new vaccines follow the suit, where a list of new vaccines is in a row to be introduced in national immunization programme of India promoted by Indian Academy of Pediatricians and the industry (Parhasarathy 2002). These trends reflect that the post-liberalization period facilitated the growth of private vaccine sector whose interest lies in the production of new vaccines with high profit margins, while public sector continue to manufacture traditional vaccines (Fig 2).

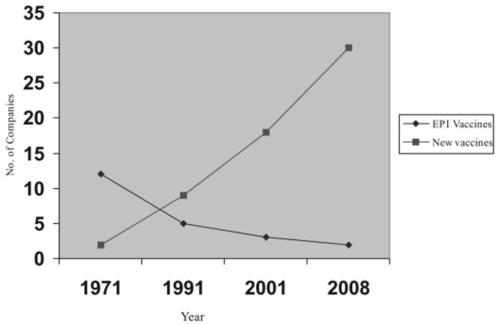

Fig. 2: The Growth of Private Sector in Indian Vaccine Market

In addition to liberalization, globalization and new patent regime imposes new challenges on domestic pharmaceutical industry including vaccine development. Due to the new Intellectual Property Rights (IPR) regime, Indian vaccine industry cannot produce new vaccines until the patents for the existing new vaccines expire. Either it has to adopt long-term strategy to ensure their future markets by strengthening their in-house R&D or they may adopt short-term strategies such as outsourcing, contracting etc. Starting from scratch to develop new vaccine at this juncture is risky due to the incubation period of 20 years and whose costs any Indian company may not be able to afford. Therefore, Indian companies may opt for short cuts, such as to wait for the expiry of patents on vaccines to prepare them indigenously at low cost.

Liberalization impact on Indian vaccine Science & Technology

India was early bird in vaccines and one among leaders when vaccine research began to gain importance in the rest of the World and continues to do so even today despite some lag period during I & II World war and the following period till 1970s (Madhavi 2005). Fair institutionalization of vaccine R&D during British India and its expansion in the independent India with the emergence of several dedicated vaccine R & D institutions during the period 1950s-1980s had kept Indian R&D efforts at consistent pace. However, India could not keep up its pace with the developments in post biotechnology period, though it could meet domestic vaccination needs with incremental innovations to save costs and to improve yields of the vaccines produced indigenously. For instance, India being member country of WHO, launched expanded Programme on immunization (EPI) in 1978 to vaccinate children against childhood diseases and accordingly the existing vaccine R&D institutes that were set up during British India were restructured to produce DPT group of vaccines (DT, TT, DPT) and typhoid vaccine to meet EPI requirements of various States. Entire BCG vaccine requirement for the country is supplied by BCGVL, Chennai. India imported 100% OPV and Measles vaccine undermining the ability of Pasteur Institute of India's (Coonoor) indigenous production of OPV between 1967–1976 as an coordinated activity between Indian Government, WHO and the developer of OPV vaccine Dr. Sabin himself (Madhavi 2007). Measles vaccine was imported until 1992, till a Pune based private company started supplying the vaccine to Indian EPI. All the EPI vaccines that were indigenously manufactured used conventional techniques of production such as heat inactivated or chemically attenuated preparations though as and when required minor innovations improved yields as well economized. Meanwhile the emergence of disciplines such as modern biology and its specialized fields in mid 1970s radically transformed vaccine technologies of production in several parts of the world, while India was struggling to catch up with technological developments elsewhere. India launched Universal immunization programme in 1985 to meet the objective of 1977's World Health assembly's global objective to 'United Child Immunization' (UCI) by 1990. To meet UIP objectives, Ministry of health and family welfare (MOHFW) launched a technology mission and Department of Biotechnology (DBT) was the nodal agency to implement the programme of EPI. Thus, the real emphasis for new vaccine technology development and new techniques of production came up with DBT's active involvement to promote vaccine R&D as well as production to achieve the self-reliance and self-sufficiency to meet the objectives of EPI and UCI by 1990.

The issue of affordability of vaccines to the majority of the population has been discussed extensively. Some studies propose that an increased national, bilateral and multilateral public sector support is needed to solve the problems of developing vaccines and a new kind of public-private collaboration is needed (Bloom and Widdus, 1998). Indian government launched in 1996 an ambitious project to develop and manufacture new 'home grown' vaccines against several communicable diseases (malaria, TB, cholera, rabies, Japanese encephalitis and AIDS) in 3 years for $4 million. They will be developed and manufactured in 12 basic research institutions and 2 private companies (Indian Immunologicals, Bharat Biotech, Hyderabad) (Jayaraman, 1999). This was for the first time that the Indian government had allocated funding specifically for vaccine R&D. It is to be seen whether this academia industry linkage would promise indigenous development of vaccines and ensure affordability/availability of future vaccines in public health programmes. A study on the vaccines for the third world points out that developing countries have to rely on their own abilities, intellectual and material for developing their own biotechnology to develop vaccines in their country and political will and imagination is needed to ensure the availability of vaccines and essential drugs (Bloom, 1989).

Efforts of DBT led to basic R&D initiatives in more than 14 vaccine areas, with 6 vaccine candidates in the pipeline and more than 7 vaccines reached clinical trial stage in 23 Indian research organizations and university departments. However, there is a mismatch between Indian R&D priorities (based on the disease burden) and the actual research activity owing to the factors such as fund availability, international collaborations/international aspirations that have influenced direction and focus of Indian vaccine R&D. Liberalization distorted Indian vaccine R & D priorities and international collaboration, public private partnerships have come to conduct more of clinical trials of imported vaccines rather than research collaboration that India may benefit. Indian indigenous vaccine development efforts did not receive enough patronage they deserve. For instance, vaccines against Japanese Encephalitis, Cholera, and Leprosy developed from Indian strains are not promoted as aggressively as other imported vaccines (eg: HB, Hib, chickenpox, rotavirus etc.) are promoted for which there is no unambiguous evidence exists for their need in India.

It is believed that open competition would facilitate new collaborations nationally and internationally and facilitates access to new technologies and new vaccines. Though, liberalization ensured access to expensive new vaccines to those who can afford them, it did not ensure easy access to new technologies, except for those vaccines, which are off the patents. All five domestic companies (Shantha biotech, Bharat biotech, Panacea Biotech, Serum Institute of India and Biological E Ltd.) that have come up in vaccine business in mid 1990s in India banked on the indigenous production of Hepatitis B, followed by Hib vaccine, which were off the patents. Indian structural adjustment policy allows equity participation to foreign companies at par with Indian companies and increase in tariff rates would provide incentive for foreign investment and tough competition for Indian companies. Therefore, the domestic pharmaceutical market faces tough competition with MNCs, who are the holders of latest technologies. MNCs would not like to part with the new technologies as India promises a huge market. This is evident from the fact that a public sector company in France that had agreed to transfer the measles vaccine technology to Indian government had denied it when the French public sector company became private. Similarly, international technology transfers are very meager when compared to international collaborations for testing/conducting clinical trials or marketing alliances of vaccines. Therefore, the availability of vaccine technology may be difficult in future and India may not get better deal even while bargaining technology transfers. India is left with no option but to strengthen its in-house R&D, strengthen academia and industry linkages for long-term benefits. Under the liberalization policy, since labs have to generate their own money to do research, they would prefer to opt for short-term goals and long-term strategic research options may not workout due to inadequate resources. This trend is already apparent in some national labs and autonomous institutions where laboratories are shifting to short-term projects, to field research to synthesizing already existing molecules, but no basic research. Moreover, liberalization did not make congenial for the corporate sector to establish linkages with the research centers. Industry sources point out that bureaucratic procedures continue to stymie indigenous R&D efforts (Bhattacharya, 1998). Thus, liberalisation policy of declining funds to universities and national labs may affect the basic research and long-term research may suffer in India. Industry would also prefer short-term options with its weak in-house R&D. Therefore, unless some strategic academia-industry linkages are forged to save the costs, it is difficult to face the global competition.

The trend to opt for short term strategies such as sub-contracting or outsourcing to compete in the global market under new IPR regime by domestic pharmaceutical companies is already evident in Indian vaccine industry (Madhavi 2003). For instance, SII, Pune will market Hepatitis B in the domestic market with a technology licensed from foreign firm, Rhein Biotech. It will pay a royalty of 5% sales to Rhein and `Transgene Vaccines' will manufacture the vaccine (Kamat, 2000). SKB is working with Serum Institute of India (Pune) to make a combined Hepatitis B and DTP vaccine in India (Hari, 1997). Companies such as Shanta Biotech, Reddy's labs, Hyderabad and SII, Pune are a few examples, which are strengthening their in-house indigenous capabilities for long-term benefits. Also, due to large investments involved in vaccine development and due to globalisation and liberalisation in several countries across the world, several companies are merging to save the costs. Over the last ten years the vaccine industry has gone through major transformation, with vaccine companies merging and being acquired by larger pharmaceutical companies due to globalization. At present vaccine industry is composed of a few large MNCs and several smaller firms and a host of publicly owned national production entities primarily serving their domestic market. Also, for their own survival Indian vaccine companies are collaborating with foreign companies/organizations for contract research such as product development or pilot production of vaccine to conduct clinical trials (Ghaswalla, 1999). It is apparent in all the new entrants of Indian Hepatitis B market. For example, Shanta Biotech is Indo-Omnase collaboration and Bharat biotech, Panacea Biotech are also companies with international collaboration. Recently Shantha biotech sold out to a French Company reflects tough competition domestic vaccine industry has to face for its survival. Thus, post liberalisation imposes new constraints on the industry as well as on R&D front and both are in a stage where on one hand they are struggling to survive in the domestic front and on the other trying to catch up with technological development and global competition.

Impact of Liberalization on the access to affordable, needed vaccines:

Though, vaccines account for only 2 percent of the entire pharmaceutical industry, they have become indispensable due to their availability and due to global/national immunization policies/ progrmammes that have greater implications on global and national health policies and public health. WHO, UNICEF and World Bank are in favour of including more vaccines in EPI in future that may have larger implication on the future availability of vaccines, especially in developing countries. In India, Liberalization has led to the decreased role of public sector leading to attenuation of indigenous capability that was initiated and nurtured in the last 100 years (Fig 1). As there is steep decline in the number of vaccine PSUs in the last 3 decades leading to the declined production of EPI vaccines by public sector. It is evident from the Fig. 3 that it is the public sector that is contributing to the production of EPI vaccines compared to private sector till recently. There is also steep rise of vaccine private companies in India during period 2000–2008. However, the private sector is more interested in the production new and combination vaccines (Fig2). As a result, the number of companies that manufactured and supplied vaccines to EPI programme has declined both in public and private sector (Fig 3).

This led to the increased demand supply gap for EPI vaccines (Table 5) in India adding to the existing problem of erratic production

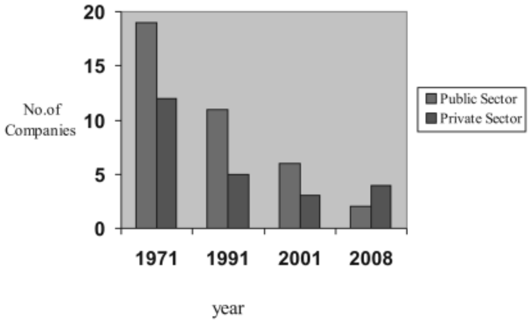

Fig 3: Primary vaccine Suppliers to Indian EPI in The Last Four Decades

pattern of the vaccines (Fig. 4) over the years. Orphanization of EPI vaccines, despite the growth of private sector in India is also true for many other countries as well. The demand supply gap for EPI vaccines is the current global worrisome phenomenon as regular suppliers to UNICEF have stopped the production of EPI vaccines and expanded their production capacities for new vaccines as shown in Fig 5 (http://www.unicef.org/supply/index_vaccine_security.html).

TABLE 5 : DEMAND & SUPPLY OF UIP VACCINES

UIP vaccine	**1991–92** (lakhs doses)		**2006–07** (lakhs doses)	
	Demand	**Supply**	**Demand**	**Supply**
DPT	1320.24	1270.30	1916.96	1636.88
DT	350.00	650.82	378.01	370.29
TT	1190.00	2319.71	3651.45	2887.94
BCG	500.60	168.50	894.94	758.66
OPV*	1550.60	950.50*	4823.66	4812.48
Measles	500.00	680.00	2688.10	2688.10
Hep.B			843.83	843.83

Source: Compiled from Annual Reports of Health information of India and National Health Profile 2008, DGHS, India.

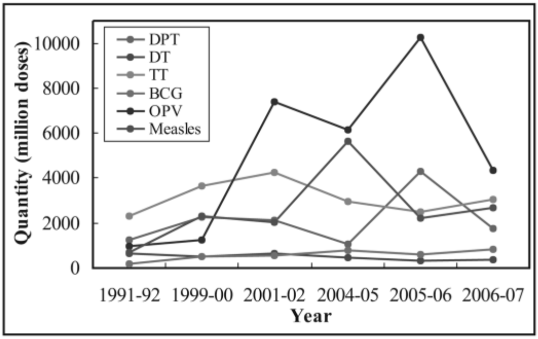

Fig 4: Erratic production of UIP vaccines

Source: Compiled from Annual Reports of Health information of India and National
Health Profile 2008, DGHS, India.

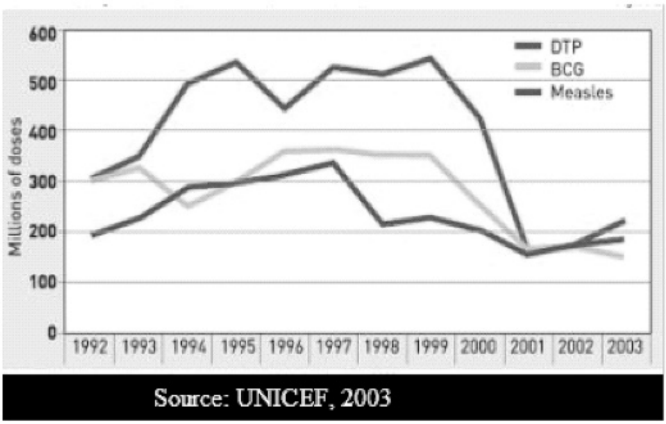

Fig 5: Global Shortage for EPI vaccines

It is apparent from the trends in India and in the world that it is the public sector that was meeting the EPI demands and private sector is interested only in vaccines which are profitable and not interested in meeting short supply of EPI vaccines, though some Indian companies recently been qualified by WHO as suppliers to UNICEF procurement system. The fact that the public sector is no longer fashionable in the liberalized World and its implications for public health programmes like immunizations is evident from the recent closure of 3 vaccine public sector (Central Research Institute Kasauli, Pasteur Institute of India, Coonoor and BCG vaccine Laboratories Ltd., Chennai) units in Jan 2008 and a project for upcoming vaccine park was envisaged in 2011 to meet Indian EPI vaccine needs of the country (Kannan 2008). This has fuelled much deserved debate in the media, medical doctors, consumers and public health workers were concerned and critical about these developments as the question of meeting EPI vaccine needs till vaccine park comes up after 3 years. Though, several PSUs have been phased out in the past several years, the closure of the above PSUS made significant negative impact on the national immunization programme and it is much more glaring and serious as these companies contribute 80% of DPT group of vaccines and 100% of BCG vaccine requirements of the country. This led to the orphanization of EPI vaccines risking child health and in India. This is evident from the fact that there is acute shortage for EPI vaccines reported within 6 months of Closure of the 3 PSUs in 23 States as presented below (Table 6).

TABLE 6: REPORTED SHORTAGES OF EPI VACCINES FROM DIFFERENT STATES BETWEEN JAN-OCT 2008

State	Vaccine shortage
Haryana	TT for pregnant women (TT Pw), DPT
Andhra Pradesh	
Arunachal Pradesh	BCG
Andaman and Nicobar Islands	BCG
Assam	DPT, Measles
Bihar	DPT, BCG, Measles
Chandigarh	TT Pw, DPT, BCG
Chhattisgarh	DPT
Delhi	TT Pw, DPT, yellow fever (No DPT vial stock since mid July 08. No stock of yellow fever vaccine for last 4 months)
Gujarat	TT Pw, DPT

Himachal Pradesh	DPT
Jharkhand	TT Pw
Karnataka	TT Pw
Kerala	DPT, yellow fever (State requires eight lakh doses of vaccines a year against the 2.5 lakh doses provided by the Centre this year. The State cannot procure these vaccines locally as the Centre was not ready to fund their purchase
Lakshwadeep	TT Pw, BCG
Madhya Pradesh	TT Pw
Maharastra	TT Pw, DPT yellow fever
Orissa	TT Pw and shortages of DPT, BCG, OPV and measles was also reported from Koraput district
Punjab	DPT
Rajasthan	TT Pw
Tamil Nadu	TT Pw, yellow fever
Uttar Pradesh	TT Pw
West Bengal	TT Pw, DPT

Source: Compiled from Newspapers and NRHM Dec 2008.

Private Sector promised Indian union health ministry that it would supply EPI vaccines at par with prices supplied by public sector (Ramachandran 2008). However, private sector complained after 6 months that its sales revenue gone down by 22% and it may not be able to supply at same price next year (Biospecturm 11th July 2008). The situation ahs not improved even after one year (Ramachandran 2009). Parliamentary Standing committee on health also pointed out the resultant shortages due to private sector's short supply and resultant consequences to country's child immunization programme.

The demand-supply gap following vaccine procurement from private suppliers during 2008-09

Table 1 (In lakh doses)

Supplier	Vaccine	Total order placed	Total requirement	Difference
B.E. Ltd., Hyderabad	TT	1,360.00	1,708.00	348.00
B.E. Ltd., Hyderabad	DPT	800.00	1,579.87	
SII, Pune		300.00		
IIL, Hyderabad		63.00		
Total		1,163.00		416.87
B.E. Ltd., Hyderabad	DT	375.00	432.66	57.66
Bharat Biotech Ltd., Hyderabad	OPV	1,350.00	1,581.86	
HBPCL, Mumbai (Pipeline)		180.50		
Total		1,530.50		51.36
SII, Pune	Measles	360.00	391.20	58.80 excess procurement
IIL, Hyderabad		90.00		
Total		450.00		
SII, Pune	BCG	600.00	759.21	159.21

Source: 34th Parliamentary Standing Committee Report on Health and Family Welfare

(Source: Reproduced from Ramachandran, Frontline 2009)

TABLE 7: PRIVATE SECTOR MEETING EPI VACCINE SUPPLY AFTER THE SUSPENSION OF 3 PSUS

Vaccine	2006–07			Private Sector supply in 2008–09		
	Demand	**Supply**	**Shortage**	**Demand**	**Supply**	**Shortage**
DPT	1916.96	1636.88	280.08	1579.87	1163.00	416.87
DT	378.01	370.29	7.72	432.66	375.00	57.66
TT	3651.45	2887.94	763.51	1708.00	1360.00	348.00
BCG	894.94	758.66	136.28	759.21	600.00	159.21
Measles	2688.10	2688.10	0.0	391.20	450.00	-58.81
OPV	4823.66	4812.18	11.48	1581.86	1530.50	51.36

Source: Compiled from National Health Profile 2008, Directorate General of Health Services

(DGHS) & 34th Parliamentary Standing Committee on Health and family welfare, India.

Thus, it is evident from Table 7, that shortage for EPI vaccines when supplied by private sector (except Measles) is more when compared to PSUs meeting EPI vaccine shortages. At least from Indian example it is evident that liberalization facilitated private sector's growth at the cost of public sector and at the cost of child immunization programme. This underscores need for good governance and regulatory structure in place, where there can be some deterrent on private sector to meet country's EPI needs.

Affordability of New Vaccines

New vaccines are available in abundance in Indian market and in Private clinics that are prescribed by private practitioners. Prices of EPI vaccines produced by Public sector in general are lower compared to private sector's prices in the open market. All new vaccines are produced by private sector and are very expensive (Table 8).

TABLE 8: PRICES OF VACCINES PRODUCED BY PUBLIC & PRIVATE SECTOR

Vaccine	Quantity	Public Sector	Private Sector
Primary (UIP) Vaccines		**(Indian Rupees)**	**(Indian Rupees)**
OPV	10ml	9.22	52.11
DPT	5ml	13.75	~15.00–215.00
TT (adsorbed)	5 ml	~2.40 to 5.12	37.50
TT	5 ml	2.68	5.83
DT	5ml	5.75	-
Measles	1 ml	None	~56.84 to 1125.
New/Improved Vaccines			
Hepatitis B	Pediatric dose	None	~45.00 to 181.00
DTP-Hepatitis B conjugate	Adult dose -	None	~97.00 to 225.00
R-Vac (against rubella)	1 dose	None	36.80
MMR	0.5ml	None	66.05
Anti-Rabies	0.5ml		~147.00 to 184.50
HAVRIX	1ml	None	~294.00 to 1125.66
(for hepatitis A)	Pediatric dose	None	712.00
Meningococcal A&C	Adult dose	None	1360.00
Influenza type B	1 dose	None	48.85 to 370.00
Typhoid	0.5ml	None	~185.00 to 400.00

Source: Compiled from MIMS India 2008

The Indian government provides vaccines under universal immunization programme free of cost at primary healthcare centers. For full immunization, vaccines may need one or more doses and costs are high if a parent has to spend out of his pocket for all these vaccines (Madhavi 2005). It is burden on the consumer to buy vaccines in open market whose benefits are not proven in Indian population (Madhavi 2003, 2006, 2007, Phadke and Kale 2000). There is pressure from international agencies as well as industry in WHO member countries to introduce many new vaccines in their National immunization programmes. One can imagine the burden on national governments if these vaccines have to be introduced in National Immunization programme. Several Indian studies indicate that many of the new imported vaccines may not be cost-effective and beneficial in Indian population keeping in view of epidemiology of prevailing diseases and protection efficacies of those vaccines (Phadke and Kale 2000, Arora and Puliyel 2005, Madhavi 2003, 2005, 2006, 2008, Puliyel and Madhavi 2008).

Improved/new vaccines are in general expensive and these vaccines in national immunization programmes can be made available only if prices come down. How to ensure the affordability of prices for new vaccines became a major concern for the policy makers. The affordability of new vaccines by the majority of population is dependent upon the price of a vaccine, which is based upon its cost of production and economies of scale. Several authors (Krahn & Gafni 1993; Holliday and Faulds 1994; Brenzel & Claquin 1994; Batson 1998; Ruff 1999; Martin 1999 and West 1999) have extensively illustrated vaccine economics. According to "Batson (1998), vaccine manufacturing is a fixed cost business with roughly 85% of costs fixed at a batch, site or corporate level and only 15% of costs remaining variable". Therefore, a large volume manufacturer, which shares the fixed costs over a great number of doses, will have a lower cost per dose than low volume manufacturer. Though a small proportion of the cost difference is due to variation between national lab markets and regulatory requirements in different countries, almost 50% of the difference is directly attributable to the scale. Thus, major global manufacturer can benefit from a rapid decline in cost per dose and can attain a more competitive cost position than smaller manufacturers. Also managing product life cycle is important and it determines vaccine market. The global market demand fuelled by the public sector provides an outlet for large volumes and enables manufacturer to lower the costs of production. However, tensions exist between the manufacturer and public health agencies because, while public health agencies can afford traditional vaccines at affordable prices, they have limited access to affordable new products (Batson, 1998).

Vaccines purchased at low price through UN procuring mechanism make only small contribution to the full R&D investment made by the manufacturer, but help create all segments of demand to be met, at an appropriate price. Prices of vaccines are steeply tiered for different markets determined by the affordability, particular market and competition. Vaccine prices span a very broad range; the average price differential between the poorest and the richest market is a factor of 70 (Ruff, 1999). Global manufacturers are in favour of tiered pricing because it would satisfy public health objectives and also safe guard global demand, revenues and even reducing costs. Health Specialist, World Bank suggest that the public sector's capacity to centralize the procurement of vaccines for the neediest countries can provide an efficient mechanism to target the lowest tiered price to the neediest countries.

While the above studies express their concern about access to affordable vaccines in the best of interests of global health, most of these studies presume that all vaccines are effective, safe and economical in all populations and in all countries alike, contrary to the evidence that the species variation among disease causing pathogens across the World is vast. This presumption tend to emphasize more on 'introduction' and 'coverage' of vaccines rather than the protection achieved by vaccination and tend to de link global priorities with local realities. For instance, recently WHO and GAVI recommended that India should include HB in its combination form (DTP-HB), Hib and Pneumococcal in its national immunization programme. However, evidences from India reflect that there is no actual prevalence data on these three diseases and the low price of vaccine or the support for introduction vaccines for 2 years from GAVI (which may not be sustainable when it would withdrew its support) is not the only issue that justifies any new vaccine introduction in any country, there are other issues which are more important that ensures that population is actually getting protection against these diseases. For instance, Indian children develop natural immunity against Hib during their infancy (Puliyel 2001)and whether it is worth spending so much money for its universal introduction rather than concentrating on other diseases like TB, Malaria and diarrohoea etc., is worth considering. It is argued that imported 7 valent Pneumococcal vaccine is not effective in Indian population, it protects only radiological pneumonia and not pulmonary pneumonia and it has risk of causing asthama, a life long debilitating disease (Chowdhary and Puliyel 2008). Moreover, the disease can be cured with medicines. The obvious question would be why does India risk introducing an expensive vaccine risking its child health? Is it cost-effective? Heaptitis b vaccine was introduced in India in phases in the midst of controversy (Madhavi 2003, Dasgupta and Ritu Priya 2002, Phadke and Kale 2000, Lodha and Kabra 2001, Puliyel 2004). GAVI is interested in the introduction of only new vaccines in developing countries, and it puts condition that India should introduce only the combination vaccine of Hepatitis B. This would only increases the burden on the national governments rather than relieving from them. Critics argue, now that prices have fallen for Hepatitis B in India, industry is pushing for a combination vaccine, which is more expensive than DTP or HB and there is no unambiguous evidence to suggest that the combination of HB-DTP is superior to its counterparts given individually in terms of their protection efficacy (Madhavi 2006). Similarly, rotavirus vaccine in USA was banned for a while as there have been protests from parents that it was causing intusssesption, and in India public health critics argue that rota viral diarrhoea can be tackled by oral rehydration therapy. Thus, it is not only the high price but, most importantly it is the safety and protective efficacy of the vaccine and economic evaluation studies that qualifies particular vaccine introduction based on the disease burden of a country. Therefore, even to meet global health, local factors such as disease burden, susceptibility to diseases, immunity to different vaccines, resources available etc., are important to meet national public health priorities. Research should be promoted in all countries that establish the need, safety, efficacy and suitability of all imported vaccines in the target population.

Conclusion:

The case of vaccine scenario in India during post liberalization period indicate that decreased role of public sector coupled with the increased role of private sector did not ensure access to vaccines

Indian children need. In fact, there is acute shortage for childhood vaccines (TT, DT, DPT, Measles, BCG, Polio) which India still needs, as private sector could not deliver. The abundance and promotion of expensive new vaccines in Indian market also indicates that the Indian vaccine/vaccination decisions are being drifted by 'supply push', rather than the 'demand pull'. The resultant consequences to national immunization programme with the closure of Public sector units (Madhavi 2008) indicate that in India there would not have been indigenous private sector today if there had not been Indian indigenous public sector. Evidences also indicate that the public sector's presence is essential and replacement of private sector in place of public sector is not a solution to access affordable vaccines. The indigenous efforts of PSUs absorbing new technologies such as tissue culture based anti-rabies and HB-DTP vaccine whose prices are much lower than the prices quoted by private sector should be promoted by Indian government. Private sector may be complimentary in meeting public health needs with regulatory system in place. Thus, India should promote indigenous capacity building and advance market commitments in public funded organizations for vaccines India needs. Firstly, India should revive and strengthen its indigenous vaccine capacity in PSUs to meet self-sufficiency in EPI vaccines. Secondly, before introducing any new vaccine in National immunization programme its need, suitability, efficacy, safety, and affordability must be established in Indian population that underscores the need for the promotion of R&D, good governance and regulatory system to meet Indian vaccine needs. Many countries in Europe, UK and USA are reconsidering the importance of reviving public sector in view of biosecurity and national security (Bunn Sarah 2008). India should also prioritize its national vaccine needs, and indigenous capacity building in view of national health security especially under current stringent IPR regimes and competent global milieu.

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SCIENCE COMMUNICATION AND CULTURE

Elena Z. Mirskaya

Modern ICTs as the Driving Force of Contemporary Scientific Communities: The Russian Case

Abstract:

Computer mediated communications (CMC) and all the recent information and communication technologies (ICTs), assimilated by global scientific community last decade, have essentially affected science. The advancement in electronic networks and the possession of Internet service became an important factor of successful investigations. However, different national scientific communities are not homogeneous in their assimilation of new technologies.

So, in Russian science computer telecommunications appeared as a visible ones only in the beginning of the 1990s, but very soon they were picked out for sociological investigations. There were carried out three surveys: the first represented the initial use of CMC by Russian academic scientists (1995/96), the second mirrored a new situation after their attachment to the Internet technologies (1998/99), and the third one (2001/02) gave a review of contemporary issues. These longitudinal studies revealed the specific features and dynamics of CMC/ICTs use in the Russian academic community as well as the influence of scientists' ICTs activity on other aspects of their professional life, especially on international scientific cooperation.

All the surveys had been realized in elite physical, chemical and biological research institutes of Russian academy of sciences (RAS) and collected a unique database, — an excellent ground for the objective analysis of the actual trends and challenges of the today's scientific community which is an imposing part of Information Society. The paper is to represent the original sociological data with their interpretations, and discussions.

Sociological study of CMC/ICTs use in research institutes of RAS

The core of the paper consists of the reliable empirical results[1] which give a good basis for the objective analysis of contemporary situation and its dynamics.

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The first survey represented the electronic network use by Russian academic scientists as it looks at the beginning (400 respondents, 50% CMC-users, in the main only *e*-mail service). But the data of this time are interesting and helpful as a "point for counting off". The next survey '1998 (300 respondents, 76% CMC/ICTs-users, Internet and all the modern services) was concentrated on the ICTs user after attachment of the academic institutes to Internet, The results of this investigation have engraved the enthusiastic reaction of scientists on this novelty. During three years between the first and second surveys the use of electronic networks in advanced academic community has enlarged and diversed so well that there could be certified a visible transition from CMC to ICTs. *New technologies became the helpful addition to the scientific activity but nevertheless they* ***have not radically changed*** it. The high degree of general scientific activity correlated with the same of ICTs use, but the most active in ICTs scientists were not the best in total. Scientists' priorities both *for sources of information* and *for types of communication* have not altered.

The last survey 2001/02 (300 respondents, 88% ICTs-users) had to fix the continuation of ICTs assimilation in the relatively stabile conditions, without radical novelties, only in the course of time. Naturally, we expected to see the obvious progress in all the aspects of ICTs using and noticeable changes in the style of research work and in the scientists' priorities. However, not all expectations were realized. Below are represented the original sociological data about such ***aspects of ICTs using*** as:

- length of use,
- geography of contacts,
- the most frequent employment of ICTs,
- types of using service (from *e*-mail to virtual experiment),
- levels of *e*-mail activity,
- prevailing contents of CMC,
- the evaluations of ICTs use,
- the preferences for different types of scientific communications
- the preferences for information sources, and so on.

The dynamics of the main CMC/ICTs indicators, 1995 — 2001/02

Now you can see these ten indicators and their dynamics (1 — 10 columns). Please bear in mind that the *bold type* data belong to survey 2001/2, the *ordinary type* — to survey 1998, and the data *in brackets* — to survey 1995.

1. Length of using			2. Geography of contacts			
Before 1992...	**18 %**	6 %	US .	**61 %**	67 %	(60 %)
1992–1995...	**36 %**	43 %	Germany	**45 %**	42 %	(31 %)
1996–1998...	**30 %**	31 %	Russia	**78 %**	58 %	(24 %
1999–2000...	**16 %**		NIS	**27 %**	12 %	in sum)

As to indicators 1–2, it's interesting to note the deceleration of users' growth which is reflects the process of saturation. During last two years the increase of users in physical institutes was near nought. Practically, in 2001/02 all the persons who were in need of Internet already had it on their work-places. In «geography of contacts» the heaviest fact is the restoration of scientific communications inside the Russian Federation.

3. Type of service			
E-mail correspondence	**99 %**	97 %	(90 %)
Access to distant databases	**75 %**	68 %	(33 %)
Participation in conferences	**9 %**	20 %	(15 %)
active participation	**4 %**	4 %	(1 %)
Use of the distant computer	**7 %**	13 %	(0 %)
Taking part in the distant experiment	**3 %**	6 %	(0 %)

The data received from users suggest that ***e-mail*** was and is the most popular type of network service among Russian scientists. Today nearly all users put it on practice although with a different intensity which will be discussed further. An *access to distant database* was essentially less popular but ever showed a good growth.

Neither *teleconferences* were and are not popular, moreover last years the interest to this form of communication has decreased. The appearance of Internet has added two new types of service which provide for scientists the practical integration into international research system. There were the *use of distant computer* and *taking part in the distant experiment*. We thought that the use of these services will increase but unfortunately, this hope was not realized.

4. *E*-mail communication activity

More then 10 messages in a day	**3 %**	3 %	(0 %)
Some messages in a day	**28 %**	22 %	(5 %)
Some messages in a week	**35 %**	39 %	(48 %)
Some messages in a month	**34 %**	36 %	(29%)

It's light to see that till now the most typical *correspondence intensity* in elite research institutes of RAS is some messages in a week, but the number of users who receive some messages in a day shows a permanent growth. The second survey has revealed a new phenomenon — a little group of over-active correspondents (more then 10 messages in a day). Naturally, this group has attracted a great attention: were these correspondents so productive in other aspects of their professional activity or not? Alas, they were not. These respondents, which could be named "the professionals of which ICTs", were mostly the young people who have still not found their right places in science and in the local teamwork. The last survey has fixed alike group which was the same in quantity (3 %) but absolutely another in quality. This little group consisted from very productive and successful scientists. Such episode testifies that in the course of time the research work becomes the leitmotiv of ICTs use. The next two indicators confirm this inference.

5. The prevailing content of CMC

Co-ordination of research	**49 %**	50 %	(59 %)
Scientific results discussing	**48 %**	46 %	(41 %)
Data and reports of joint research	**41 %**	43 %	(26 %)

Visits arrangements (for Russian scientists)	**40 %**	32 %	(50 %)
Issues of publishing	**41 %**	30 %	(27 %)

6. <u>The most frequent employment</u>

For research work	**67 %**	65 %	(43 %)
For organizational questions	**50 %**	48 %	(70 %)

The indicators 5–6 mirror the process of normal assimilation of ICTs in scientific community. In time a number of joint projects have been already coordinated and were going on. Therefore the efforts for *coordination* of research slightly decreased meanwhile *scientific results discussions* and *issues of publishing* increased. These data could be interpreted as a sign of gradual progress of scientific collaboration. The information about most frequent ICTs employment also reflects a very important evolution in ICTs use and confirms our foregoing inference: if at first the main share of ICTs use in Russian science was connected with *organizational questions*, then they begun to serve mostly *the research work* on the whole.

7. <u>The evaluation of ICTs use</u>

Very important	**24 %**	19 %	(27 %)
Important	**35 %**	41 %	(27 %)
Medium important	**32 %**	26 %	(26 %)
Not essential	**8 %**	14 %	(20 %)

8. <u>The opinions about a «balance» of ICTs use</u>

"Using ICTs, I receive more then I give"	**53 %**	78 %
"Using ICTs, I give more then I receive"	**3 %**	4 %
"It's difficulty to evaluate"	**44 %**	18 %

About the evaluation of ICTs significance for the professional work of scientist (col. 7), there is to note that a part of respondents obviously raise their estimation. Seemingly, this indicator is reputed as a sigh of prestige and some scientists try to «save the face». A visible decrease of brilliant opinion about ICTs use (from 78% to 53%) between two last surveys (col. 8) can be explain as a transformation of the first, Internet generated, delight into the normal, may be, partly sceptical perception of new technology.

The next information about scientists' preferences for *information sources* and *scientific communications* has to attract a special interest. The following data were received by a standard procedure: the respondents have to select three priorities of the four offered variants of both indicators. So, in the columns 9–10 we see the share of respondents who have placed each form of *information sources* or of *scientific communications* not to the last position, i.e. that's the *rating* of these forms among the scientists.

9. The preferences for different information sources

Printed editions	**92** %	88 %
Personal communications with colleagues	**61** %	60 %
Official seminars, conferences	**47** %	52 %
ICTs	**36** %	33 %

10. The preferences for different scientific communications

Local colleagues with similar interests	**84** %	83 %
Authoritative Russian specialists	**70** %	62 %
Authoritative foreign specialists	70 %	62 %
"Group of interest" in Internet	**3** %	6 %

Practically the data show that the rating of the main traditional *information sources* and *scientific communications* is high and absolutely stable. Meanwhile, the popularity of ICTs remains the least one without any noticeable growth (average over the sample)[2]. The

[2] The super-active users have given the second place of popularity for *ICTs*, straight away the *printed editions*.

professional communications with Internet "group of interest" have even decreased (col. 10). How could such inertness of respondents be interpreted? Is there the effect of "healthy conservatism" as an attributive quality of scientists and scientific community in general? or of the "specific Russia character"?

Such comparative ***study of national peculiarities of ICTs use*** and their influence on research style and reorganizing of science could be very interesting and useful. A similar international project was going to do at the end of 1990s but regretfully was not realized. Today such project is not less topical.

The influence of ICTs: some interesting correlations

The modern and significant idea of our sociological study was connected with an additional original mode of data processing: distribution of surveyed scientists accordingly the different degrees of their ICTs activity. There was applied an own constructed "generalized index" of ICTs use which divided all the respondents into *five groups* — K (max), L, M, N (zero). Such approach gives a wide possibilities to investigate the influence of new ICTs on professional performance of scientists: the *correlations* between the ICTs use and traditionally essential indicators of scientific life demonstrate their latent interconnections characterizing the role of ICTs.

At first we ought to mark that not only the single respondents but also the definite sub-samples demonstrate the different ICTs activity. Table 1 shows the distribution of ICTs using in *gender*, *age*, *position*, and *scientific fields* sub-samples (survey '2001).

TABLE 1
THE ICTS ACTIVITY (GENERALIZED INDEX)
BY DIFFERENT SUB-SAMPLES OF USERS (%)*

Gender, age, position, etc.	K	L	M	N	O
Male	2	26	31	33	8
Female	0	9	27	38	26
Under 30	0	30	30	40	0
31–40 years	0	36	36	21	7

41—50 years	2	40	24	29	5
51–60 years	2	22	36	31	9
Over 60	1	11	28	41	19
Director, deputy director	16	42	0	42	0
Head of subdivision	1	34	34	24	7
Research fellows	0	12	32	39	17
Physics	0	24	36	34	6
Chemistry	0	15	30	40	15
Biology	6	33	23	26	12
Theorists	3	30	27	27	10
Experimenters	1	21	31	36	11
Average over the sample	1,5	22	30	34	12,5

* Please read only along the lines.

The main difference inheres in the gender sub-sample: *male* are much better than *female* (28% and 9% of active persons, 8% and 26% of not users, correspondingly). No comments! The *age* distribution may be estimated as “normal”; the people under 30 are not represented neither in K-, nor in O-group (both position are undesirable for young scientists); the people over 60 — very active and productive in other aspects of scientific performance — are the worst in ICTs use. The ICTs activity is “proportional” to the position of users: the “champion’s” position is occupied by leaders of institutes, the second place belongs to heads of subdivisions and the third one — to research fellows. It is interesting to note that in the first survey research fellows were much better as their heads. The *chemists* are ever the worst, but the possessor of the first place has been changed: earlier there was *physics*, now — *biology*. *Theorists* (on average) are the more active users as *experimenters*.

The most essential issue concerns the correlation between *productivity* of scientists and their ICTs activity. The exhaustive results are represented in the table 2.

TABLE 2
PROFESSIONAL PRODUCTIVITY OF THE SCIENTISTS WITH DIFFERENT DEGREES OF THEIR ICTS USE*

	Quantity of journal publications				**International reports**	
Groups	in total through 3 years	% of authors	in foreign editions	% of authors	in total through 3 years	% of speakers
K	**19,7 19,7** 7,6 6,4	**100** 85	**12,7 12,7** 5,2 4,3	**100** 81	**4,7 4,7** 4,6 3,6	**100** 78
L	**16,0 16,0** 9,3 8,9	**100** 96	**11,6 11,2** 5,5 4,9	**96** 89	**6,5 6,1** 3,7 2,6	**93** 70
M	**11,4 11,0** 9,8 9,0	**97** 92	**4,6 4,0** 5,1 4,3	**87** 84	**4,5 3,2** 3,5 2,2	**71** 63
N	**7,6 7,3** 9,5 7,3	**96** 77	**3,9 2,9** 11,0 6,4	**74** 58	**3,0 1,5** 3,5 2,3	**50** 65
O	**8,8 7,8** 6,6 5,0	**88** 77	**3,0 1,9** 4,9 1,6	**64** 33	**3,7 1,2** 4,3 1,1	**27** 27
Average over the sample	**11,0 10,6** 8,6 7,5	**96** 86	**6,4 5,3** 6,1 4,2	**82** 70	**4,8 3,1** 3,9 2,3	**64** 60

* The ***bold type*** belong to survey 2001, the ***ordinary type*** — to survey 1998;
to the left — the mean values calculated ***per author***,
to the right — the mean values calculated ***per capita***.

This table contains many interesting and weighty information. There are:

• the general growth of quantity of publications in all the groups with the exception of group N (the 1st column),

• the general growth of authors' share (the 2nd column),

• the vigorous increase of foreign publications in groups K — L and the decrease of this indicator in groups M — O, especially in group N (the 3rd column),

• the same results with regard to the quantity of international reports (the 5th column),

• the harsh degradation of all productivity indicators in group N.

Moreover, one has to take into account, that the empirical data concerning the group O were doubtful, because there was revealed a disposition of some O-respondents to embellish the real situation.

These results have formed the reliable ground to declare ***the evident strengthening of correlations and, correspondingly, of interconnections between productivity of scientists and their ICTs activity***.

The next two tables will represent the correlations of ICTs use with another indicators of scientific life: scientists participation in the *international grants* and their *intention to go abroad*.

TABLE 3
THE CORRELATION OF THE ICTS USE WITH THE PARTICIPATION IN INTERNATIONAL GRANTS (%)*

Groups	Supervisors of collective grants	Participants of collective grants	Executors of individual grants	Persons without grants
K	**67** / 15	**33** / 54	**0** / 0	**34** / 35
L	**58** / 23	**22** / 58	**4** / 8	**29** / 27
M	**10** / 8	**32** / 38	**3** / 3	**57** / 57
N	**6** / 8	**14** / 40	**1** / 4	**78** / 56
O	**0** / 7	**17** / 34	**0** / 0	**83** / 62
Average over the sample	**19** / 12	**22** / 44	**3** / 3	**60** / 48

* The ***bold type*** belong to survey 2001, the ***ordinary type*** — to survey 1998.

TABLE 4
THE CORRELATION OF THE ICTS USE WITH SCIENTISTS' INTENTIONS TO MIGRATION ABROAD (%)*

	The intention to go abroad		
Groups	no desire in any case	only a trip for the definite time	the desire to go off for ever
K	**67** / 42	**33** / 54	**0** / 4
L	**47** / 30	**53** / 70	**0** / 0
M	**42** / 35	**58** / 57	**1,5** / 8
N	**58** / 38	**42** / 57	**1,5** / 4
O	**68** / 67	**32** / 33	**0** / 0
Average over the sample	**52** / 42	**45** / 55	**1** / 3

* The ***bold type*** belong to survey 2001, the ***ordinary type*** — to survey 1998.

Without additional analyses, it's easily to see the same character of correlations and especially of their dynamics. But we have to make clear that the correlations themselves don't confirm the influence of ICTs use: the using may be both *cause* and *effect* of process. They are interconnected, and only the *dynamics* of correlations confirm the positive influence of ICTs use.

Modern ICTs in science: contemporary situation and possible perspectives

By and large, the performed sociological study has shown an enhanced stratification of the Russian scientific community due to the expansion and deepening of international interactions. Scientists which combine a high professional level with the active scientific international relations including ICTs use have gained a significant advantage over their colleagues lacking these features or having only one of them.

Why the results characterizing the Russian scientific community which finds itself in a very specific situation could be not only of national but also of a wider interest?

Two reasons should be indicated here. First, assimilation of the new communications technology in Russian science started only in the 1990s and has evolved literally before our eyes. Besides, this process is very "transparent" and its impact is easily observed because of an inadequate state of other communication means. The performed study allows to suggest that due to a specific Russian situation the use of computer communications in present-day Russian science has turned from a mere technical facility to a form of international collaboration. It can't be argued that from the 1990s the international CMC involvement became an *universal indicator* of the international interactions intensity valid for all the national scientific communities: each nation has its own communication traditions, opportunities and preferences. However because of the malfunction of the regular communication system, Russian scientists' integration in world science is largely determined by their involvement in international communication networks. Therefore here the CMC/ICTs use represents such indicator.

The other reason, in my view, is that during the recent years, the Russian scientists' behaviour in the main — no matter how much has been said about the "unique Russian character" and "Soviet mentality" — looks like a scientist's behaviour in any scientifically developed country under the circumstances of a radical funding reduction. Those who have firmly linked their fate with science switch to other, even "alien", organizing forms (if the latter render a promising source of funding support) and easily assimilate new rules and requirements without worrying much about their national and institutional loyalty.

Modern ICTs connected all countries and all the scientific groups relieve such behaviour. Practically, they have created a new illusory perception of reality as a global inseparated community. This situation vivifies the old problem in a new node. It's not the first time that the issue of a scientist's ***self-identification and loyalty*** arises. Social history of science shows that such problem unfailingly accompanies the establishment of any radically new form of science organiszing and functioning. Let's recall discussions of the 1960s, after the institutionalization of "great science" which got accommodated in bureaucratically structured organisations. The issue under discussion then was an "insoluble" situation which demanded an alternative loyalty from a scientist: to the organisation paying for his/her hired labour and to science to which he or she decided to devote his/her life[3]. As we know, also then there existed two distinct types of scientists: *people of the organisation* (or "institutionalists", "localists") and *specialists* (or "professionals", "cosmopolitans") and great cataclysms were expected since institutionalists were less successful in science while the organisation allegedly didn't need cosmopolitans. However, life and time have quietly resolved this insoluble paradox, finding for everyone a proper place and function. The point of the old story is that those not so much loyal to their organisations and cosmopolitans still were more useful in scientific work, especially in basic research. Such people exist at all times, and in any transformation of science it is important to preserve those who are orientated at *scientific* values, advancement and recognition in *science*.

Another question for discussion relates to ***effective potentialities of ICTs*** in science. Can ICTs serve as an instrument for integrating

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[3] Glaser B. Organizational Scientists: Their Professional Careers. Indianapolis, 1964; Miller G. 'Professionals in Bureaucracy, *American Sociological Review*, 1967, vol.32, No 5; Bucher G., Reece J. What Motivates Researchers in Times of Economic Uncertainty? *Research Management*, 1972, vol.15, No 1 and others.

the current mosaic of national basic research into a global system? They can, since they perfectly correspond to the tasks of scientific communications. Acceleration, simplification, increase of an information capacity of scientific contacts — that's what researchers have always aspired for. If so, all the scientists' wishes have been maximally embodied in CMC/ICTs linking a user to world banks of scientific information and providing a nearly direct communication between users[4]. They will be easily accepted by those who do not use them as yet or will be activated by those who use them insufficiently.

Will the further ICTs development and expansion lead to the national research system integrating into a global one? I don't think it will: this is a necessary but an insufficient condition. Globalization is coming and ICTs are one of its mover. But until computer networks become also by ***funding-linked***, they will remain a very convenient, efficient, priority but still — only one of the means of scientific communications. *Grid*-system[5] and modern *collaboratories*[6] connected not only by means of joint research work but also by financial links are the first steps of practical integration.

Counting so much on ICTs, one should be more attentive to some latent trends which might later prove hazardous for science. These hazards, as usual, are a continuation of CMC/ICTs virtues and are largely connected with long-term perspectives. Thus, providing access to an extraordinarily great amount of information and facilitating its target-oriented search, new information technologies — paradoxically as it might seem — narrow a scientist's scope of view excluding a spontaneous review of information on contiguous problems, methods and approaches. Likewise, virtual scientific groups easily forming on the basis of common professional interests unite ever more homogeneous teams, obviously less mixed than

[4] It is to note that currently they are ahead of the scientists' communication needs or rather their ability to use the new technology potentialities.

[5] *Grid* — a modern computer system for distributing calculation: the data of experiment get going for processing to the grid of computers located in different places.

[6] *Collaboratory* (*Virtual Laboratory* — VL) provides the virtual access to project-driven collaboration (as a rule connected with unique instruments) for some groups from different cities or countries. There is an absolutely new form of scientific collaboration which was impossible without ICTs.

former invisible colleges. Enhanced fragmentation and closure of problem areas — so called "capsuling" — weaken and even eliminate the possibility of "cross-pollination" which is a basic stimulator of scientific knowledge advancement. ***Preservation of variety*** is an essential condition of a stable capability and productivity of the integrated global science. As with biocenosis, the viability of science is provided by variety (on the personal, group, and national levels), hence its retention is a serious research task and problem.

It is also to consider that a new way of a fast researchers gathering for an evolving problem area — calling together the available and already well-known specialists into a network — is efficient in a short-term perspective but it does not promote the growth of new research workers and will be restricted to the current ideas and approaches[7].

Instead of conclusion

On the whole, the ICTs deployment and implementation provides scientific community with a new scene of activity offering new potentialities and imposing new regulations. Previously, scientific life proceeded on *constitutive* and *contingent* scenes[8], i.e. in the sphere of *formal* (books, paper journal publications, scientific meetings) and *informal* (private discussions — paper letters and talks) communications where the conduct was governed, as is known, by completely different, still already established rules. How will the ICTs sphere interact with the previous ones: will it complement, modify or displace them? How will *social relationships in science* and the mechanisms of *new knowledge generation* change? All these (and many other) issues are still unclear and require a special research so that not to proceed further blindly. The foregoing results of our longitudinal study give some information which may compose a basis for the well-grounded discussion.

[7] Another challenge of ICTs in science (mainly the economics aspect) are represented in: David, Paul A. The Digital Technology Boomerang. Paper for ESF-IIASA-NSF Workshop, Laxcenbourg, December 1999.

[8] According to H. Collins' terms.

Gregory Sandstrom

The Extension of Extension *OR* the 'Evolution' of Science and Technology as a Global Phenomenon

Background and Context

"Because there is no law for the wind, the eagle, a maiden's heart."
– Alexander Pushkin

The field called 'sociology of science' (SoS) amplifies new insights into science and human-social life. The German social scientist Max Weber's public lecture, "Science as a Vocation" (1919), available to us as a text, opened the view that 'science' is a less mysterious enterprise than was previously imagined during the European Enlightenment. At that time, the importance of science was elevated into becoming almost a worldview, what is known today as 'scientism.' Now, at a time when scientism has been identified as an ideology and not as a scientifically-supported view itself, the current landscape of science and technology studies (STS) offers the potential for fresh views regarding what science and technology mean to societies and peoples in local and global contexts.

The Russian-American sociologist Pitirim Sorokin's view of cultural systems, in which he included the realms of science and technology, laid the groundwork for SoS and STS as independent fields and also inspired the work of his American pupil, Robert Merton, who popularised SoS. Sorokin's work provides a broad context of civilisation types[9] for which to understand the proliferation of science and technology in our age. Weber's and Sorokin's views taken together offer an alternative perspective to the heavily American tone of Merton's work. The alternative they offer is conducive to non-evolutionary or post-evolutionary thought in the human-social sciences, a product of Germanic-Russian tradition. This sets the stage for recognizing Russia's contribution to global sociology and also the development of science and technology around the world, which is what this paper addresses.

[9] Ideational and Sensate cultural super-systems, with an Idealistic model demonstrating a mixture of the two.

The analysis of science and technology as a global phenomenon in this paper is now filtered through my experiences of living in the Russian Federation for more than five years. During this time I have found that sociology in Russia indeed suffers from immaturity after the great socio-political experiment of socialist-communism, but that it contains many intellectual seeds from the past that have as of yet gone unplanted in fertile ground. As Pushkin's phrase above indicates, there are aspects of human-social action and experience that cannot be explained by 'pure science' in a naturalistic sense of the term. I have found the Russian sociological imagination well-endowed to offer a great fund of ideas for human-social sciences, a great cache of stories, examples and circumstances already fit to compliment the global sociological discourse. What is therefore required is an alternate type of 'general law' for the human-social sciences to what evolution proposes in the natural-physical sciences. We need to break free from the now endangered model that Charles Darwin began as a small seed in the human-social sciences.

Introducing Methodology

What this paper introduces to the field is a 'general method,' or what some people might prefer to call a 'paradigm,' that can be applied as an alternative to evolutionary sociology (or neo-evolutionary sociology[10]) of science and technology. That is, a method is introduced that is non-evolutionary and that functions outside of the paradigm of evolution as commonly conceived. This may sound like an ambitious proposition, yet it seems readily achievable and even overdue in our information-electronic age.

Rapid technology growth in the 20th century testifies to scientific innovations and inventions that demonstrate the power of new discoveries. It also reveals quite obviously that neither science nor technology 'evolve' in the same way as biological entities change-over-time[11]. The current social scientific landscape has significantly

[10] Sandstrom, Gregory. Evolutionary and Neo-Evolutionary Paradigms in Sociology (SPbGU reference paper, 2007)

[11] In this paper we use the phrase 'change-over-time' with hyphens to highlight the jargon connected with evolutionary thought, i.e. one definition of 'evolution' given in standard textbooks and dictionaries is simply 'change over time.' We reject this definition as it gives an undue monopoly to 'evolution' over the meaning of change; everything that evolves also changes, but not everything that changes can be said to evolve. There are non-evolutionary types of change, such as extension.

changed in the 150 years since Charles Darwin's major work and ideas were presented. His audience was mainly naturalists, which is in contrast to ours: mainly human-social scientists and scholars. The task is now set for us in the 21st century to chart a new course for understanding the growth and development of science and technology, with an alternative concept to 'evolution.'

We begin by asking a question: why is it that the concept of evolution is applied so widely, not only in natural sciences, but also in social sciences and humanities or human-social thought? This widespread usage of evolution is considered as problematic due to the differences and disanalogies between human-made and non-human-made things. If the concept of 'evolution' were to be removed from the discourse or taken off the discussion table, then on what basis can growth and decline, progress and regress, adaptation, differentiation, variation, modification, stratification and other features of societal change be measured, identified or explained?

This paper explores a non-evolutionary sociological approach to science and technology. The term 'evolution' is deemed inappropriate for human-made things, including science and technology. Instead, the well-worn term 'development' is used to describe human-social changes-over-time and a new term is introduced: 'extension.'

Thesis Contra-Evolution

Evolution is over-applied 'as an ideology' outside of evolutionary biology and evolutionary natural-physical science. We are not questioning that biology is a sovereign academic field unto itself or saying that biologists cannot choose their own preferred concepts and theories. That is certainly their prerogative and is not in the proper jurisdiction of a sociologist to tell them otherwise. In this paper biological evolutionary theories are taken for granted as legitimate and not directly challenged. Thus, right up front the common approach made by anti-evolutionists against biological evolution is set aside and not applicable in this paper.

The problem we are faced with is the lingering talk about sociocultural evolution, which includes the realms science and technology. This is confusing linguistically, however, because science and technology do not 'evolve' like non-human-made things (e.g. topics in biology, geology, ecology, anatomy, etc.). It is not really a debatable contention to note this, however, the point seems important to make time and again because the legacy of socio-cultural evolution still lives on. Science and technology as human-made things are different in kind (not only in degree) from non-human-made things and thus deserve an alternative grammar than what evolutionary theories currently offer[12].

The uniqueness of human-made things as non-evolving global and local phenomena is the special problem confronted in this paper. We highlight science and technology as expressions of our special human capacities to create and build and to make and shape our physical environment using our minds, souls and bodies. What some people call the 'noosphere' is in notable ways unlike the 'biosphere' (as V. Vernadsky and others have shown) and requires a particular vocabulary to describe it. Thus, we are bringing into the conversation the concept of 'extension' in human-social thought to fill this need.

Our thesis is that there is no 'law of scientific and technological evolution,' as is sometimes suggested (e.g. Basalla 1988). Sciences and technologies represent what we call 'human-made things,' which are 'extensions' of humankind. The basis for this idea comes from the Canadian communications theorist Marshall McLuhan, a pioneer in the field of media, technology and cultural studies, who said, "All human artefacts are extensions of man[-kind][13]." There is thus a sound intellectual precedent for proposing the idea of extension in human-social thought now.

A note of philological concern; the title of this paper really does mean to place focus on the OR. We can speak of extension ***OR*** we can speak of the evolution of science and technology. We cannot speak of 'evolution' (V) and 'extension' (X) both at the same time in human-social sciences because they are fundamentally different approaches, focussed on different things[14].

The main argument is that 'extension' is a more appropriate term than 'evolution' to apply to the development of human-made things because human-made things are made with a purpose. We may therefore update our vocabulary for the information-electronic

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[12] Cf. Henning Andersen, 2006.

[13] 1988*:* 116.

[14] As Henning Anderson notes, "all Adaptive innovations and Extensions are purposeful." (2006: 10)

age and say that science and technology ‘extend.’ Searching for their extensions then becomes a method of detecting or discovering how science and technology extend to and from human choices to make, design, build, or to diffuse science and technology and what their effects are on us as individuals living in our various societies. When we speak about social and cultural development then, ‘extension’ is seen as a more suitable and preferable term than ‘evolution’ to describe the innovation and diffusion of both science and technology.

What we are doing herein is applying McLuhan’s insights about ‘extension’ into the field of sociology to propose an alternative to evolutionary sociology of science and technology. To do this, we turn to three examples of ideas and practises currently in use: the Theory of Inventive Problem Solving (TRIZ), innovation diffusion theory and what are called Extension Services. These three examples offer legitimacy first to the idea that technological change is ‘non-random’ and second to the idea of ‘extension,’ though the latter two examples offer an alternative meaning of extension than what we articulate below.

It should be noted there is another alternative also available in Richard Dawkins’ theory of ‘memes’ as cultural replicators (1976). But that theory is not of concern to us in this paper. We are arguing in favour of a view of ‘extension’ that transcends the physical and biological realms (as Sorokin’s approach augmented) to involve human beings at a deeper or higher level, which includes the Ideational-creative realm of science and technology development.

TRIZ as a Russian Contribution

TRIZ is the English acronym for the Theory of Inventive Problem Solving (Теория решения изобретательских задач — *Teoria resheniya izobretatelskikh zadach*), which focuses on technological change that is quantifiable and empirically measurable and thus ‘scientific’ in a positive sense. It highlights the role of the inventor in making an invention, and explores the realm of creativity. TRIZ is said to study ‘technological evolution,’ though this paper considers such a description as a misnomer. Nevertheless, TRIZ gives us tools to promote a kind of reflexive science because it links creativity and real change in science and technology through systematic problem solving. In one sense we are therefore accepting what Michael Burawoy calls ‘reflexive science,’ though in quite a different way than what he means with his ‘Extended Case Method’ (1998).

The Russian-Uzbek engineer and scientist Genrich S. Altshuller (1926-1998) (or nickname Genrich Altov), after studying and cataloguing patents while working in a patent office[15] looking for principles of innovation, put forth the idea (1956) that a technical system ‘evolves’ not as an entirely random process, but as a process directed or guided by human minds and actions. Evolutionary theory in biology regularly involves and even requires randomness, yet technological development is predominantly not a random occurrence[16]. Technology therefore does not ‘randomly’ evolve. Technology is instead governed by certain ‘objective laws,’ what Altshuller called ‘system evolution;’ terminology which his followers have used (e.g. Petrov and Zlotina, 1990) in their linguistic expression.

These ‘laws,’ which came to be called TRIZ, can be studied and used to *consciously* build or form a system along its path of scientific technical development by determining and implementing innovations. This is what we call ‘extension.’ In our language, TRIZ actually studies how innovations *extend*, i.e. what they extend from and to, which agrees closely with Altshuller’s conception of technological change as a process guided by human minds and actions.

One result of Altshuller’s theory that inventiveness and creativity can be learned, as for example he wrote in *And Suddenly the Inventor Appeared* (1989), is a psychological model of creativity. Our question to Altshuller is whether or not there can actually be an ‘exact science of creativity’ as he thought there could. It should be noted at this point that Altshuller was, in addition to his theoretical work on patents and technological development, also a science fiction novelist. This fact need not, however, necessarily take anything away from his ‘pure’ scientific work. Instead, the point is raised in history, philosophy and sociology of science (HPSS)

[15] Soviet scientists had investigated and analysed about 1,500,000 patents domestically and globally.

[16] Note the concept of ‘unanticipated consequences’ coined by Robert Merton does not negate that the consequences of human-social action, including the development of science and technology are nonetheless a result of intentional human decision-making. Unanticipated consequences are due to human-making, which is not random, but purposeful and goal-oriented.

that discussion of what does and does not constitute ‘science’ has covered considerable ground since the heyday in which TRIZ was formulated in the 1950s–70s in the Soviet Union.

TRIZ is now discussed and used around the world as a general method of problem solving, especially focussed on engineering technologies. It uses an algorithmic approach based on the documented history of innovation and unique patterns of innovation to solve technical problems, providing tools that help engineering design. This is how it is applicable to “science, technology and innovation,” the theme of the International Sociological Association’s RC23 Research Section.

The major TRIZ principles are:

1. All engineering systems have uniform evolution; there are laws to remove technical contradictions.

2. Any inventive problem represents a conflict between new requirements and old systems.

3. An ideal end result is desired.

Using these major principles, along with almost 40 other minor TRIZ principles, Altshuller’s theory applies to trends and possibilities of developing human-made technologies and scientific patents. Outside of the scientific and technological spheres, Altshuller also suggested that many other systems (e.g. economic and educational) display the same developmental trends. As Stan Kaplan said, TRIZ is “a system for creative thought which has grown to include applications to management sciences, education, business, marketing, social and political issues, pure science, biology, etc.” (1996: 26). The moral dimension of science and technology is, however, left aside in TRIZ, leaving us no indication of when innovation can be hazardous to the human condition. This leaves room for advice such as McLuhan’s dictum:

We should think out the effects of a technology before we put it out [i.e. mass produce it].

It is our contention in this paper that TRIZ contributes an important point of view on the human-making of technologies and scientific patents, even if it fails to make a convincing psychological breakthrough on the topic of human creativity. Its lack of accounting for moral values in the realm of science and technology reveals it more as a tool for engineering or applied sciences than as relevant for human-social sciences, including the sociology of science and technology. More information about TRIZ via links to articles and/ or web-sites can be found in the references below.

Cooperative Extension Services

Cooperative extension services refer to the spreading out (i.e. *extendre*) and adoption of innovations and to the sharing of knowledge (oftentimes fee-based) such as science and technology through education. The provision of services model was first developed and applied by the U.S. Department of Agriculture (1914). Since then, it has been exported from America to countries around the world as a model of scientific management of agricultural and educational resources, promoting development and cooperation among farmers, teachers, learners and innovators. This model is most closely related to the extension method that we are proposing in this paper through its application of decision-making to practical human-social problems and situations.

The main idea behind cooperative extension services is the extension of knowledge, experience and expertise from those people who 'have' to those people who 'have not[17].' Whether focussed on improving efficiency, stability, productivity, growth rates, training, management structure, delivery of programs and goods, or other related topics, extension services are designed as a combination effort between local and global partners. They follow the trend of network logic and are not reducible to a uni-linear view of science and technology innovation diffusion. On the one hand this could just mean negotiations over money for technology, on the other hand there could be a genuine desire to share and spread technological innovation and the fruits of human creativity and problem solving for the betterment of under-developed countries.

Some examples of extension services include:

a) The Cooperative Extension System (CES) is an educational network based in America's land-grant universities, using research-oriented practical education in urban and rural communities, agriculture, industry and business.

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[17] As George Gurdjieff put it: "A person can only attain knowledge with the help of those who possess it. This must be understood from the very beginning. One must learn from him or her who knows." Knowledge, experience and expertise can be shared between 'haves' and 'have nots,' along with resources, money, equipment, etc.

b) The Association for International Agricultural and Extension Education (AIAEE); The Cooperative State Research, Education and Extension Service (CSREES); The Extension Disaster Education Network (EDEN)

It is worth pointing out that cooperative extension services are offered in more than 30 African countries (Bagchee, 1994). The 1970s–90s were the heyday of international agricultural development. Cooperative Extension Services are still offered as a model of local-global interaction and participation for the purpose of improving harvest yields and enabling more effective distribution of resources, knowledge, skills and products.

Cooperative extension services are well-represented in the sociology and economics of development and rural studies literature. The most controversial questions involve whether or not innovations are being forced on countries and peoples from the 'outside' or if they are being wilfully accepted from the 'inside.' This is where sociology of science and technology contributes helpfully with its notion of 'insider' and 'outsider' knowledge. Also important is how much equity or inequity results from politico-economic decisions regarding who to cooperate with or not. In the different ways that services and systems are offered to or imposed upon 'less developed' countries by 'more developed' countries (e.g. tied together with debt relief, aid agreements, etc.), there are a variety of questions about suitability, sustainability, speed of adoption and sovereignty that inevitably surface.

What is significant in the conceptualisation of cooperative extension services is the connection between theoretical ideas and practical applications. This is where the method of extension presented below adds to the discourse of science and technology development on a global scale. The sociological idea of extension is employed to signify the decision to act by individuals and groups in a variety of situations and circumstances, from developed and over-developed countries, to those developing or under-developed. The key is making a commitment to act and then discovering what the consequences of the action will be. The results of the extension of human decisions are explored with extension methodology.

Innovation Diffusion Theory

Extension Services commonly make use of innovation diffusion theory (Ryan and Gross, 1943; Rogers, 1962). Innovation diffusion theory is otherwise known as 'extension theory' because it uses the idea that innovations extend from innovators to adopters. The internet published *Journal of Extension* has widely studied innovation diffusion theory, involving agriculture, education, fisheries, forestry and many other sectors, in a variety of global situations.

In this paper we are highlighting 'extension,' not as a grand theory, but rather as a general method of identifying human-making, which necessarily takes into account both creativity and productivity. Innovation diffusion theory focuses on the extension of innovations based on the timing of adopting new sciences and technologies, which is displayed in the Innovation Diffusion Curve illustrated in Figure 1. What we are focussed on is a broader usage of the term 'extension' to include all sciences and technologies, as studied by sociologists and other human-social scientists.

Figure 1. Innovation Diffusion Curve
(Rogers, 1958)

The adoption of innovations is shown by Beal, Rogers, and Bohlen (1957) to follow a sequence of stages related to the acceptance and distribution of cutting-edge science and technology. The figure above shows how adopters of new agricultural practices are categorized according to a time-scale of when they accept an innovation. Adopters are said to go through a five-stage process, from awareness of innovation to adopting an innovation, as follows:

1) Awareness — Becoming aware of the existence of an innovation, but lacking details.

2) Information — Seeking information due to interest in an innovation.

3) Evaluation — Weighing the alternatives regarding resources, e.g. land, labor, capital, and management ability.

4) Trial — Using the innovation on a small-scale basis.
5) Adoption — Using the innovation on a full-scale basis.

Critiques of innovation diffusion theory take several forms. First, sciences and technologies are broadly measured by more than just science and technique; they are inevitably intertwined with social, economic, political and cultural interests. Second, there is a pro-innovation bias (e.g. innovators are positive versus laggards are negative). Third, there is a tendency to blame individuals who do not adopt new innovations as responsible for their unprofitability. Fourth, there is a bias in favour of the larger and wealthier farmers, who are more capable than smaller and poorer farmers of investing in research and development or in experimenting with new innovations. And fifth, there is the downside of trying to make equal what is unequal. That is to say that there may be multiple reasons for not innovating (i.e. choosing not to innovate), which include risk avoidance, moral or ethical hesitations, bad timing and other legitimate concerns. These points each relate to the idea of human-social extension that we are presenting in this paper in that innovations do not 'randomly evolve' but rather 'purposely extend' from human decisions to innovate and to spread innovations to others. The personal choice to innovate is acutely important to extension whereas to evolution it is subsumed by statistical and environmentalist reasoning.

At this point in the paper, let us pause to give a brief review of what has been covered so far before moving on to the proposed new methodology. First, the Theory of Adaptive Problem Solving (TRIZ) contends that technology evolves according to laws or rules that are guided by human minds and actions. Technological innovation is not a random process or purely the result of environmental pressures. Next, the phenomena of cooperative extension services is one that recognizes and invites people to participate in innovating and diffusing innovations, across a range of sectors and fields, from agriculture and education to fisheries and forestry. This model is the closest to what we will build below. Third, the idea of innovation diffusion (or extension) theory describes the tendency to adopt new innovations as science and technology change-over-time. Though initially focussed on agriculture it can also be applied to other human-made things, science and technology included. This brief review summarizes how the ideas of technological diffusion (TRIZ), extension theories and services relate or overlap with our conceptualisation of human-social extension, which is what follows next.

Human-Social Extension: An Alternative to Socio-Cultural Evolution

"[W]e should always be on the look out for possible alternatives to any dominant theory[18]."

– K. Popper (1973)

The three examples given above suggest that an alternative to evolutionary social science would be a possibility if a counter-concept could challenge the meaning of evolution. To provide a legitimate alternative and a positive contribution to the field, it would be necessary to offer a more accurate, precise or clearer vision of the origins and processes of human-social change, including the realm of science and technology. This is what is under consideration in the remainder of the paper.

To expand on 'extension' as an alternative to socio-cultural evolution is to propose a new grammar for dealing with human-made things, e.g. artefacts, institutions and social systems. We are thus not only arguing against evolution, but at the same time promoting extension as a suitable alternative. This alternative is (and will be) opened to criticism simply because it is something new and unknown. That is, if the concept of 'extension' is given due credit, then human extension methodology (HEM) will have its early adopters too. In fact, 'extension' has a deep and wide history both in mathematics and physics and also in cultural studies, philology and philosophy, not to mention in theology, which ensures that the 'extension of extension' into sociology we are proposing may prove to be a worthwhile practical possibility. Doing so will support the perspective of Sorokin, who predicted a return to Ideational science, instead of maintaining dependence on Sensate ideas demonstrated in evolution.

Likewise, the recent 'Extended Mind' model proposed by Clark and Chalmers (1998) and Logan (1997, 2000, 2004, 2007) indicates the

18 "Evolutionary Epistemology," 1973

ripeness of the concept of 'extension' for contemporary application, though each of these authors employs extension within an evolutionary framework and not independently from evolution. McLuhan and Logan (1977) set the pattern upon which Logan's approach, which he playfully calls a Grand Unification Theory of Human Thought, is based. What we are offering is much more humble than that.

In the case of a proposed alternative to evolution, especially one which offers a positive contribution to the sociology of science and technology, resistance to the idea will inevitably arise. What is promoted as a welcome part of science is healthy dialogue with criticisms. Noteworthy, in this regard, however, is that resistance to extension methodology is in part defused by recognizing that the resistance of critics 'extends' from their confronting a new idea (i.e. in this paper or elsewhere) and that the criticism does not occur *ex nihilo*, nor does it 'evolve' due to some exterior force or pressure. Criticism is itself an extension of choice, which is a fact that cannot be escaped from without subverting reality.

Extension is a "fundamental notion concerning the nature of reality[19]." — A.N. Whitehead

With such an endorsement from Whitehead, the concept of 'extension' is now being extended as a class of explanation and description in the realm of human-social thought. In so far as human beings are creative inventors and innovators, we are actively expressing our desire to understand the natural world and to improve the social environment in which we live. In so doing, we are participating as organic and super-organic (i.e. cultural) beings in the extension of both mechanical and non-mechanical things. It is thus important to distinguish the extension method presented in this paper with the mechanistic or physicalistic idea of extension held by thinkers in the past.

Extension has traditionally (since Descartes[20]) been seen as the ultimate metaphor for mechanical things, physical things, the idea

[19] *Adventures in Ideas*. New York [1933] 1967–158.

[20] Extension may sound unfamiliar, especially in non Latin-based languages. It found expression in Descartes' *res extensa,* which he contrasted with *res cogitans*, what became known as the Cartesian dualism. McLuhan's *Understanding Media* (1964), which was subtitled *The Extensions of Man*, cuts through the Cartesian dualism by focussing on the formal causes of media and technology. McLuhan used the metaphor of 'extension' to speak of 'all technologies' which result from human innovation and its inherent teleological component.

and fact of substance and now in the information age, electronic things. For example, the cords or cables that connect electronic devices with power sources are called 'extension cords.' That 'extension' need not be a mechanistic concept is demonstrated, however, in how it is used for non-mechanical things, such as extending contracts, privileges, rights, responsibilities, greetings and apologies, categories and grammar, which all involve wilful organic-human decision making. These are not just pre-programmed robotic or automatic events, actions and ideas, but involve personal choices, responses and intentional decisions that express the ancient understanding of psyche or soul. This short diversion into the philosophy and linguistics of extension is meant to provide context for those who would initially doubt or deal coldly with extension methodology.

"The method common to all Cultures—the only way of actualizing itself that the soul knows—is the *symbolizing of extension,* of space or of things[21]." — O. Spengler (1926)

When extension is used to symbolise not only physical or mechanical things, but also particularly human-made things, a new approach to understanding societal change can take place. Scientific and technological creations are not themselves considered to be natural according to how natural scientists practice their methdologies because science and technology are artificially created by human decisions, discoveries and inventions. The symbol of 'extension' with respect to human-made things makes sense when used to express socio-cultural development through science and technology. The distinction, then, between what is natural and what is social or cultural or non-natural is at the heart of this topic. 'Evolution' is not a natural concept to use when speaking about human-made things.

It is indeed especially difficult to distinguish these things in a tradition such as the Anglo-American one which places natural sciences against social sciences and humanities. The latter fields reflexively involve culture and civilisation, while the former take a positive, command-style perspective. It is thus somewhat ironic that

[21] Oswald Spengler (*The Decline of the West,* [1918, 1926] 1991, 60)

human-social science is now in a position to inform natural scientists that science and technology don't evolve as natural phenomena.

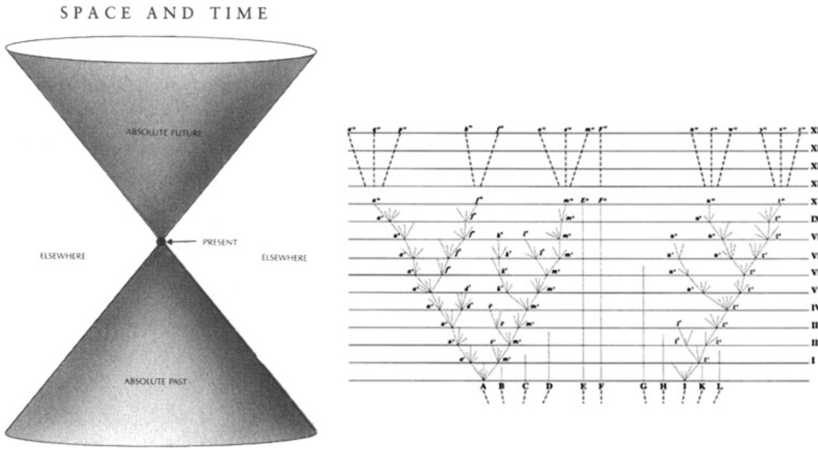

Figure 2. Hawking's Space and Time cones and Darwin's Tree of Life

Stephen Hawking's Space and Time cones (A Brief History of Time, 1989) illustrate that extensions happen in the present, at a certain moment, while evolution (Origin of Species, 1859) *represents a model of one-directional bifurcations based on irreversible time. Note the shape comparison of images: left — Extension (X) to right — Evolution (V).*

The time and space cones illustrated by Stephen Hawking provide justification for the notion that space and time are relative and therefore cannot be held captive to a 19^{th} century view Darwinian or Spencerian view of existence, both human and non-human. As persons living in a world where speed of change differs across space and place, we are all well accustomed to acknowledging what Hawking posits. Only in denying the outdated, one-directional, two-dimensional model (V) proposed by Darwin's natural selection on the pathway to perfection and the homogeneous to heterogeneous model of Spencer can we hope to encounter a new vision of human social change that embraces the simultaneous, poly-directional, multi-dimensional model (X) that the electronic-information age foists upon us.

What is the Problem with Evolution in Human-Social Thought?

"It is in my opinion a great danger for psychology if concepts of physics are used there instead of those concepts which have developed in psychology itself[22]." — Albert Einstein (1955)

Following our contention that as human-made things science and technology do not 'evolve' like biological entities, three key problems with evolution in human-social thought are now highlighted: 1) the problem of agency, 2) contrasts between 'survival of the fittest' and 'mutual aid,' 'natural selection' and 'human selection,' and 3) human-social science as a sovereign realm.

Evolutionary theories dislocate agency, personhood, character and personality by analogy with biology. This implies that sociology is merely 'subjective' and thus non-scientific, and insists that human beings are a zoological rather than an anthropological or spiritual category (e.g. Trivers, 1985). There is thus no logic of 'creativity' in the purpose-less, a-teleological, 'random' process of biological change-over-time. Yet in human-social thought agency is a central concept that cannot be avoided in studying artefacts of human creation, including science and technology.

Secondly, 'survival of the fittest' is a conflict-based ideology, while 'mutual aid' is a cooperation-based ideology. Though some social scientists have explored altruism, cooperation and mutual aid within an evolutionary framework (e.g. Sanderson, 1994), the Anglo-American evolution tradition is dominated by a conflict, competition, and war-based ideology. The Russian geographer Piotr Kropotkin (1902) expressed the dilemma clearly:

> "If we ask Nature, 'Who are the fittest: those who are continually at war with each other, or those who support one another?' we at once see that those animals which acquire habits of mutual aid are undoubtedly the fittest. They have more chances to survive, and they attain, in their respective classes, the highest development of the intelligence and bodily organization."

Herbert Spencer's phrase 'survival of the fittest' is now long outdated and deemed inappropriate for global-international relations.

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[22] *Letter*, Feb. 3, 1942, in E.F. Molnar's *Human Action*, 1955: 23.

In this sense, evolutionary theory that includes the idea of 'survival of the fittest' is inappropriate for global-international relations. When scientific and technological development is spread around the world for the benefit of humanity, rather than as a contest for superiority, we enter a new phase of 'post-evolutionary' human existence. It is thus the ideology of evolutionism, i.e. the over-use of evolutionary ideas in realms that they do not belong, and not the natural science of evolution that is the primary problem.

Erroneous thinking is also displayed in the misattribution of 'natural selection' to the human environment. We propose instead the term 'human selection.' It is not only consistent with Darwin's view that 'natural selection' differed from 'artificial selection' (i.e. 'human selection'), but also with the notion that peoples and nations choose which sciences and technologies they will adopt into their cultural milieus. It is not 'natural' to adopt a technology that would go against the core beliefs, rights or needs of a nation, group or community. Rather, it is something uniquely human to decide or 'select' which sciences and technologies we will accept and which we will reject. Thus, when we purposely choose which sciences and technologies to adopt and which to reject, evolutionary thinking does not make sense linguistically to apply in describing the results. Evolution is saying that science and technology change-over-time, but what it misses out on is the purposeful, intentional, goal-oriented character of science and technology change, which is something different than a purely 'natural' process.

What we have seen instead is a dictatorial motive in the move by socio-biologists and evolutionary psychologists to enter human-social thought (e.g. Wilson, 1975, Dawkins, 1976, Trivers, 1985, Pinker 2002) with a worldview that is dependent on evolutionistic ideology, thus threatening the sovereignty of human-social science (cf. Einstein's warning above). We are suggesting that by embracing an extension methodology related to science and technology, human-social scientists can resist the imposition of hegemony by natural scientists. Sociologists of science and technology can safely reject the natural scientific term 'evolution' for a legitimate and appropriate alternative that arose within sociology itself.

Theodosius Dobzhansky, co-contributor to the so-called 'modern synthesis' of Darwinian biology and Mendelian genetics, expressed the danger of evolution being applied to the human-social realm directly, saying "Darwin's theory was good biology which was perverted by others to support bad sociology[23]". With this distinction sharply in mind, the grave sociological weaknesses of neo-Darwinism are exposed by Russian philosophy on the topic of evolution. Russian philosophers have taken a different view of evolution than their Anglo-American colleagues, most clearly demonstrated in the outright rejection of Malthusianism[24] and its impact on Darwin (Todes, 1989). Russia/U.S.S.R. was not exposed to the 'evolution vs. creation' controversy of the 20th century, though a recent 'monkey trial' in St. Petersburg attempted to gain public awareness for the importance of 'special creation' in contrast to biological evolution. Most assessments of the trial claim it failed to be taken seriously.

The Russian language usage of 'evolution' is predominantly restricted to natural sciences. On the other hand, the preferred concept of 'development' (развитие or razvitiye) is chosen as more relevant for human-social thought. This sets an example for other languages to follow, though it would mean linguistically cleansing the noun 'evolution' and the verb 'to evolve' from western human-social sciences as misplaced. Each national speech pattern may choose its own grammar related to science and technology, so that no one from the outside may force upon them a new grammar to understand a given phenomena. The main point is that something other than evolution is suitable outside of natural sciences to indicate change over time. Traditionally the idea of 'development' has been used regarding science and technology, but this idea can be supplemented by extension methodology which places the focus on human-making, decisions, choices, agency and teleology for the (hopeful) benefit of humanity as a whole.

Extensions as Science and Technology Markers

A better understanding of the global phenomenon of science and technological invention, innovation and development would be

[23] *The Biological Basis of Human Freedom*. 1956

[24] Malthusianism: the view that unchecked population growth occurs at an exponential rate, while food supply grows arithmetically. This ideology expresses the views of Thomas Robert Malthus, who thought that giving charity to the poor would lead to more poverty and dependence upon the State. It was argued that progress in science and technology would allow for indefinite population growth.

served by studying the 'extensions' of science and technology. This is as a more effective and accurate methodology than speaking of the 'evolution' of science and technology, with its almost unavoidable connection to the ideology of evolution. Our preference involves the moments of choice, decision, event and action that surround scientific and technological change; extension (X) marks the spot.

Using extension as one's language preference generates more focus on inventiveness, creativity and the uniqueness of national scientific systems. It offers a vehicle for promoting cooperation (cf. mutual aid) rather than conflict (cf. 'survival of the fittest') in terms of international science agreements, educational exchanges, training activities, and scholarly consulting. These are just a few examples consistent with extension logic.

Indeed, this is exactly the strategy recently proposed by Vice Chancellor of the University of South Africa, N. Barney Pityana, who calls for creative planning and development in education, sharing resources, recognizing the capacity and power of African initiatives and of South Africans being the instigators for their own development (2008). A similar strategy based on extension principles was proposed recently at the Commonwealth conference on Open and Distance Learning (i.e. education extension services).

What is called for is a massage or self-correction of one's linguistic preferences, priorities and habits to allow the concept of 'extension' its respective role and place in human-social thought.

Difficulties for this Position

There are several difficulties for this position:

1) Many people use the term 'evolution' or the verb 'to evolve,' without any intended connection to the ideology of evolutionism. The argument that science and technology 'unfold' or 'unroll' as a process of knowledge accumulation is widespread throughout the natural and applied sciences and also in philosophies of science. It will be difficult to get rid of the word 'evolution' because it is sometimes used to mean something simple (e.g. when it is meant as mere 'change-over-time') when the constellation of vocabulary that has grown around it[25] is rather complex. The difficulty is thus

[25] As John Dewey called them, "the group of ideas centering in the term Evolution." ("The Evolutionary Method As Applied to Morality: 1. Its Scientific Necessity," *Philosophical Review* 11, 1902: 107–124)

how to massage people's language, i.e. to convince them to use an alternative to evolution when discussing intentional, directed, goal-oriented change, which is predominantly the case with science and technology.

2) TRIZ itself refers to the 'law of evolution of technical systems,' thus seemingly contradicting our argument that technology does not 'evolve.' TRIZ theorists assert that science and technology evolves, yet there is good reason for rejecting their linguistic expression. They are predominantly not human-social scholars, but rather engineers and applied scientists who are not theorizing about science and technology. They are trained to be active, to participate, to innovate and to work 'inside' science and technology rather than to analyse it from 'outside' on a broader socio-cultural scale. Their linguistic phrasing (i.e. 'law of evolution of technical systems') under-emphasizes the topics of agency, intention and human-social environment in the development of science and technology, which have been highlighted in this paper. Thus, for us to present TRIZ as an example of the non-randomness of scientific and technological change is to express how evolution is unsuitable to describe or prescribe the change. That TRIZ theorists still use the term 'evolution' is the symptom of a larger problem, for which it is our intent to offer a solution in the idea of 'extension.'

3) Extension has not previously been applied to sociology as a general method and will be questioned with respect to how narrowly or widely, deeply or shallowly, short-term or long-term it can be applied.

Why apply Extension to the Human-Social Realm?

To apply 'extension' to the human-social realm is to invoke the human factor, agency, character and personality, purposeful action, as not simply normal 'natural' elements. There is something special about humanity which extension methodology uncovers. It acknowledges the teleological component in human existence, that is, our directional orientation(s) and its/their source(s), as multiple and pluralistic or as singular and monistic as it/they may be.

Applying extension methodologically involves human beings acting, aiming, building, composing, constructing, creating, designing, doing, fulfilling, making, performing, reaching, stretching, etc. This is what creates meaning in our lives, alongside of our physical behaviours, instincts, emotions and rudimentary daily survival needs. Extension involves striving to reach beyond what the current living conditions offer us or allow us to experience via constraints; in being creative culturally and civilisationally in building a society. It is consistent with human cognitive processes to extend ourselves individually while living in and being responsible to (a) community.

"The key to the creative process which brings all cultures into existence (is) the extension into social institutions of the central form and mystery of the human cognitive process[26]." — M. McLuhan (1964)

Here McLuhan's vision of extension provides a bridge between Altshuller's 'science of creativity' and the mystery or conscious faith of daily human living. The positive reasons to apply extension are also subsidised by the real and actual reasons to reject evolution in human-social thought. In the example above with innovation diffusion theory, it is quite obvious that before an innovation can be diffused, first the invention itself must have occurred[27], i.e. come into being or having become. That is, the origin of an invention to be diffused comes from the mind, body and soul of the inventor himself or herself. This is why Altshuller brought into recognition the creativity of sciences and technologies, even while he still remained isolated within the evolutionary paradigm that was not yet logically defeated. When thinking about extension as a method of studying origins of change, rather than first being interested in evolutionary processes of change, McLuhan's insight becomes much more relevant to the innovation and diffusion of science and technology than Altshuller's.

"The analogy that relates the evolution of organisms to the evolution of scientific ideas can easily be pushed too far. ...

[26] Marshall McLuhan (*Understanding Media,* 1964)

[27] This observation is akin to the biological recognition: "Microevolution looks at adaptations that concern only the survival of the fittest, not the arrival of the fittest." — Scott F. Gilbert, John M. Opitz, and Rudolf A. Raff ("Resynthesizing Evolutionary and Developmental Biology," *Developmental Biology* 173, 1996: 357–372.)

Successive stages in that developmental process are marked by an increase in articulation and specialization. And the entire process may have occurred, as we now suppose biological evolution did, without benefit of a set goal, a permanent fixed scientific truth, of which each stage in the development of scientific knowledge is a better exemplar." — T. Kuhn (1970)

It is necessary to note, on the one hand, that in developing (a) science or technology it is not always possible to achieve adequate foresight regarding its present or future effects on a given society. One cannot fault scientists when an invention or innovation leads to 'unintended consequences' (Merton 1936) or for refusing to embrace a single, pre-determined path of scientific and technological development, e.g. according to ideology. On the other hand, the concepts that form the core of biological evolution do not legitimately transfer from organic things to human-made things as easily as some socio-cultural evolutionists today seem to assume. Henning Anderson makes this point directly, stating "why the mechanisms of evolution do not explain language change[28]." The evolution analogy is indeed, as Kuhn indicates and as Andersen verifies with respect to human language, commonly pushed too far to become a disanalogy.

The point Kuhn makes is poignant in that scientific and technical development may not always have a set goal or 'fixed truth' towards which it is working. Nevertheless, the involvement of human beings in science and technology development, with various goals, aims, plans and purposes, works against the non-teleological (and sometimes anti-teleological) language that forms the core of evolutionary thought. Anyone who would insist that 'evolution' is a teleological idea is outside of the historical usage of 'evolution' as un-teleological. For this reason, a conceptual alternative to evolution seems overdue in the human-social sciences, which are based on teleology.

As human beings, we are inevitably and inherently teleologically-oriented creatures. We extend ourselves rationally, emotionally,

[28] "Synchrony, Diachrony, and Evolution." http://www.humnet.ucla.edu/humnet/slavic/faculty/andersen/Synchrony.pdf Also published as "Synchrony, Diachrony, and Evolution". Competing models of Linguistic Change: Evolution and Beyond, ed. by Ole Nedergaard Thomsen, 59–90. Current Issues in Linguistic Theory, 279, Amsterdam–Philadelphia: John Benjamins, 2006.

spiritually — body, mind and soul — we decide to make things, including sciences and technologies. We set goals and pursue them, make plans and try to achieve them. The choices we make involve both ourselves and those in our societies with whom we come into contact and have relations. The causes and effects of an individual's choices of action and participation begin with them, but they in turn influence others around them locally and sometimes globally.

Extension is thus a more appropriate way of speaking about science and technology development because of its inherent teleological implications and inclusion of the language of person-hood beyond mere animal nature. We have 'souls' as even the original meaning of 'psyche' attests. Likewise, treating people as machines (or as mere collections of genes) is a similar exercise in dehumanisation. It makes sense therefore to at least consider extension as an alternative to evolution in human-social thought. The field sociology of science and technology seems a suitable place to do this.

Second Conclusion

Innovations and inventions, both scientific and technological, are sometimes said to 'evolve.' There is no reason to deny that nowadays 'evolution' is the preferred vocabulary for some people to describe any kind or even all kinds of change-over-time. Evolution is considered a stylish or fashionable term to speak about processes of change, even outside of natural science; it can just mean an 'unfolding' or an 'unrolling.' As human-made things, however, science and technology are better said to 'extend' from decisions to act, to innovate, to build and construct new tools, machines, ideas and inventions, all of which takes place in human societies. The events of human extension are notable as X's in human history.

What we have suggested in this paper is that evolution's conceptual territory is over-stretched, that it has turned into ideology outside of natural science, and that its days in human-social thought, despite what the socio-biologists and evolutionary psychologists might suggest, are numbered. The amplification of 'extension' logic, theory and method can serve to dislocate[29] evolutionary vocabulary by offering an improvement to evolution. The option is

29 Dislocation here means: "*the process by which an established body of ideas, people, or things gives way to another.*" — Trevor Barnes (*Logics of Dislocation*. Guilford Press, New York, 1996: 250)

available that some may then conclude, as Thomas Gallagher did (2001) that, at least for the English language, "Extension is a very powerful and valuable concept."

Others may be content to discuss change using evolutionary ideas. Or they may seek new pathways and possibilities in the global discourse of human-social change. Whether or not the alternative choice of 'extension' and 'extensive change' is relevant for sociology of science and technology will determine if the message in this paper is or can be a success and if new language may echo and resonate into the future.

Closing Remarks

"For last year's words belong to last year's language / And next year's words await another voice." — T.S. Eliot

The replacement of (an) old grammar with new grammar is not a process that happens immediately or easily in science or anywhere else. A process of persuasion, adoption and acceptance is normally involved. Coincidentally, the building and refining of a general method to analyse and observe human-social change in science and technology is equivalent to a paradigm shift of the Kuhnian variety, except this time happening outside of natural-physical academic fields. The change in thinking starts with confronting the weaknesses in evolutionary thought and being open to consider alternatives.

The perspective that evolution is a universal theory is simply no longer tenable or believable in our academy today. When natural-physical science is elevated into a worldview that discounts other types of knowledge we recognize a form of 'scientism' that can be situated and circumscribed without difficulty. Technologies and sciences are human-made things whose histories we can most often trace to the actions, inventions, discoveries and innovations that individual persons make or do. It is in this sense that the extension of extension, i.e. the multi-dimensional spreading out of a human-social method with interdisciplinary relevance, can overcome the felt need for using socio-cultural evolutionary theories. The examples given above of TRIZ, extension services and innovation diffusion theory provide a way to approach the idea of 'extension' as both a counter-concept to evolution and as a positive contribution to human-social scientific knowledge.

Sociology of science is an academic field that is conveniently positioned to investigate issues that confront our globally intertwined world today. Not focussing primarily on politics or on economics, but rather on society, this field is free to investigate the extension of human creativity in science and technology, education, health, welfare, natural resource allocation and distribution, environmental protection, and other human-social spheres. Without committing to a position of sociologism, or the over-extension of sociological thought in the academy, where everything is seen as socially constructed, the idea of human extension offers an opportunity to study inventions and innovations with a fresh language that addresses the 'demands of the day' (Weber, 1919). It is a typology that would satisfy Sorokin, in rebalancing Sensate culture with an Ideational-friendly term; extension is not only about substance and matter (as Descartes contended), but also about ideas, values, goals, plans and beliefs. It brings together creativity with purpose and acknowledges human agency where evolutionists have left gaps.

If humanity is moving toward or in some cases already engaged in what McLuhan calls, "the technological extension of consciousness[30]," then we should be prepared to understand the effects this will have on human understanding, behaviour and relationships. After all, this is what we are confronted with as the information-electronic age takes shape around us. We extend in various ways — in science, technology, philosophy and theology — with each other and with the rest of the world.

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[30] "In this electric age we see ourselves being translated more and more into forms of information, moving toward the technological extension of consciousness." — McLuhan (1964: 64)

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Brinder Kumar Tyagi

Re-defining the Conceptual Framework of Science Communication in India

Abstract:

With the impact of Science and Technology (S&T) on social life and economic development, the importance of S&T Communication/popularization was realized decades ago in India. It was very clear to our policy makers and planners. This concern is reflected in the scientific policy resolution of 1958 and 2003; and even in the Constitution of India. Interestingly Science communication in India has its roots in the scientific renaissance in the late nineteenth century. With the establishment of governmental agencies like National Council for Science and Technology Communication (NCSTC) and Vigyan Prasar, and networks of voluntary agencies coming into being in the last twenty five years or so, a variety of activities now take place all over the country aimed at taking science to people. A new class of trained professionals is now engage in making people scientifically more aware and attitudinally rational. Due to concerted efforts of dedicated individuals and organizations, the conceptual framework of science communication has attracted an increasing number of adherents both among the common people and among communicators, cutting across several divides including the urban/rural. It is not gaining saying that the conceptual framework of science communication has now been standardized as per the socio-cultural milieu of India. In a country of billion plus like India with so much of social, cultural, linguistic diversity and economic disparity, the efforts seem to be too meager. There is still a considerable section of the society, among them the literacy rate is low and the reach of mass media is far form satisfactory level. Further, in the last decade the combined result of the liberalization in economy and the phenomenal growth in the field of Information Technology has brought a marked change in the social fabric in India. In such change scenario do we have to redefine our conceptual framework of S&T Communication and evolved more suitable approaches, strategies, methodologies?

Key Words: Science Popularization/communication, Parallel approach, conceptual framework, minimum science

1. Introduction

With the impact of Science and Technology (S&T) on social life and economic development, the importance of S&T Communication/

popularization was realized decades ago in India. It was very clear to our policy makers and planners that its people cannot play the role of global citizen if they are not scientifically literate and attitudinally rational. This is evident from the various S&T policies and planning documents drawn out from time to time. The latest S&T policy 2003, in its objectives has clearly spelt out the importance and the commitment to support S&T communication as;

"To ensure the message of science reaches every citizen of India, man and women, young and old, so that we advance scientific temper, emerge as a progressive and enlightened society, and make it possible for all our people to participate fully in the development of science and technology and its application for human welfare. Indeed, science & technology will be fully integrated with all spheres of national activity. In strategy and implementation plan."

It is further stated that, "Every effort will be made to convey to the young the excitement of scientific and technological advances and to instill scientific temper in the population at large." And that"Support will be provided for programmes that seek to popularize and promote science & technology in all parts of the country. Programmes will also be developed to promote learning and dissemination of science through the various national languages to enable effective science communication at all level".

Interestingly Science communication in India has its roots in the scientific renaissance in the late nineteenth century in West Bengal and Punjab. West Bengal owed it to the efforts of Mahendra Lal Sarkar, Fr. Eugene LaFont, P. C. Ray, Ashutosh Mukherjee, and Jagdish Chandra Bose through the establishment of the Indian Association for cultivation of Science. The Association put in efforts to take science to the people through public lectures and exhibitions. Around the same time in Punjab, Ruchiram Sahni initiated a movement to take science to the people in Punjab by organizing public lectures.

After independence the notable efforts in Kerala in taking science to the people in 1960s culminated in the establishment of Kerala Sastra Sahitya Parishat (KSSP), the pioneer of science movement in India. Since then, there is no looking back. In 1982, with a view to consolidate, coordinate and catalyzed and support the effort of science popularization/communication at the micro and macro level in the country, the Govt. of India established the National Council For Science & Technology Communications (NCSTC) as apex body. The NCSTC was the result of The Working Group on S&T for the 6th Five Year Plan (1980-1985), which in its report stressed the need for creating an institutional mechanism to promote and facilitated the dissemination of scientific temper in society. Science Advisory Committee to the Cabinet (SACC) considered this matter and recommended the creation of The National Council for Science and Technology Communication (NCSTC), which was constituted by the Government in May 1982. Again in 1989, Vigyan Prasar, an autonomous body was created for development and dissemination of software for S&T popularization like publications, books, films, CDs, TV/Radio programmes, posters, Kits etc. The specific aims and objectives of these agencies gave a definite direction for the development of conceptual framework of S&T communication/ popularization in India. Broadly these aims and objectives are as follows:

2. The Aims

1. S&T Communication and Popularization in the country and:
2. Promote and propagate-as widely as possible-a scientific and rational outlook in the society.
3. Coordination and orchestration of all such activities in the country.

2.1. Objectives & Goals (Why S&T Communication/ Popularization?)

"Any science popularization activity or programme, be it designed for common man, children, farmers or women, has three major inherent objectives and goals":

1. "To make people aware of scientific and technological developments to enhance the level of S&T literacy".
2. "To enable them to take an informed and rational decision making and strengthen their decision making ability" ;
3. "To develop scientific and technological temper in them which would reflect on their systematic and rational role, behavior and conduct in society".

TABLE I:

<table>
<tr><th colspan="2">Objectives</th></tr>
<tr><th>NCSTC</th><th>VIGYAN PRASAR</th></tr>
<tr><td>Basic Objective of The National Council for Science & Technology Communication are:
Popularization of Science and indigenous technology among the people;
Stimulation and nurturing of scientific and technological temper among the people; &
Taking all steps necessary to provide support for the above (I) and (II) including coordination/orchestration of S&T popularization activities throughout the country.

The major programme elements of NCSTC are :
Training in S&T Communication.
Development of S&T communication software and its dissemination.
S&T communication networks/systems and coordination with the other agencies.
Field based programmes
Research in S&T communication.
Incentive schemes
Policy and Planning in science communication</td><td>Introduction:- Vigyan Prasar was set up by the Department of Science & Technology, Government of India, as an autonomous registered Society in 1989 for taking up large scale science popularization task. The primary objective of Vigyan Prasar is to promote and propagate as widely as possible-a scientific, rational outlook in society. To achieve this, its efforts go beyond mere dissemination of information to a conscious attempt at inculcating amongst people the sprit of “scientific temper”. The broad objective of VP may be summarized as follows:-

• To undertake, aid, promote, guide and coordinate efforts in popularization of science and inculcation of scientific temper among the people and to increase the knowledge, awareness and interest about science and technology among all segments of the society.
• To provide and promote effective linkages on a continuous basis among various scientific institutions, agencies, educational and academic bodies, laboratories, museums, industry, trade and other organization for effective exchange and dissemination of S&T information.
• To undertake development of materials-audio, visual, audio-visual and printed-methods and modes of communication, so as to enable the masses to better understand, appreciate and comprehend abstract scientific principles and practices.
• To organize research work, courses, workshops, seminars, symposia, training programmes, fairs, exhibitions, films shows, popular discussions, street plays, quizzes, song-dance-drama etc; in furtherance of objective of the society.
• To participate in trade fairs, exhibitions and other mass forums as well as to develop syndicated features and to contribute periodically to newspapers, magazine and journals in order to disseminate and create awareness on issue of science and technology.
• To undertake the design, development and construction of models, exhibits and other relevant instruments for hands-on visuals and other modes of communication.
• To institute and award fellowships, stipends, prizes, medals and any other kind of monetary incentives.</td></tr>
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3. Science Communication in India: Present Scenario

With establishment of governmental agencies like National Council for Science and Technology Communication (NCSTC) and Vigyan Prasar, and networks of voluntary agencies coming into being in the last twenty five years or so, a variety of activities now take place all over the country aimed at taking science to people with new approach generally termed as parallel or alternative approached of S&T Communication. A new class of professionals, trained through various short term and long term training programmes and courses conducted by various universities /Institutes and voluntary organization, using various modes and medium are engage professionally in making people scientifically more aware and attitudinally rational. National campaign to built and maintains the bridge between science and the people based on parallel approach are now more frequent and effective in science communication. A series of such successful examples are Bharat Jan Vigyan Jatha in 1987 (BJVJ-87) and Bharat Jan Gyan Vigyan Jatha in 1992 (BJGVS), programmes built around the natural phenomena (Total Solar Eclipses, Transit of Venus 2004 etc), Year of Scientific Awareness-2004, Vigyan Mail/Science Express, Year of Planet Earth-2008 and at present, the campaign to observe International Year of Astronomy (IYA 2009).

S&T coverage in the newspapers / magazines is also steadily picking up. Popular science magazines have proliferated in several regional languages. As regards the other traditional media. Several AIR stations with science cells broadcast three programmes per day. Doordarshan — the National Television Channel — telecasts about two programmes every week on the national network and all regional centres put together produce and telecast more than 150 S&T programmes every year. Agencies like University Grants Commission, Central Institute of Educational Technology, Indira Gandhi National Open University, and Vigyan Prasar also have regular slots on Doordarshan. Programmes on S&T Popularization for telecast / broadcast are also produced by several Government / Non-Government agencies. There are 24 state-of-the-art planetaria spread in different parts of the country. Interestingly the Indian Science Report 2005, first of its kind, has also gives us an insight into the public understanding of science.

Vigyan Prasar, an autonomous body under the Department of Science and Technology, Ministry of Science and Technology, has developed itself into a national resource-cum-facility centre; and is developing a variety of software, utilizing different means, media and modes. Regular programmes are being aired on television on various aspects of science and in all major Indian languages. Vigyan Prasar has set up a network of satellite interactive terminals spread throughout the country exclusively for S&T communication using Edusat, India's satellite for education. Print media and the Internet are also being utilized by Vigyan Prasar for science popularization.

National Children's Science Congress first of its kind and unparallel in the world, is being organised by NCSTC, for the last fifteen years in the country. This unique programme has already caught the imagination of a few Western and West Asian countries. In this programme, some 600,000 children participate. They undertake studies / projects on specific scientific themes. The reports are then submitted at school, district, state and national levels. The selected children then participate in the special session of the annual Indian Science Congress in January every year. Participation of Children from a few other countries is now also regular feature of the programme. Vigyan Prasar Network (VIPNET) of Science Clubs — mostly in rural areas, with nearly 10,000 member clubs as of today, has laid the foundations of a national science club movement. The Ministry of Environment and Forests have also established a countrywide network of Eco-clubs established to spread awareness about conservation of environment, biodiversity and sustainable development.

It is needless to say that programme like Children Science Congress, activities built around celestial events (Eclipse, transit of Planets etc), S&T for visually challenged, teaching aids and toys, networking of Govt./Non Govt organizations for S&T communications, "Vigyan Rail" or "Science Exhibition on Wheels" are all pioneering efforts to popularize S&T in India through parallel approach.

4. Public Understanding of Science — India

The India Science Report 2005 (ISR), first of its kind, presents the state of science and technology in India quantitatively. The report also gives an insight into the public understanding of science or science communication. In particular, it states that there is no decline in interest in the proportion of students who wish to study science. On the other hand, half the teachers interviewed believed that more computers / equipment were required for teaching science subjects since inadequate science training was a serious issue.

ISR 2005 draws very interesting inferences as regards public attitude towards S&T. Over three fourths of the public feel that S&T is important for education; and believe that S&T makes lives healthier and more comfortable. On an average, the level of knowledge the population has about the scientific concepts is very high — 57% of the people knew that the centre of the earth is hot and 86% knew that that the oxygen we breathe comes from the plants. Not surprisingly, given how women are blamed for not having a male child, just 38% knew that the sex of the child depends upon the father. Surely, the answers to science related questions tend to be increasingly correct as the level of their understanding of science will go up. The report also finds that television is the most popular source of information for most people. But this also calls for a conscious action on the part of all concerned to generate quality S&T programmes for television. Quality S&T TV programmes are few and far between. This finding makes a strong case to utilize television and the Edusat infrastructure for S&T communication in a more meaningful way. Regarding Internet as a source of information, it does not appear to be popular source of information in India. Over 44% of S&T information in the US is got from the Internet as compared to 0.2 % in India at present! There is a need to ensure greater penetrability of Internet and other ICT tools at the school level as also in rural and remote areas so that access to reliable and updated information is considerably improved.

But what is of prime concern is the findings of the report that extremely low percentage of people visiting science museums, planetaria, aquaria etc. The science museum, science cities and planetaria are the forerunners of the so-called modren approach of science communication. Is this due to less awareness or less motivation? This needs to be ascertained. But this is a stark reality on which the future strategies of science centres and museums would need to be based.

5. Parallel or Alternate approaches of S&T Communication

Over the past few decades, due to concerted efforts of dedicated individuals and organizations, the conceptual framework and the parallel approach has attracted an increasing number of adherents both among the common people and among communicators, cutting across several divides including the urban/rural. In fact, the approach and conceptual framework have been put to countrywide test several times after the Bharat Jan Vigyan Jatha in 1987 (BJVJ-87). The success and the large scale participation of people in BJGVJ-92, and nationwide campaigns built around natural phenomena like eclipses, transits of planets, comets etc, Year of Scientific Awareness (YSA) -2004 , World Year of Physics-2005 etc, and programmes like National children science congress, mega radio serials, science clubs movement (VIPNETS), etc; have not only validated the conceptual frame work of S&T communication/ popularization but has also proved the efficacy of the approaches and methodologies used which are found to be more in tune with Indian ground realties.

6. The Conceptual Framework of S&T Communication in India.

"In context of science communication, the word science is often used to convey a meaning which covers a much wider canvas than what it does when one talks about in conventional sense. The word "Science" in science communication, therefore would not only cover physical or biological science, it would also take in their basic, applied and environmental aspect, together with their social, societal and economic dimension as well as their inter-relationship". Hence "S&T communication is not only flow of scientific & Technological information and facts from source to target group through some medium." "It also includes spreading and nurturing of scientific temperament/ values and method of science". "Mere dissemination of scientific information and facts is not to be confused with the main objective of science communication, or even of science popularization. In fact this can be a small, albeit an unimportant, component of the whole thing". Science-communication should aim at conveying that:-

1. "Science is everywhere: at home, out in the open, at school, on the way to or from school and all around them; anything and everything that we touch, feel and experience has to do with one or another aspect of science".

2. "Science has tremendous possibilities and potential-both good and bad. It is for us to ensure that 'science' is used only for good of people, society and the country."

3. "Anyone and everyone can use the knowledge and the tools provided by science to one's and society's advantage."

4. "Increasing adoption and internalizations of the method and values of science in every-day life can help one get more out of one's resources through their optimal utilization."

5. "Research in S& T communication include development of field level projects with a view to studying and researching various existing impediments to the spread and promotion of scientific outlook/attitude/temper among people; and devising and developing more effective communication methods, means, tools, techniques and technologies than those presently in use.

6. Development of evaluation methods and mechanism for determining the efficacy of various tools employed for S&T communication

7. Pools and survey to assess levels of S&T and attitude among various section of the population.

Accordingly, science communication ought to focus more on conveying the basic approach, the attitude, the method, the processes and the values of science and less on its content, facts and information. Particularly, for general and common people Science communication needs to aim at promoting and encouraging:-

- Curiosity and a sense of wonder (meaning how and why) about things, happening, events/phenomena around them;
- Spirit of inquiry and asking and seeking well-reasoned and convincing answers to these questions;
- Keen and systematic observation of things, facts and oddities around them
- Experiment to check out, verify, disprove or confirmed a suspicion or guess;
- Correctness, precision and meticulousness in whatever they do; and so on.

7. Important characteristics of Strategies and methodologies used for S&T Communication/ popularization in India

- Use of all possible media, modes and methods of communication — traditional , non-traditional , electronic, non-electronic, including folk forms for effectively conveying messages and information for discussion, debate and exchange of experiences;

• Use of the local language and idiom in all communication especially folk forms;

• Use of Interactive and participatory form of communication.

• Emphasis on the learning-by-doing method and on low or no cost activities which employ common and easily available local material;

• A conscious effort to make communication as much of a two way process and preference to those methods and media, which allow more of this.

• Science communication on the whole and in overall Indian context includes a critical examination and assessment on a scientific basis of its age-old tradition in different areas (viz; agriculture, health, education etc), especially before entirely new or parallel things are sought to be promoted by way of dissemination of information.

• Science being a process and method rather than a mere branch of knowledge, naturally permeates every human activity. Whatever the topic and whatever the medium of communicator, scientific approach must farm part of our thought and actions, — Scientific temper must reflect at every state.

• A basic assumption that the communicators, in the process of science communication, also have a lot to learn more those whom they would be trying to reach or communicate with- even in the case of those who might be illiterate in common parlance.

• Involvement of large numbers of people in the various stages and processes of communication.

• Preparing large number of resource persons through training in the preparation and use of common software materials prepared centrally as well as at the local level.

• Holding of workshops/rehearsal camps at different levels (nationally, and at the State-level) for science communicators, science clubs coordinators, teachers, science activists and so on.

8. Parallel/Alternative Communication Approach

The so-called modern approach, actually western, rooted deeply in science museum, science city, science exhibitions (fixed & mobile), displaying the latest gadgets or model of hardware etc. is capital intensive and highly centralized. Such exhibits hardly generate any interest among the visitors. Considering the many fold diversity (social, cultural, religious, linguistic and regional- unparallel in the world) and target audience, of which 70 % still rural and a considerable section of which till date living below poverty and illiterate; the efforts from the very beginning were more on to establish and create parallel, more relevant, indigenous images of science and science communication. It was well understood that for the achievement of the objective of S&T communication/popularization something more suitable to our country will be a approach which is decentralized, activity based, low cost, participation-intensive and allows our environs to be used as learning and teaching ground. It was also realized that through this parallel or alternative approach what we do or learn is to be directly and closely connected with real problem(s), situation, things and happenings in every day life.

As a matter of fact, what all has been achieved in this country over the years. in the field of S&T Communication / popularization by means of parallel approaches, a few other countries are trying to emulate. For example, the annual event National Children Science Congress has caught the imagination of a few western and west Asian countries. China has initiated campaigns with the help of school children to overcome superstitions and attempts are made in England at communication S&T through science plays.

8.1 The basic premise and philosophy of all S&T Communication Programmes based on Parallel Approach

"For any S&T communication and popularization programmed to be effective, it has to be participatory, interactive and in a language employing an idiom which belongs to those one is trying to reach, or communicate with."

"In any interactive S& T communication, the communicators involved too, have much to learn from those whom they may be trying to communicate with, even if the latter may not be either literate' or formally educated."

8.2 Strategies to achieve the Goals of S&T Communication/ Popularization.

Through parallel approach what is emphasize is as follows:

Reaching larger numbers of people across the country. To achieve this, among others, should begin in the form of major, large scale, coordinated projects on specific themes with specified objectives and time frames;

Reaching people using all possible media, both traditional and non-traditional, and by employing software in the language of target group.

Using the existing S&T communication software, producing new and additional software on a large enough scale, by using adaptations of the original software;

Developing proper manpower of various S&T communication tasks, including resource persons for parallel programme and activities; and

Providing linkages to and martyring of all elements of the programme, and using other innovations not specifically mentioned above as per the needs of target group.

However, no formal pre & post studies have been done for the impact assessment of such programmes based ob parallel approach. The difficulty is, if we were to find major difference in various parameters in the pre and post studies, we would not be able to attribute them solely to any single effort or programme of science communication. The reason is simple; the sample target group during same period also subjected to countless other influences at school at home, at work place or elsewhere. Apart from this complication, all the studies would probably cost much more than what cost to amount science popularization activities themselves (like training programme). For this reason only indirect methods are employed to assess the impact of our and similar other programmes. All indirect evidence suggests that our programme have had a positive impact among the audience we have attempted to reach

9. Issues that Need to Be Addressed

There has been a marked change in the social fabric over the last decade as a combined result of the liberalization in economy and the phenomenal growth in the field of information technology. If we compare the modren and parallel approach, at present the distinction between the two is being obliterated. The science centre/ museum are now re- modeling all their programme and activities in such a way to make a much deeper penetration into the society by using strategies like mobile exhibitions, interactive exhibits to covey concepts in a better way, organization of science drama etc. To generate the interest, various exhibits has been designed to address the needs of different target groups ranging from school children to elderly persons. In view of what India Science Report 2005 says on public understanding of science, what should be the role and responsibilities of science centres and museums?, they have already redefine their role by adopting parallel approach for conveying the message of science for wider dissemination in the society.

So at present, there is no need to modify or redefine the conceptual framework of Science communication, which has been evolved over the years as a result of people's science movement in India. In fact there is a need to consolidate the indigenous conceptual framework, which is more suitable to a highly diverse society like India and more in tune with its social, economic, cultural and political milieu, despite the changes brought out in the society as a result of liberalization and globalization.

Given the rich experience India has had in parallel and alternative approaches of science communication and given the overlapping concerns of Afro-Asian countries, the experience can be shared for crossbreeding and cross-fertilization of ideas for mutual benefits. The Indian experience would also help the mass media and other stakeholders to reorient and modify people's mental perception about science and what constitute S&T popularization/ communication. In fact it is not out of place to mention that even in western countries the movement to promote "public understanding of Science" would benefit enormously by using the suggested conceptual framework and parallel approach either as it is or with suitable adaptations.

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Dr. Manoj Patairiya

Synchronizing Head & Hands together for Excellence: Role of Technology Communication & Technological Temper — an Attitudinal Analysis

Abstract:

We often tend to satisfy ourselves by accomplishing around 80% of a task and feel as if we had contributed enough and done a great job, but excellence lies in finishing the remaining 20%. Even out of the 80% accomplished work, only a fraction of it can be attributed to as excellent, as in most cases, we are unable to put our head and hands together in harmony for a particular work. Knowledge and attitude together play a major role in achieving excellence in every walk of life, be it a worker, student, scientist, technician, teacher, housewife, or even an artist or astronaut. Here the hands-on science becomes more significant in all spheres of human endeavors.

We have been talking about science communication, education and scientific temper and very less has been discussed about technology communication and technological temper. Although, in general, when we talk about science, it also inherently incorporates technology. In fact, the most part of our science communication activities involves technology communication, as well. Be it an exhibition, or a hands on activity, such as origami, science toys/ games, teaching/ learning aids, model rocketry, experiments with aerodynamics, water testing or HAM radio, etc.

However, at the dawn of 21st century, when we have arrived at a crucial turning point of sustainable development and multifarious technological advancements and challenges, we cannot proceed randomly and have to step ahead in much professional and systematic manner. Hence, equal focus is required to be given on technology communication and technological temper in a fast advancing world, where technology plays a vital role in not only the life and work of mankind, but also acts as one of the important deciding factors, responsible for the strength and wellbeing of a nation.

One's attitude is a highly complex attribute and varies on a variety of factors, i.e. upbringing, surrounding, parenting, schooling and above all socio-economic and cultural milieu. The present paper examines various attitudinal patterns especially amongst children and tries to find out various factors impeding them with possible ways and means to overcoming these barriers with a dose of technological awareness and technological temperament.

Introduction

When Galileo Galilee discovered that it was the earth, which revolves around the sun and not the sun around the earth, he was simply stating a fact of nature. Science is to understand the laws of nature, or in other words the process of understanding nature is science. So, science is not stray from nature, science manifests from nature. Science doesn't create something new; it rather puts forward another application of a natural phenomenon. When man experiments with nature, he could simply be trying with a different magnitude or dimension of nature. In orbiting of a manmade satellite, in experimenting with nuclear structure, in decoding genetic setup, it could never meant going against nature. Science lies buried in nature. However, as a science philosopher observed, "nature can bury science and the world, if these do not go in tandem".

Is it necessary that one has to learn from his own mistakes or commit mistakes to learn? Perhaps no! Wiser one learns from other's mistakes. But he has to keep himself abreast of the latest technologies. The role of communication in science is paramount because science has lot to do with nature and, more precisely with life. Science has a bearing on the way one thinks, lives, conducts and behaves in the society. And thinking scientific is thinking natural. Thinking scientifically is establishing harmony with nature, of which we talk so often. This activity could best be promoted by communicating science in a scientific way. Accuracy, while communicating science needs to be emphasized. Distorted information is no less dangerous than a slow poison.

Technology is an application of science. Technology is believed to have descended in man's world earlier than science. This is an observational obscurity. To the man, technology bears supreme importance. Man's quest for science began from his urge to master technology. This unfolded a chain of technological evolution, as man resorted to druid replication of nature. Many of so called technological feat have been marred by known and unknown hazards on life and surroundings. Man in many terms is a quick learner and he knows that he has but no other alternative.

Though science emerged after technology, it is too obvious to witness that science and technology are strongly interconnected with each other and their progress is interdependent. Science in its early stages was hardly distinguishable from technology. The knowledge of man regarding the use and control of fire, development of tools, primitive agriculture, use of medicinal and herbal plants, etc. during ancient age are the examples of rudiments of technology. In fact, for a long span of time during early stage of evolution of human civilization, it has been observed that technological developments were more frequent; despite there being no scientific concepts. Therefore, several scholars have conceptualized technology as applied science.

The origin of technology can be traced back from the beginning of the human civilization, when the early man had discovered the fire and understood its use and control, and explored natural resources for his benefit. A million years ago, human beings learned how to handle and shape the mud, stone and wood for different uses. Thus development of technology progressed simultaneously with the evolution of human civilization.

However, science as an organized body of thought is generally considered to have begun with the Ionian school of Greek philosophers about 600 BC. Nearly around the same time, Gautam Buddha, in India, gave the cause and effect theory and preached about spirit of enquiry, the basics of scientific thinking. Discoveries or inventions prior to 600 BC were generally referred as examples of technology.

Technology Communication

Technology communication is as old as "technology" and "communication" itself, although its ancient forms were entirely different from the present ones. The origin of communication can be traced back to the beginning of human civilization, when the early man might have communicated with each other through body language. The art of communication further developed and got refined as was visible in development of oral communication. Subsequently, man had started making sketches on the walls of the caves, rocks and on other similar objects to express his ideas, observations and imaginations. One can see the beautiful cave sketches at Bheem Betka, Near Bhopal (MP) made by the Stone Age man, depicting various technologies of that time, such as stone axe, etc. Of late, written scripts were developed and man started communicating through written words and sketches on moist soil and mud boards, clay tokens, bark of the trees, wood, stone, metals, like iron, bronze and copper, etc.

The term "technology communication" is a combination of "technology" and "communication", which is referred to the flow of technological information, thoughts and methods from their origin to the user, through a medium or mediator. In other words, all aspects related to dissemination of technological information and inculcation of a technological temper among people through all possible means, modes, methods, media, techniques, tools and processes can be referred as technology communication.

It is well understood that concerted and widespread efforts in technology communication/popularization can help achieve the goal of overall development of mankind, by making the people technologically aware and inculcating a technological temper among them. It is believed that a scientifically informed, technologically capable and rational society could progress in a much coherent way.

There is, however, an enormous gap between the common masses and scientific and technological information and an acute shortage of personnel suitable for the role of an S&T communicator, who could take up this challenging task of taking S&T to the people.

The human knowledge and intellect is driving quest for science and technology research and development. Given the consequent advancements in various streams of scientific and technological endeavors, we have to consider science communication and technology communication separately. Accordingly, communication of technological information or thoughts through writings, publications, broadcasts, telecasts, lectures, theatre performances, puppet shows, exhibitions Jathas, technological museums and making presentations in seminars, symposia, meetings, etc. is included into the gamut of technology communication.

Objectives

Although, the broader objectives of technology communication are hardly different from those of science communication. However, some specific objectives, among others, can be summarized as follows:

1. To communicate and popularize the information about the technology, confronting our day to day life, to the common people.
2. To inculcate a technological temper among them.

3. To infuse the spirit of innovation and technological advancement in every sphere of human activity.

4. To make them aware about assimilation and adoption of the latest technology and its confluence with the traditional technology.

5. To develop at least workable understanding of various technologies available around and those we use.

6. To enable people to appreciate the technological changes, that is taking place due to various kinds of research and developments.

7. To bridge the gap between the head and hands and to integrate different attitudes and cultures of white collar and blue collar jobs.

8. To develop and enhance the level of technological literacy among various cross sections of the society.

Technological Temper

The state of mind geared up to use of hands in a systematic manner in any technological operation is known as technological temper. In other worlds, the technological temper can be referred to the spirit of using head and hands for accomplishment of any task in a systematic and orderly manner.

Generally, in teamwork, if there is a mistake, we tend to put it on other's head, but in case of a success; we try to take credit of it. If everybody contributes his or her due part in teamwork, such as in an industry, mill or plant, with a high degree of proficiency and accuracy, there may be hardly any chance of a failure. The failure occurs, when any member of a team does not contribute his due part or contributes in an unsystematic manner. This is called the lack of a technological temper. The failure of the launch of GSLV spacecraft is an ideal example of the lack of technological temper, where a small lapse of someone leads to a grand failure.

It may be possible to make it more vivid by citing an interesting example. Generally, it is difficult to find an electronic engineer capable of undertaking even a small repair work of his own transistor set. On the other hand, one can find a number of persons, who have not undergone the regular educational training, but have acquired the knowledge and skill only with the application of technological temper, which is nothing but the common sense. This reflects the application part of a scientific knowledge.

When we go to market, we observe that a particular mechanic or carpenter or any other such professional is excellent in his work and we even recommend his name to others also. What is this! This is recognition of his technological temper in real term. In fact, by way of inculcation of a technological temper, a qualitative and systematic performance is expected from a person, in every walk of human activity that would lead him to perfection and excellence.

More or less, it has become a modern system that various technologies may be available, but of no use. For example, you will find a hand pump, but not working and municipality's tap with leakage of water. Similarly, one can find a public telephone, with no dial tone. This situation needs to be corrected. Here the role of State may be important, but above all, it is the role of our attitude, the technological temperament, which we are talking about. If we are able to develop a technological temper among masses, it can change the situation up to a remarkable extent.

Technology Literacy

The technological literacy, understood as an everyday working knowledge of technology, is as necessary as reading and writing (literacy in the commonly understood sense) for a satisfactory way of life in the modern world. Technological literacy is necessary for there to be a capable workforce, for the economic and healthy well-being of the social fabric and every person, and for the exercise of participatory democracy. It also implies the ability to respond to the technological issues that pervade and influence our daily lives. Technological literacy does not mean detailed knowledge of technological jargons, phenomena or deeper aspects, etc., however, it rather points out of the comprehension of what might be called the technological approach, or the systematic and orderly way of doing things and with more accuracy.

In this sense, a technologically literate person should posses a general sense of understanding technological things happening around, such as the boring for tube well, the working of a film projector, etc. There is universal need for technological literacy, since it is the basic requirement for the enhancing and strengthening further technology communication activities around the globe. Although, the magnitude of this need may vary from country to country and region to region, based on exposure of people to various kinds of technologies available around them. For example, a person coming from a remote village may not know about a pager or a digital diary. Similarly, a person from a city may not be aware of the seed driller or potter's wheel.

In our day to day life, we come across various kinds of technologies, products, gadgets, etc. at home, at work place, in a market or all around. But generally, we do not try to understand their mechanism or techniques as how do they work and what kinds of technologies are involved in their working. Accordingly, the technological literacy can be considered as a working knowledge of various kinds of technologies we use and see around us. This would not only develop an understanding about various kinds of technologies, but also develop a sense of confidence. Simply, most of us may not know as how a tube light works or how a cold storage keeps vegetables fresh or even how a fountain pen works. These are the simple examples from our every day life, where most of us lack the technological literacy.

With a view to identify a certain level of technology literacy, we have to bench mark the desired level of understanding of technologies available around a particular sect of society. This bench marking can be different from area to area and community to community, based on the general level of awareness of people. Accordingly, to reach to a certain level of technology literacy in a given area or community, the efforts of technology communication may be concentrated to fill the void. When a certain level is achieved, then it would almost automatic that societal understanding and inception of technology, changes to those at higher levels. This is the natural way to enhance technology literacy to make any society technologically strong and enlightened.

Scope

The scope of technology communication is very wide. It ranges from communication of traditional technologies to the latest ones. The country has a great treasure of traditional technologies, which form the most part of our rural technology base. For example, in Himachal Pradesh, traditional water storage systems are found in remote villages. Underground tanks are constructed in front of the houses and arrangement is made to collect the rainwater and snow falling on the roof of the house, into these tanks via mud pipes.

It is called "Khatriyan" in local language. This water is utilized for various domestic purposes, other than drinking, throughout the year. This technology needs to be propagated in other parts of country. Though, Government has now recognized the worth of this potential technology and encouraging harvesting of rainwater from various buildings. Many more such technologies are scattered here and there, especially in far flung areas of the country, needs to be communicated from one place to another, depending upon their suitability. Minor modifications can be suggested as per local requirements.

A number of technological advancements are taking place across the country in various research and development institutions, laboratories under Government and private sector. These technologies are useless, unless they reach to the end user. The technology communication efforts may be geared up for taking such newly emerged technologies to the people. There are a number of farm technologies, rural technologies, construction technologies, etc., which are not only cost effective but also time saving and durable. Information on such developments may flow from their origin to the user by way of different modes and means of communication, such as mass media, technology jatha, technology fair and technology exposition, etc.

One of the major objectives of technology communication is to create an urge for newness. Generally, most people feel comfortable to follow the beaten track. But some of them love to introduce their innovation. In other words, technology communication and technology temper also lead to certain modifications in the existing technologies, besides creating new ones. Therefore, science communication does not only make people aware about a particular technology, but also try to develop an spirit of innovation, motivating them to exercise innovativeness and creativity in every sphere of their life and work and to achieve accomplishment more perfectly and properly.

One of the major activities of technological communication programme can be to identify a technical/technological problem at local level and finding its solution. There may be plenty of technological problems prevailing at local levels. These can be solved with the intervention of technological communication. For example, industrial pollution in Kosi River, near Rampur (UP) poisoned the ground water of about 60 villages. An NCSTC's group of science journalists identified this problem, during an exercise of on the spot reporting. The detailed reports appeared in media and installing treatment plants at the polluting industries solved the problem. That apart, in case, some technological input or innovation is needed to solve a local technological problem, concerning technologists, engineers and experts can provide it and help solve the problem.

Technology and Media

Mass media plays a pivotal role in bringing technological information and technological aptitude to the common men. There may not be science columns in various newspapers and magazines, but one can find columns in various newspapers and magazines covering latest technologies, products, households, etc., not only in national dailies but also in regional newspapers. Technological columns have become an attractive and vibrant source of general reading. On television, there are many programmes on various technological products, though they are mostly confined to a commercial activity, but still they provide some sense of understanding about the products and technologies. On Internet, a number of products and technologies find prominent places with detailed description and visuals, sometime animated also.

In fact, big players in mass media know the pulse of common man and act very fast, as and when the demand arises. However, in order to harness the potential of mass media for technology communication, there is a great need for providing suitable technological information in the form of articles, features, reports, interviews with technologists/technocrats/industrialists, etc., along with good quality visuals/photographs/illustrations. More precisely, we need a whole host of technological writers/columnists/correspondents/communicators, who can contribute on various technological developments/issues in mass media, especially in vernaculars to cater to the common people and to fulfill the fast emerging demand of quality stuff on technology.

In our country, various efforts are going on for technology transfer and technology extension. But the target users hardly acquire any understanding of the same. These efforts need to be integrated with technology communication, so that, while using a particular technology, the users can also develop a feel and some degree of understanding of the technology they use or come across.

Technology Day

May 11, 1998 was a very special day for Indian technology. We had three great technological events on that day. The first event of the day (12:50 p.m.) was of the successful test flight for final certification of Hansa — 3, the first all composite indigenous aircraft, built by CSIR. The second was (followed a few minutes later) the successful test firing of the Trishul missile. The third and the most momentous was the three successful nuclear tests, known as Pokharan-II. In view of the series of our technological successes, Prime Minister has declared 11^{th} May as the National Technology Day, just as 28th February is celebrated as National Science Day in recognition of discovery of Raman Effect. Consequently, to give more impetus on technology communication and inculcation of a technological temper, we have been celebrating technology day each year on 11^{th} May since then to develop spirit of innovation and encourage innovativeness and creativity in the society.

Towards an Innovative Society

Infusion of innovativeness and creativeness may be one of the major tasks before any technology communication effort. Technology communication does not only mean to communicate technological information from laboratories or technological institutions to the people. It can be two ways. In case, some kind of technologies or technological ideas emerges from among the people that can also be carried to the scientists and technologists, so that it can be evaluated in terms of its viability, efficacy, workability and novelty. It can also be reshaped, modified and upgraded, if necessary.

It emerged from the current study that in the age group of 15-25, the creativity of children and youths is very high and they come up with a number of novel ideas. As an average, at any given time, 2-3 such brilliant students do exist in each medium city/town, who are interested in creative endeavors and putting things together in their own novel way. A mechanism can be worked out to harness the potential of such individual innovators. It has also been seen that such persons are least interested in text books or curriculum, but they posses a proven ability of doing technical/technological things. Obviously, they cannot secure good marks in their examination, but at the same time, their technological endeavors can prove them as an asset for the society. Such efforts need to be promoted and supported. The mechanism can be developed so as such technologically motivated persons driven with zeal and gleam in their eyes to doing something new and relevant, reach to the scientific/technological R&D institutions, laboratories, technology centres, etc.

Since the process of technology communication and inculcation of a technological temper stimulate the spirit of innovation among people, they must be made aware about intellectual property rights to protect their innovations and developments. Technological innovations are visible in various farms, rural and domestic technologies across the country. But almost no patent has been taken for such technologies, due to lack of awareness and technicalities involved in patenting process. Common people and even educated people are unable to file a patent with patent office and get patent right in their names for their invention. As a contrast, some people seek patent right, though their innovations may not be patentable. Therefore, the awareness about patentable and non-patentable inventions, preparation of application for a patent, writing/drawing a patent specification, process of getting a patent and maintaining a patent is required to be spread deeper in to the society in the light of WTO and GATT, and this may form a major component of technology communication.

Recommendations

Besides routine activities concerning hands-on science, various other activities are envisaged to be organized : i) at school level, involving children, students and teachers, etc., and ii) at community level, involving community people, especially women, weaker sections of the society, etc. Some activities are indicated below :

i) At the School Level

Identification of local technological problem and/or finding its solution.

Identification of the need for some change or modification in the existing tools households and other such gadgets to make them more efficient, useful and safer.

Identification of local/regional traditional technologies and collection of information on them.

Constituting technology clubs/forums in schools/localities.

Organizing discussions on various technological issues, such as CNG Vs. conventional fuels, etc.

Designing, developing and making new educational aids.

Collecting data on idle/unused technologies around and motivating concerned authorities to putting them to use and in order.

Finding the areas where new inventions are needed, developing ideas and converting them into reality by making working model.

Some time a new attachment/device can add to the quality and efficiency of a machine or equipment; such small attachments/ devices can be thought of and developed.

Organizing technology fairs, demonstrations, do it yourself activities, hands on activities, etc. and also creating/developing such new activities.

Writing/preparing technical reports for documentation and popular scripts for mass media on the above aspects.

ii) At the Community Level

Identification of local/regional technological problems/issues and finding their solutions.

Involving women, especially from weaker sections in community based programmes, such as technology Panchayat, technology demonstrations, technology appreciation, etc.

Arranging question and answer sessions with the community people on various subjects concerning the technologies generally they use, such as, how does a plough work, how does a seed driller sow.

Technological fair, industrial fair, technology exhibitions, Jatha can be developed and organized on specific themes.

Mass media can be harnessed for technology communication. As such, optimum use of print (newspapers, magazines, etc.); broadcast (radio, television); folk (puppetry, theater, folk songs, skit, etc.); interactive (lecture, demonstrations, get together, etc); and digital (Internet, CD-ROM, diskettes, etc.) can be undertaken for technology communication, as well.

Organizing contests, competitions, quizzes, etc. on various technological subjects.

Apart from technology day, some other days related to technology, can be celebrated, such as, disasters prevention day, industrial safety day, etc. Foundation days of various technological institutions, industrial establishments, engineering colleges, polytechnics, etc. can also be celebrated with an involvement of local public.

Short term awareness programmes can be organized to especially educate those, who are exposed or likely to be exposed to certain industrial hazard, occupational hazards, etc. People located nearby a hazardous industry/plant must be educated about the possible industrial hazards, so that in case of any fault, they can save their lives and belongings.

Conclusion

Indian S&T can play a crucial role in catalyzing and accelerating the economic and social development. The comparative advantage in the globally integrated technology knowledge based world economy today is becoming more relevant to those with an aptitude to absorb, assimilate and adopt the spectacular developments in science and technology, with the traditional knowledge and technology and harness them for national growth and advancement. The best alignment of knowledge and attitude by way of synchronizing head and hands together to harness the benefits of precision technology would be crucial for overall development.

Technology communication is dedicated to technological developments. This is to augment the efforts of the nation to channelise us to a technologically evolved and technologically thoughtful society. It is to work out and share better methodologies and strategies for spreading of technological literacy and technological temper/aptitude across the society.

It is important to inculcate the technological attitude especially amongst children in formative stage with an inherent urge for doing things, whatsoever it may be, in most finished way. It'll allow them to grow with a sharp edge and contribute towards more conducive and rational development.

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Author Index

Ajay Chauhan, Research Associate, IIFT, e-mail: ajaychauhan@ iift.ac.in

Alexander G. Allakhverdyan, Director of the History of Science Organization Center, Instutute for History of Science and technology, Russian Academy of Sciences, Moscow, e-mail: sisnek@list.ru

Andrey V. Yurevich, Corresponding Member of the Russian Academy of Sciences, Vice-Director of Psychology Institute, Russian Academy of Sciences, Moscow, Russia, e-mail: yurev@orc.ru

Arun P. Bali, Former Director, International Collaboration ICSSR, New Delhi, brainy47@qmail.com

B. Koteswara Rao Naik, Assistant Professor, National Institute of Technology Tiruchirappally, India

Baldev Singh, Lecturer in Economics, SGTB Khalsa College, University of Delhi, Delhi, India, e-mail: shergillbaldev@gmail.com

Brinder Kumar Tyagi, Principal Scientific Officer, Vigyan Prasar, Govt. Of India, UP, India, e-mail: bktyagi@vigyanprasar.gov.in and tyagi.bk@gmail.com

C. Raghava Reddy, Lecturer, Department of sociology, University of Hyderabad, India, e-mail: craghava@gmail.com

Deepthi Shanker, Department of Humanities and Social Sciences, India Institute of Technology Guwahati, India, e-mail: deepthishanker@gmail.com

Duru Arun Kumar, NSIT, Dwarka, New Delhi 110075, India, e-mail: duruarun@rediffmail.com

Eduard Kolchinsky, Director of the Institute for the History of Science and Technology of Russian Academy of Sciences, St. Petersburg, Russia, e-mail: ihst@ihst.nw.ru

Elena Ivanova, Head, Sociology of science and innovation, St. Petersburg Scientific Centre, Russian Academy of Sciences, St. Petersburg, Russia, e-mail eivanova@spbrc.nw.ru

Elena Z. Mirskaya, Sociology of Science Department, Institute for the History of Science and Technology, Russian Academy of Sciences, e-mail: elena-mirskaya@mail.ru

Gregory Sandstrom, (PhD) Candidate of Sociological Science, Post-Doctoral Research Fellow Autonomous National University of Mexico, Institute of Applied Mathematics and Systems, e-mail: qreqorysandstrom@vahoo.com

Ejnavarzala Haribabu, Professor, Department of Sociology, University of Hyderabad, Hyderabad, India, e-mail: hari_ejna@yahoo.com

Irina Eliseeva, Director, Sociological Institute, Russian Academy of Sciences, St. Petersburg, Russia, e-mail: irinaeliseeva@mail.ru

Jaime Jiménez, Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas Universidad Nacional Autónoma de México (UNAM), e-mail: jjimen@ servidor.unam. mx

Judith Zubieta García, Instituto de Investigaciones Sociales, UNAM, Mexico, e-mail: zubieta@servidor.unam.mx

Jyoti Yadav, Scientist, Institute of Genomics and Integrative Biology, Council of Scientific and Industrial Research, New Delhi, India, email: j.yadav@igib.res.in

Kashmiri Lal, NISTADS, K.S. Krishnan Marg, Pusa Campus, New Delhi, India.

Lakhwinder Singh, Professor, Department of Economics, Punjabi University, Patiala, e-mail: lakhwindersingh07@gmail.com

Madan Lal, Consultant, IIFT, New Delhi, India, e-mail: madanlal@iift.ac.in

Manoj Patairiya, Director (Scientist 'F'), National Council for Science & Technology Communication, New Mehrauli Road, New Delhi – 110016, India, e-mail: mkp@nic.in

Nadia Asheulova, Director of the Sociology of Science and Science Studies Research Centre, St. Petersburg Branch of the Institute for the History of Science and Technology, Russian Academy of Sciences, St. Petersburg, Russia, e-mail: simar@bk.ru

Nanyan Cao, Institute of Science, Technology and Society School of the Humanities and Social Sciences, Tsinghua University, Beijing, China, e-mail: caonv@tsinqhua.edu.cn

Nimesh Chandra, PhD candidate, Centre for Studies in Science Policy Jawaharlal Nehru University, New Delhi, India.

Parthasarathi Banerjee, Director, NISTADS, Dr K S Krishnan Marg, CSIR, New Delhi, India, e-mail: partha.parthasarathi@gmail.com

Pradosh Nath, Scientist, NISTADS, New Delhi, India, e-mail: pradoshnath@gmail.com

Rabindra K. Mohanty, Reader in Sociology, BPSPA, Bhubaneswar, Orissa-751019, India. e-mail: rkmohanty_socio@yahoo.com

Raghuvir Sharan, Former Professor, IIT Kanpur, Department of Electrical Engineering, Kanpur, India. Email: sharan@iitk.ac.in

S.P. Agarwal, Professor & Head Centre for International Trade in Technology (IIFT), New Delhi, India, e-mail: spagarwal@iift.ac.in

Sambit Mallick, Asst. Professor, Department of Humanities and Social Sciences Indian Institute of Technology Guwahati, Guwahati, India, e-mail: sambit@iitg.emet.in

Sudhir K. Jain, MHRD IPR Chair Professor, Indian Institute of Technology Delhi, India, e-mail: skjain@dms.iitd.ac.in

Sujit Bhattacharya, Visiting faculty, Centre for Studies in Science Policy, School of Social Sciences, Jawharlal Nehru University, New Delhi, e-mail: sujitacademic@yahoo.com

Sujoy Kumar Saha, Professor, Mechanical Engineering Department, Bengal Engineering and Science University Shibpur, Howrah, India, e-mail: sujoy_k_saha@hotmail.com

Suprakash Chandra Roy, Editor-in-Chief, Science and Culture, Indian Science News Association, Calcutta, India, E-mail: scie2224@dataone.in

Svetlana Kirdina, Leader of the Sub-Division of Evolution of Social and Economic Systems, Institute of Economics, Russian Academy of Sciences, Moscow, Russia, e-mail: kirdina@bk.ru

T.C.A. Anant, Member secretary, ICSSR, New Delhi, India

Tatiana I. Yusupova, Research Fellow, Institute for the History of Science and Technology of Russian Academy of Sciences, St. Petersburg, Russia, e-mail: yusupova@ihst.nw.ru

Tatiana A. Petrova, Associate Professor, State University of Culture and Arts, Philosophy and Political Sciences Department, St. Petersburg, Russia, e-mail: tatyanapetrova@inbox.ru

Valentina M. Lomovitskaya, Research Fellow, Institute for the History of Science and Technology, Russian Academy of Sciences, St. Petersburg, Russia, e-mail: lomov.vm@mail.ru

Vinish Kathuria, Associate Professor, SJM School of Management Indian Institute of Technology Bombay, Powai, Mumbai, e-mail: vinish@iitb.ac.in, vinish.kathuria@gmail.com

Y. Madhavi, Scientist, NISTADS, DR K S Krishnan Marg, Pusa, New Delhi, India, e-mail: y_madhavi@yahoo.com

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