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Globalization of Innovations: Changing Nature of India's Science and Technology Cooperation Policy

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Abstract: The present paper is an attempt to focus on the international dimensions of innovation policies that are likely to affect technological change and development process. Recently, a new dimension of innovation has been added by the offshoring of R&D services in India. This phenomenon was mainly confined to the triad countries but recently a number of firms from China, Korea and Taiwan have also figured in this process. Many theoretical and empirical studies are proving to be inadequate to explain this process of globalization of innovation. The present paper attempts to analyze the role of new actors, learning process and its impact on India's innovation system and discontinuity in India's cooperation policy if any. It is contended here that due attention on the interactions between 'national' and 'international' innovation systems can no longer be ignored for evolving balanced S&T policies.

Keywords: Globalization, international system of innovation, India, FDI, R&D

JEL classifications: L52, L88, O34, O38

1. Introduction

India's efforts in international science and technology cooperation were initiated as early as 1950s in the post-independence period. These efforts conducted through different actors and channels have been undergoing transformation through different phases of regulation and deregulation of economy. In recent years, the unfolding of globalization has tended to change the routes, nature and magnitude of this process in significant ways. There has been an unprecedented increase in the number of agreements on international R&D collaboration world over. This phenomenon was confined to the triad countries (US, Europe, Japan) while South Korea, Taiwan, Hong Kong and Singapore followed later. Hence, it is not surprising that the academic interest so far was confined only to this region rather than to the developing countries that are emerging destinations of R&D collaboration. However, these studies have focused mainly on corporate R&D (Carlsson, 2006) and have not paid due attention to other types of collaborations like bilateral and multilateral collaboration. In a developing country like India with wide socioeconomic disparities, this process might introduce new challenges and opportunities for innovations and policy making. Some scholars have argued that globalization of R&D by foreign firms divert resources from the main development needs and create high-tech islands and widen disparities. These perceptions imply further intensification of exploitation of financial, human and natural resources without any linkages with local industries or benefits to host countries. Contrarily, there are others who perceive this process as capacity enhancing with the changing nature of R&D and collaboration pattern. According to them the activities of the transnational corporations add new innovation capacity by bringing new technology, global knowledge network and the resultant diffusion of knowledge. Thus, a transition from international collaboration of R&D to globalization of innovation is visualized. In the context of the extreme position often taken, it is being realized that there is a "missing set of negotiated rules and institutions enabling the economies involved in international production activities to capture and share the potential benefits associated to it" (Zanfei, 2005).

The 'globalization' process is a complex phenomenon and hence defined differently by different scholars. However, it mainly refers to "high (and increasing) degree of interdependency and interrelatedness among different and geographically dispersed actors" (Archibugi and Iammarino, 2002). In principle, therefore, a higher level of globalization could be expected even with the same level of internationalization. Thus, this definition seeks differentiation between the term 'global' and 'international'. Further, the term 'globalization of innovation' denotes not only the economic application of new ideas and knowledge based on R&D or technology but it can also be based on organizational, managerial or institutional arrangements. In recent times, the emerging technologies like ICTs, biotechnology, nanotechnologies, etc., are intensifying the process of globalization. Many theoretical and empirical efforts to explain this varied phenomenon are proving to be inadequate. For a systematic comprehension of this concept, some scholars have categorized this process mainly into three stages. These stages are: international exploitation, global generation and global collaboration. "These categories emerged in three successive stages, even though the second and the third coupled rather than substituted the oldest one" (Archibugi and Iammarino, 1999). The first category refers to the efforts of innovators to obtain economic advantages through the exploitation of their own technological competence in markets other than the domestic one. In this category of 'international exploitation' as against the category of 'global' (interdependent and integrated), the actors introducing the innovations preserve their national identity even while the innovations are diffused and sold in multiple countries. However, further explorations are required to analyze these changes and the complexities of the interrelationship between the three categories in its historical context. It is also essential to note here that this phenomenon is not only being shaped by the structure of the international S&T innovation system which is hierarchical in nature and tilted in favour of the countries where S&T resources are concentrated but it is also shaping the same. To provide a focus on the contentious issues of globalization of innovation process, an attempt has been made here to analyze whether the 'globalization process' is likely to change the collaboration pattern or introduce any discontinuity in the international cooperation policy. The impact of these changes on India's innovation capabilities is analyzed after having identified these new changes, the role of new actors and the learning process.

The paper is structured around six sections that include the changing structure of international system of innovation to explain the process beyond NIS, an overview of India's NIS, and the fourth section has analyzed the shifting focus of India's international cooperation policy in the wake of the globalization process. This section is not restricted to R&D collaboration in the corporate sector but includes bilateral cooperation between different countries and also inward and outward FDI that adds to learning. The fifth section focuses on the recent phenomenon of FDI flows in R&D with an analysis of the areas and nature of these investments.

2. Changing Structure of International System of Innovation (ISI)

The innovation system in any country consists of Institutions (laws, regulations, rules, habits, etc.), the political process, the public research infrastructure (universities, research institutes, support from public sources, etc.), financial institutions, skills (labour force), etc. that affect how it generates, disseminates, acquires and applies knowledge. "To explore the technological dynamism of innovation, its various phases, and how this influences and is influenced by the wider social. Institutional, and economic frameworks has been the main focus of this type of analysis" (Fagerberg, 2005). Tapping global knowledge is another powerful way to facilitate technological change through channels such as FDI, technology transfer, trade, and technology licensing. The NIS approach that rightly recognized the interactions between socioeconomic, political and institutional factors in the NIS within the national boundaries has not only visualized its crucial role in the developing countries but also the increasing significance of international cooperation in the catching up process (Freeman, 1995). However, the relationship between NIS and ISI has been de-emphasized. There are other scholars (Fromhold-Eisebith, 2006) who perceive the effective linkages between the NIS, regional innovation system and ISI as beneficial for evolving balanced science, technology and innovation policies for the developing countries. Without assigning any causal priority to any of these levels, it is argued that these linkages would provide adequate understanding of the interactions between the international institutional factors, R&D collaboration, migration and return migration of knowledge workers and other linkages. It is observed that the technological gaps in a few instances are bridging (East Asian Tigers) and at the same time it is widening for many other developing countries. Neoclassical economists for a long time did not perceive this technology gap between industrialized and developing countries as a major problem calling for political action.

These linkages at three levels are not only important for countries like Singapore, Malaysia, Philippines, Indonesia, China where the share of TNCs in exports ranges from 50 to 70 per cent (Asian Development Bank, 2006) or even the overwhelming portion of manufactured products is accounted for by the TNCs but also for other developing countries where international collaboration takes place in various forms. Moreover, International S&T collaboration hold significance for not only areas like space, ocean and atomic energy with international scope but it is observed that there is more international collaboration in agriculture and health that are more regional in character (Desai, 1997). With the increasing complexities of emerging technologies like information and communication technologies, biotechnologies and nanotechnologies and the multiplying convergence between them, a greater need is felt for S&T collaboration. In the recent past, many international institutional frameworks[1] have evolved that either regulate some interactions in the NIS or support national markets, facilitate technology transfer and capacity-building, and reduce financial barriers.

In recent times, the structure of ISI that holds significance in this process is also changing as revealed by the following basic indicators. As far as world share of gross domestic expenditure on R&D (GERD) is concerned, North America still remains the dominant region with 37% share. Asia has now emerged as the second largest investor, with a share of 32%, overtaking Europe, which contributed 27% of world GERD in 2002 (El Tayeb, 2005). Asia also had the highest number of researchers in the world accounting for 37% compared to Europe (33%) and North America (25%). Similarly, the global share of North America in the patents issued by the USPTO and EPO remained at the top with 56% and 36% respectively. The share of Asian countries was higher (27%, 30%) as compared to Europe (19%, 29%). During the year 2006, the share of patents originating from the Asian countries in the patents issued to residents of foreign countries by the USPTO was also as high as 47%. However, a few Asian countries like Japan, China, Newly Industrialized Countries and India contributed the overwhelming portion. Thus, the Asian regional S&T order still remains hierarchical as there is unequal distribution of S&T resources, intellectual property rights and the digital divide is threatening to widen. This also explains the divergence in their innovation system and its role in economic development. With the increasing trend of globalization and Asia's integration with the global economy, there are signs of rapid intra-Asian economic integration. Apart from North-South and South-South FDI flows, it is estimated that intra-Asian FDI flows accounted for about 40 per cent of Asia's total FDI flows. Moreover, some changes are also taking place in the mode and structure of outward FDI from the developing countries that may constitute the third 'wave' in OFDI. "The value of outward FDI stock from developing countries reached US$859 billion in 2003, up from US$129 billion in 1990, and has increased 11 times since 1985" (Gammeltoft, 2008). Though these investments are mainly coming from the BRICS (Brazil, Russia, India, China, South Africa) countries, the changing sectoral composition and diversification in destinations reflect the increasing technological learning and capacities. Along with the increased levels of FDI, there has been increasing FDI in R&D activities. This is a new feature added, which is likely to hold greater influence on the National Innovation System (NIS) of the countries receiving greater share of the same. Table 1 reveals

Table 1: Strategic FDI in R&D by Destination Country (2005)

Destination Country	Research and Development	Total	Share of R&D Projects
India	146	224	65
China	109	241	45
UK	32	122	26
USA	24	146	16
France	24	62	39
Russia	20	82	24
Singapore	20	50	40
Canada	18	67	27
Germany	17	38	45
Ireland	13	44	30
Poland	10	86	12
Hungary	7	48	15
Brazil	7	35	20
Czech Republic	6	47	13
Romania	5	46	11
Other Countries	130	742	18
Total	588	2080	28

Source: *Prime Locations: Strategic Investment Location 2005*, Issue 3-Qtr 4, 2005.

that India has emerged as the top destination of R&D investment globally out of the major strategic[2] investments received during the year 2005. It is also interesting to note that even as percentage of total FDI, the share of R&D during 2002-2007 was as high as 24 per cent and during the year 2005, the share was 65 per cent as shown in the global strategic FDI in R&D. Similarly, Table 2 provides data on some of the major Asian countries that have attracted the FDI flows in R&D as the key business function. It does not seem to be merely a coincidence that this region has recently witnessed economic revival and also an increasing share in the ISI.

Table 2: FDI by Multinational Companies in Research and Development Projects

Sr. No.	Country	R&D Projects	Percentage Share in Total FDI Projects
(Asia, Developing, 2002-2007)			
1	India	745	24
2	China	485	8
3	Taiwan	61	16
4	South Korea	53	11
5	Malaysia	47	7
6	Thailand	26	4
7	Philippines	14	5
8	Vietnam	14	2
Total		1445	
(Asia, Developed, 2002-2007)			
1	Singapore	104	13
2	Japan	54	8
3	Hong Kong	16	3
Total		174	

Source: http://www.locomonitor.com

It is in the preceding context that the relationship between the different stages of international collaboration and innovations requires to be analyzed. As far as developing countries are concerned, the exploitation of nationally produced innovations from the developed countries was facilitated by several factors. Firstly, the priorities of the multilateral and the bilateral programmes overlapped, as agriculture remained the top priority for both the programmes. Moreover, the overwhelming part of the many of the multilateral organizations including United Nations Expanded Programme for Technical Assistance was allocated for surveys, education and organizational work in the pre-globalization period. Hence, no direct economic benefits accrued from this rather this assistance prepared ground for the bilateral assistance or the developing countries were left with no choice but to depend on the TNC for the other productive sectors (Desai, 1997).

In the second category of global generation of technologies the TNC activities have more or less remained confined to the developed countries. In the developing countries as some of the studies have indicated, the R&D conducted by the TNCs was also primarily of adaptive in nature to suit local conditions and not necessarily leading to any significant innovative activity. Nonetheless, the spillover effects of the home-base-exploiting strategy of the TNCs on science base and local R&D institutions of the host country may require further exploration.

In the recent period, many studies have analyzed the partnerships from various theoretical and empirical perspectives (Hagedoorn et al., 2000; Hagedoorn, 2002). The following observations in these studies prove to be inadequate to explain the phenomenon of globalization in the light of the changing situation.

1. These studies have covered a wide range of theories starting from cost transaction theory, strategic management, and industrial organization theory, competitive forces, resource based view of the firm, etc. These theories have certainly explained certain features like the concentration of the research partnership in the developed world resulting from preferences for geographical proximity, cultural and linguistic affinities. Some studies have also highlighted the role of the historical and colonial roots (Rhode and Stein, 1999).
2. An analysis of patents (Guellec and van Pottelsberghe de la Potterie, 2001) and internationally co-authored papers (Glänzel, Schubert and Czerwon 1999) reveals that the size-effect of a country was one of the factors determining the level of international collaboration. This implies that the greater the size of the scientific community in a given country, the lesser is the need for international collaboration. Another insight from the study is that internationalization of a country's technological activities decreases with the increasing level of its GDP and with its R&D intensity. Moreover, the major aim of multinational firms when establishing research facilities abroad is to adapt their products to local conditions rather than to 'tap' foreign technology. Moreover, the role of intellectual property rights in research partnership (Hertzfeld, Link and Vonortas, 2006) is also assuming greater significance.
3. In the case of France where the share of co-authored papers in all papers published is more than 30 per cent, the factors like geographical proximity, historical, colonial (Rhode and Stein, 1999), cultural and linguistic affinities (Zitt, Bassecoulard and Okubo, 2000) are explained by the fact that France

had Spain, Portugal and Italy as main partners. All the former colonies of France in Africa and the Maghreb show high probabilistic affinities to France, even though the absolute number of co-authorship is low.

Many of the foregoing features are changing or are likely to change rapidly with the accelerating globalization. This is reflected in the fact that the share of foreign R&D sites has increased from 45 to 66 per cent during 1975-2004 (Doz et al, 2006). Recently in the last five years or so, there was a wider geographic dispersion and India and China are emerging as the major destination. This phenomenon is taking place between the countries with stark differences in their political, socioeconomic, cultural and innovation systems. It is also reported that by 2007, India and China will account for 31 per cent of the global R&D staff. This will be a sudden jump from a figure of 19 per cent in 2004. The major companies involved responded by stating that 41 per cent of all new sites will be in India and China. The major reason for dispersion in India was not simply low cost skill base but also highly qualified human resource. Another interesting feature of the R&D partnership is the types of sectors in which these alliances are taking place and that most of them are in high-tech sectors. In 2000, 574 new technology or research alliances worldwide were reported in six major sectors: information technology (IT), biotechnology, advanced materials, aerospace and defence, automotive, and non-biotechnology chemicals (National Science Board, 2002). Thus, the emergence of new technologies is also influencing the unfolding of globalizing forces. The vast majority involved companies from the United States, Japan, and countries of Western Europe. Companies from the United States remains the top investors and India has emerged as the major destination with R&D in the ICT sector as the major focus of investment. The European TNCs had high levels of R&D internationalization (41 per cent on average).

Moreover, the FDI continues to surpass other private capital flows to developing countries as well as the flows of official development assistance (ODA). In 2004, it accounted for more than half of all resource flows to developing countries and was considerably larger than ODA (UNCTAD, 2005). However, FDI is concentrated in a handful of developing countries, while ODA remains the most important source of finance for most of the least developed countries (LDCs). The high rates of growth of FDI were common to both developed and developing countries although the developed countries still account for over 70 per cent of the world's FDI. Some developing countries received more FDI compared to others. In this regard, the case of China is highlighted which now accounts for around 20 per cent of the inward stock of FDI to developing countries. Out of total outward stock of FDI in 1995, the developed countries accounted for an overwhelming portion of around 92 per cent and the developing countries only for 8 per cent of the same. In particular, for the first time, TNCs are setting up R&D

facilities outside developed countries that go beyond adaptation for local markets; increasingly, in some developing and South-East European and CIS countries, TNCs' R&D is targeting global markets and is integrated into the core innovation efforts of TNCs.

In the changing environment and qualitative technological change, it is pertinent to discuss India's NIS before analyzing India's international cooperation policy.

3. India's National Innovation System

In recent times, despite glaring socioeconomic disparities, India has witnessed rapid socioeconomic and technological development. This is reflected in some of the key indicators like higher GDP growth rate that has touched around 9 per cent in 2006 (Ministry of Finance, 2008, http://indiabudget.nic.in). In terms of purchasing power parity (PPP), India's GDP is already the fifth largest in the world after the USA, China, Japan and Germany (World Bank, 2008, http://go.worldbank.org/UI22NH9ME0). There has been a significant increase in the adult literacy rate and decrease in population living below poverty levels. India like many other developing countries does not have an explicit innovation policy to strengthen the innovation system as a whole. It was despite the fact that India was the first country in the world that passed the Scientific Policy Resolution in 1958. As far as R&D is concerned, an overwhelming portion of 76 per cent was performed by the central and state governments including the public sector industrial sector. The private sector spent 20 per cent and 4 per cent was spent by the higher education sector (Department of Science and Technology, 2006). This situation is in contrast with the developed countries where a large proportion of R&D is performed by the private enterprise and the universities have strong linkages with the corporate world. Though the proportion of the private sector in the overall national R&D expenditure is relatively small, out of the total industrial R&D of 27 per cent (1998-99), the private sector invested 81 per cent and the rest was accounted for by the public sector. 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 decreased from 27 in 1998-99 to 25 per cent in 2002-03. The decrease in the share of R&D expenditure of industrial sector in the total R&D expenditure is mainly due to the decrease in the share of public sector R&D expenditure. The share of private sector has remained constant during the period 1998-99 to 2002-03. During 1998-99, Biotechnology and Drugs and Pharmaceuticals groups that constituted 13.8 per cent of total industrial sector R&D units accounted for 35.6 per cent R&D investment.

India's innovative performance (World Bank, 2008, http://www.worldbank.org./kam) improved from 3.65 to 3.93 during the period 1995-

2007. A small but positive change of +0.28 was observed despite the fact that India's R&D expenditure during 1990-2007 has hovered around only 0.8 per cent of its GDP. Table 3 reveals some of the basic indicators of development

Table 3: India's Innovation Performance

Variable	Actual	Normalized
Annual GDP Growth (%), avg 2001-2005	7	8.49
GDP per Capita (in/nal current $ PPP), 2005	3452.5	2.99
Human Development Index, 2004	0.61	2.46
Trade as % of GDP, 2005	44.7	1.08
Intellectual Property Protection (1-7), 2006	4.5	6.97
Regulatory Quality, 2005	-0.34	3.64
FDI Outflows as % of GDP, 2000-05	0.2	5.2
FDI Inflows as % of GDP, 2000-05	0.9	1.2
Royalty and License Fees Payments (US$ mil.), 2005	420.8	7.08
Royalty and License Fees Payments (US$/pop.), 2005	0.4	2.92
Royalty and License Fees Receipts (US$ mil.), 2005	25.2	6.17
Royalty and License Fees Receipts (US$/pop.), 2005	0	0
Researchers in R&D, 2004	117528	9.06
Researchers in R&D / Mil. People, 2004	119	2.19
Total Expenditure for R&D as % of GDP, 2004	0.85	6.28
Manufacturing Trade as % of GDP, 2005	17.1	1.08
High-Tech Exports as % of Manufacturing Exports, 2005	4.9	4.34
University-Company Research Collaboration (1-7), 2006	3.6	6.81
Technical Journal Articles, 2003	12774	8.99
Technical Journal Articles / Mil. People, 2003	12	4.32
Availability of Venture Capital (1-7), 2006	4.6	8.32
Patents Granted by USPTO, avg 2001-05	316.4	8.36
Patents Granted by USPTO / Mil. People, avg 2001-05	0.3	5.07
Private Sector Spending on R&D (1-7), 2006	4.2	7.9
Firm-Level Technology Absorption (1-7), 2006	5.8	8.66
Adult Literacy Rate (% age 15 and above), 2004	61	1.29
Gross Tertiary Enrolment Rate, 2005	11.8	2.88
Science & engineering enrolment ratio (% of tertiary level students) (2002)	25.00	43.00
Life Expectancy at Birth, 2005	63.5	2.43
Public Spending on Education as % of GDP, 2005	3.7	2.9
Brain Drain (1-7), 2006	3.7	6.1
Total Telephones per 1,000 People, 2005	127.7	1.79
Mobile Phones per 1,000 People, 2005	82.2	1.71
Computers per 1,000 People, 2005	15.5	2.12
Internet Users per 1,000 People, 2005	54.8	3.21
ICT Expenditure as % of GDP, 2005	5.8	4.27

Source: World Bank, "Knowledge Assessment Methodology," http://www.worldbank.org./kam normalized on a scale of 0 to 10 against all countries in the comparison group.

as well as the index of innovation performance. India receives very little in worldwide royalty and license fee. As far as scientific and technical articles in mainstream journals (per million people), the contributions are very low compared with those of developed countries. FDI, although increasing, is also rather low by global standards. The majority of the R&D-related inward FDI in India materialized only after the economy had been liberalized. This FDI, however small, has been creating a new competitive advantage for the country, especially in the IT domain and in industries, such as automotive. Availability of venture capital is also rather limited in India, but some signs of vibrancy are evident, and a notable venture capital investment market is emerging. In addition, India's share of global patenting is small; therefore, despite having a strong R&D infrastructure, India is weak on turning its research into profitable applications. But, an increasing trend is discernible in the number of patents granted to companies by the Indian Patent Office, indicating greater awareness of the importance of knowledge (Ministry of Commerce and Industry, 2008). India has done a remarkable job of diffusing knowledge and technology, especially in agriculture. As a result of the 'green revolution', India has transformed itself from a net importer to a net exporter of food grains. India's 'white revolution' in the production of milk has helped it to achieve the twin goals of raising incomes of rural poor families and raising the nutrition status of the population. It also has vast and diversified publicly funded R&D institutions, as well as world-class institutions of higher learning, all of which provide critical human capital. It is endowed with a critical mass of scientists, engineers, and technicians in R&D and is home to dynamic hubs of innovation, such as Bangalore, Chennai, Delhi, Hyderabad, Mumbai & Pune. There has been significant structural change in S&T human resource in the recent period. In the year 2001 at tertiary level, enrolment in science and engineering was 79 and 21 per cent respectively. This has changed to 71 and 29 per cent by 2004 (UNESCO Institute for Statistics, 2008, http://stats.uis.unesco.org/unesco). From an innovation point of view, the increase in engineering branches is considered to be a positive development. This is despite the fact that India's labour force is concentrated in the informal sector as the formal sector is relatively small.

Among Indian patents, the drugs and electronics industries have shown a sharp increase in patenting in recent years (Ministry of Commerce and Industry, 2008). In addition, several Indian firms have registered their inventions with the United States Patent and Trademark Office (USPTO). The average number of patents filed annually during the period 1987-96 was just around 25 and during 1998-2007 this number has increased to around 300 (USPTO, 2008). Thus, the total number of patents filed with USPTO has witnessed a significant increase. This shows that the focus of research is shifting to patentable inventions and awareness for patenting internationally has heightened. The recent amendments to the Indian Patent Act adopted in a move toward adhering to the intellectual property norms under Trade-Related Aspects of Intellectual Property Rights (TRIPS) has possibly encouraged greater interactions with the international players.

4. Shifting Focus in India's International Collaboration Policy

International collaboration discussed here includes not only the bilateral cooperation but also technical collaboration that has taken place between India and different countries through either inward or outward FDI and also the recent flows in R&D. Many studies have focused a positive relationship between export-orientation and R&D intensity but it was observed by many that even the outward FDI and licensing activity had a role in learning and positive influence on R&D intensity.

4.1 India' Bilateral S&T Cooperation

As far as bilateral S&T cooperation is concerned India has entered into bilateral agreements with 73 countries ranging from low to high tech (see Table 4). These countries have heterogeneous background in terms of income levels, S&T infrastructure and resource endowment and market conditions. During the period 1947-1997, the pattern of India's bilateral cooperation (government-to-government) in S&T revealed that India had pursued a diversified cooperation in terms of geographical dispersion and areas of S&T. However, areas like agriculture and atomic energy had attracted greater cooperation. These were highly endowed areas in terms of human and financial resources. Due to this, it is argued that a country with stronger innovation system is expected to benefit more from such type of cooperation. It also suggests that cooperation was not inversely proportional to the size of country or R&D. Moreover, during this period cooperation was confined to capacity building or scientific research was not directly leading to innovations as commercialization of results was not pursued. This has also highlighted the fact that a fine balance between different objectives like scientific, socio-economic and diplomatic objectives was hard to attain. In many countries, the diplomatic objectives have overbearing influence or socio-economic and scientific objectives are subordinated to political, diplomatic objectives. In the case of USA it is observed that the security concerns or political objectives have at times sidetracked S&T objectives or many European countries had integration of Europe as a major objective. As against this, many East-Asian countries have energy security as a major objective or other developing Asian countries economic objectives can dominate.

Even the other type of cooperation like multilateral cooperation or bilateral Official Development Assistance had similar nature of cooperation

Table 4: Bilateral Cooperation in Indian Science and Technology

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
1. ***Agriculture***	
Agriculture and Food	Australia (1975), Mexico (1981)
Rapseed Mustard Improvement	Sweden (1987)
Food Technology	Mexico (1984)
Agriculture	USA (1955), Netherlands (1981), Bulgaria (1972), Hungary (1975), USSR (1984), Yugoslavia (1988), Afghanistan (1969), South Korea (1976), Saudi Arabia (…), Mongolia (1993), Mozambique (1982), ARE (1983), Argentina (1985)
Agriculture & Biotechnology	China (1989)
Agricultural Science	France (1978), Italy (1979), Australia (1983), USSR (1971), Iraq (1975), South Korea (1981), Mongolia (1982), Bangladesh (1983), Mauritius (1991), Cuba (1976), Mexico (1984)
Dryland Agriculture	Canada (1955), Canada (1982), Saudi Arabia (…), Mexico (1976)
Krill & Fish Processing Technology	Poland (1989, 1993)
Photosynthesis	USA (1976)
Post Harvest Technology	USA (1976)
Fungal Pathogen Alternaria	UK (1992)
Horticulture Tissue Culture for Propagation of Forest Trees	Bulgaria (1974) Mauritius (1991), Vietnam (1976)
Veterinary and Animal Sciences	Australia (1983), USSR (1971), G.D.R. (1973), Iraq (1975), Nepal (…), Cuba (…)
Soil Conservation	USA (1976), Italy (1979)
Water Resource Management	DPR Korea (…), South Korea (1981), UAR (1969), Argentina (1985)
Drinking Water Purification	Ukraine (1993)
Education	Yugoslavia (1988), South Korea (1981), Mongolia (1982), Bangladesh (1983)

Table 4: (continued)

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
2. ***Biological Sciences***	USSR (1970)
Microbiology	Yugoslavia (1988)
Molecular Biology	Poland (1975), Cuba (…)
Biotechnology	Hungary (1988), Poland (1889), Mexico (1984), Argentina (1985), Bangladesh (1982), Malaysia (1998), Mongolia (1993), Vietnam (1996), Sri Lanka (1997), Nepal (2002), Israel (2005)
3. ***Fruit Conservation***	Vietnam (1976)
4. ***Fermentation Technology***	Vietnam (1976)
5. ***Leather Research***	Mongolia (1989, 1993), Poland (1993), Mauritius (1991)
6. ***Rural and Intermediate Technology***	Nepal (2002)
7. ***Atomic Energy***	Belgium (…), Canada (…), France (…), FRG (1971), Italy (…), UK (1955), USA (…), Czechoslovakia (1966), GDR (…), Hungary (1973), Rumania (…), USSR (…), Yugoslavia (1979), Afghanistan (…), Bangladesh (…), Iran (…), UAR (1962), Syria (1980), Indonesia (1981), Vietnam (1988), ARE (1971), Algeria (1980), Argentina (…)
8. ***Physics***	
Nuclear Physics, Astrophysics	USSR (1970)
Standardization, Quality Control, Testing	USSR (1981), Hungary (1992), Mongolia (1993)
9. ***Technology of Energy***	Australia (1975), USA (…)
Power Transistor & Thyristor	Vietnam (1976)
Coal Mining & Thermal Power Generation	Poland (1989)
MHD Power Generation	USSR (1980)
Solar Energy	France (1978), Mexico (1975)
New & Renewable Energy Sources	Sweden (1988), Yugoslavia (1988), Mauritius (1991)

Table 4: (continued)

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
Alternative Automobile Fuel	Ukraine (1993)
Alternative Sources of Energy	Mexico (1984)
10. ***Nanotechnology***	Israel (2005)
11. ***Space***	FRG (1971), France (1977), USA (1978), UK (1981), Sweden (1986), ESA (1988), USSR (1976), Australia (1986), China (1991), Sri Lanka (1997), Malaysia (1998), Nepal (2002), Israel (2005)
12. ***Radio Astronomy***	Australia (1975), China (1989)
13. ***Semiconductors***	Australia (1979)
Electronic Material	Hungary (1988), Korea (1993)
14. ***Tele-Communication***	France (1978), Saudi Arabia (…)
Laser Optics	Hungary (1988)
Ultrawave Frequency Antenna Design	Vietnam (1976)
Manufacture of Microprocessor Based Control System used in Railways	
Optical Fibre Communication	
15. ***Transport Engineering & Road Research***	Hungary (1992)
16. ***Electronics***	
Computers	Czechoslovakia (1973), GDR (1973), Hungary (1992), Poland (1992), Ukraine (1993), Saudi Arabia (…), Vietnam (1996)
Electronics	USA (…), China (1989), Mexico (1984)
Scientific Instruments & Measurement Device	Saudi Arabia (…)
Remote Sensing	China (1989)
Laser S&T Optics	USA (…), USSR (…), Poland (1993), China (1989)

Table 4: (continued)

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
17. ***Solid State Chemistry***	Australia (1979)
Materials Science	USA (…), Poland (1989, 1993), Hungary (1992), Vietnam (1996)
New Materials	Ukraine (1993), Mongolia (1993)
Advance Material	Malaysia (1998)
Low & High Temperature Superconductivity	Ukraine (1993)
18. ***Chemistry***	EC (1993), USSR (1970), Hungary (1992)
Chemical Industrial Processing, Mineral Colours, Glue & Adhesives	Yugoslavia (1988), Mongolia (1989)
Polymers, Plastics & Textile Garments	Korea (1993)
Chemical Technology	Korea (1993)
Ceramics, Industrial Aluminum	Hungary (1988)
Catalysis	Hungary (1988), USSR (…)
19. ***Metallurgy R&D in Sponge Iron***	Austria (1970), Ukraine (1993), ARE (1973)
Electrometallurgy	USSR (…)
Anti-corrosion Protection of Metals	USSR (…)
Equipment for Powder Metallurgy	Maldova (1993)
Powder Metallurgy	Belarus (1993), USSR (…)
20. ***Mathematical Statistics and Mathematics***	USSR (1970), GDR (1975), Yugoslavia (1988)
21. ***Earth Sciences***	USA (…), Australia (1975), USSR (1970)
Seismology	Italy (1979), Yugoslavia (1988)
Hydrology	Italy (1979)
Ground Water Development	USA (1955), Sweden (1979)
Geology	Yugoslavia (1988), Mauritius (1991)
Geophysics	GDR (1975)

Table 4: (continued)

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
Building Materials	USSR (1981), Poland (1989)
Building Technology	Ukraine (1993), Mauritius (1991)
Mining Technology	Ukraine (1993)
Ore Beneficiation & Mineral Processing	Mongolia (1993)
22. ***Oceanography***	USA (…), Norway (1972), France (1978) USSR (1970), Vietnam (1996), Mexico (1975)
23. ***Environmental Sciences***	France (1978), Australia (1975), Mauritius (1991)
Ecology & Environment	USA (…), Mexico (1984)
Meteorology	USSR (1981), Australia (1989)
Numerical Models of Analysis & Prediction of Tropical Meteorology & Satellite Meteorology	Australia (1989)
Monsoon, Agro and Satellite Meteorology, Numerical Weather Prediction, Snow and Glacier Studies	Nepal (2002)
Earth & Atmospheric Sciences including Meteorology	Bangladesh (1982)
Biodiversity	Nepal (2002)
24. ***Medical Sciences***	Italy (1979), USA (…), EC (1993), China (1989), Mauritius (1991)
Filariasis Control	USA (1955)
Traditional Medicine	Mongolia (1993), Malaysia (1998), Cuba (…)
Medicinal Plants	Nepal (2002)
Malarial Control	USA (1957)
Maternal and Childcare, Tuberculosis, Endemo-epidemic diseases, Venereal diseases, Mental Health, BCG Campaign	USA (1957)

Table 4: (continued)

Area of Cooperation	Name(s) of Cooperating Countries (Year of Agreement)
Neurosciences	Hungary (1988, 1992)
Immunology	Poland (1989), Hungary (1992)
DNA Gene Mapping of Hemoglobinopathies	France (1986)
Nutritional Sciences and Toxicology	GDR (1975), Sweden (1987)
25. ***CSIR***	Czechoslovakia (1966), Poland (1966), Yugoslavia (1966), Brazil (1985)
26. ***Flexible Manufacturing***	Korea (1993)
27. ***Material Handling Equipment***	Korea (1993)
28. ***Machine Tools***	Hungary (1988)
29. ***Aeronautical Science***	Poland (1989), Ukraine (…)
30. ***S&T Policy & Manpower***	Vietnam (1976, 1996)
31. ***Information in S&T***	USA(…), Japan (1985), Mexico (1984)
32. ***Information in Biotechnology***	Mongolia (1989), Malaysia (1998)

Notes: (…) = Data not available.
Source: The information is based on actual agreement, *Foreign Affairs Records* of the corresponding years and the *Annual Reports* of the DAE, DST, ICAR and Department of Space.

and agriculture as the top priority. Hence, India had no other options but to depend on the TNCs for other productive sectors.

The cooperation efforts in terms of frequency were concentrated in the North American and European region during the first three decades in the post-independence period (1950s-70s) and the geographical diversification took place later. It was only during the late 1990s that India started focusing on commercialization of R&D results that these kinds of programmes started appearing in the S&T agreements like with some European countries and later with some Asian countries like China, Singapore, and Israel. Some programmes were also initiated recently in industrial research and its application that targeted the SMEs of the cooperating countries. There has been traditional reluctance to collaborate between industry and scientific institutions and secondly the sharing of patent benefits has also contributed to this reluctance. It is because of these reasons that it has taken so long evolve some mechanism to exploit the results commercially from occasionally resulting industrially relevant research.

A need was also felt to create a permanent organizational mechanism after growing interest in international S&T cooperation with some of the countries like USA, France, Uzbekistan and the Non-Aligned Countries. This mechanism was perhaps created to involve greater commitment and insulate international S&T cooperation from ups and downs in the diplomatic relations.

4.2 FDI and Technical Collaboration

Learning and knowledge accumulation through inward and outward FDI is feature de-emphasized by the NIS approach evolved during the definite historical context. In the changed economic environment, many scholars have analyzed the role of this process with fresh empirical insight.

In India, the policy governing outward FDI has been progressively liberalized and with recent amendment, Indian enterprises are now permitted to invest abroad up to 100 per cent of their net worth on automatic basis. This has resulted into a sharp rise in outward investments since 1991 and is marked by a shift (Kumar, 2006) in geographical and sectoral focus. Before the liberalized period more than 50 per cent of the total FDI was concentrated in the Asian developing countries and now the share of the same has been reduced to about 30 per cent. Against this, the share of the developed countries has risen to about 60 per cent. Similarly, India's outward FDI was concentrated in manufacturing sector accounting for over 65 per cent. After 1991, nearly 60 per cent of these flows have gone to services and other major sectors where OFDI is concentrated. These sectors are drugs and pharmaceuticals, IT, communication, software, media, broadcasting and publishing services. This geographical and sectoral shift illustrates greater technological competence through learning and not only a result of liberalization.

India's inward FDI flow pattern in the regulated economic regime had revealed a higher level of technical cooperation but this pattern reversed after the mid-nineties with higher proportion of financial over technical collaboration. During the post-liberalization period, the export-import ratio became unfavourable and declined from 78 to 68 per cent indicating no improvement in global competitiveness if export is treated as a proxy to technological capability. The sectoral distribution pattern (see Table 5) has

Table 5: Sectoral Distribution of the FDI Inflows in India (1991-2007)

Sr. No.	Sector	Percentage Share
1.	Electricals Equipment (Incl S/W & Elec)	19
2.	Service Sector	17
3.	Telecommunications	9
4.	Transportation Industry	8
5.	Fuels (Power & Oil Refinery)	6
6.	Chemicals (Other than Fertilizers)	5
7.	Drugs and Pharmaceuticals	3
8.	Food Processing Industries	3
9.	Cement and Gypsum Products	2
10.	Metallurgical Industries	2

Source: *SIA Newsletter*, Ministry of Commerce and Industry, Government of India, February 2007.

also undergone change and the service sector has received greater investment than the pre-liberalization period. In the pre-liberalization period, the FDI pattern revealed a higher level of technical cooperation and this pattern reversed after the mid-nineties with higher level of financial over technical collaboration.

In the second stage of global generation of technologies the transnational corporations' (TNC) R&D activities have more or less remained confined to the developed countries. In the developing countries as some of the studies have indicated, the R&D conducted by the TNCs was primarily of adaptive nature to suit local conditions and not particularly leading to any significant innovative activity. Due to institutional changes during the 1990s, both in India and other Asian countries, the Southeast Asian countries emerged as significant investors. However, the proportion of the technical collaboration was reduced from 39 (1991-95) per cent to 26 per cent (1995-2000). As far as the Asian developing countries are concerned, countries like Korea, China, Malaysia and Thailand had significant levels of technical collaboration.

5. FDI Inflows in R&D

R&D so far was treated as the least fragmentable activity of the TNCs. This was not restricted to theoretical understanding in innovation studies that assumed technological complexity a constraint to the internationalization of innovation. Technology usually involves tacit knowledge that requires physical proximity for its meaningful transmission. Many scholars (Patel and Pavitt, 1991) have attempted to substantiate these theories in empirical light by using patent data and have demonstrated that innovative activities of the world's largest TNCs were among the least internationalized of their functions. They argued that firms tended to concentrate innovation in their home countries, in order to facilitate the exchange of complex knowledge. In recent times, this situation has been changing worldwide as a greater dispersion of TNCs' R&D has become evident. This is a result not only of the increasing liberalization in various developing countries and changing nature of technology but also because of shortage of highly skilled S&T human resources. This was revealed in many studies and surveys conducted on the subject. One of the examples is the chip design that has witnessed a rapid expansion in leading Asian electronics exporting countries, a process that creates the high value in the IT industry and that requires complex knowledge. Similarly, biotechnologies that require local resources and local trials require conducting R&D in the target region.

India has not remained untouched with this phenomenon and a discernible change has been observed in India during the period 1998-2007. A new dimension has been added by the offshoring of R&D services. During the five-year period 1998-2003, a major FDI inflow in R&D worth of US$1.13 billion has already been approved and a much higher level has been planned. These companies have filed at least 415 patents from India in the US. Nearly half the FDI companies have relocated their in-house R&D in home country to offshore location in India. Though TNCs from US, Germany, UK and France figure prominently, a number of firms from China, Republic of Korea, and Taiwan have also appeared with noticeable R&D activities in India (Table 6).

More than 50 per cent of the companies that have invested in R&D sector in India are from the US and account for about 72 per cent of the total FDI. These companies have also filed an overwhelming portion of the patents filed in US. Korea has emerged as one of the major investor second only to USA. The Korean companies that have invested R&D have established themselves in IT and automobile production network. Similarly, Chinese firms in telecom & IT and Taiwanese in agro-biotechnology. Some of these companies have domestic partners from developed country TNCs like Korean companies Hyundai has Daimler Chrysler and Tyco Electronics has Siemens as domestic partners in India. Thus, these efforts are also creating a global R&D network. These companies in addition to supporting own manufacturing activities were also found to be engaged in exports including R&D exports benefiting the host economy. However, compared to other TNCs from the developed countries, these Asian TNCs have limited capacity building programmes. These programmes could be categorized as training programme for R&D employee, contract research, collaborative research with universities/firms, supporting own manufacturing activity (Agarwal and Sarkar, 2006). None

Table 6: FDI in the Indian R&D Sector and Capacity Building Programmes

Country of origin	No. of Companies	Planned Investment	R&D Investment	R&D Workers	Exports + Domestic	Manufacturing Domestic + R&D Exports	In-house Out Sourcing	Contract Research
					No. of Companies (%)	No. of Companies (%)	No. of Companies (%)	No. of Companies (%)
North America								
USA	53	12673.74	3650.14	15901	13	25	32	8
Canada	3	32.76	51	594			1	1
	56	**12706.5**	**3701.14**	**16495**	**13 (23)**	**25 (45)**	**33 (59)**	**9 (16)**
Europe								
Germany	7	3835.56	345.69	2050	1	2	4	2
UK	7	112.49	108.9	954		3	3	1
France	5	992.69	93.82	970		1	2	3
Netherlands	3	730	82.5	530	1	1	3	
Switzerland	2	29.18	34	170	1		1	1
Sweden	2	95.8	5.2	80	1	1		
Denmark	1	0.15	0.15	5				
Norway	1	1.23			1			1
	28	**5797.1**	**670.26**	**4759**	**5 (18)**	**8 (29)**	**13 (46)**	**8 (29)**
Asia								
Japan	**7**	**765.53**	**42.22**	**200**	**3 (43)**	**2 (29)**	**2 (29)**	**0 (0)**
Korea	3	501.1	350	650	2	2		
China	2	135.8	270.8	510				
	5	**636.9**	**620.8**	**1160**	**2 (40)**	**2 (40)**	**0 (0)**	**0 (0)**
Africa								
Mauritius	2	235.5	51.5	265	1	1		
South Africa	1	775	3	50	1		1	1
	3	**1010.5**	**54.5**	**315**	**2 (66)**	**1 (33)**	**1 (33)**	**1 (33)**
Australia	**1**	**0.26**	**10**	**50**	**0 (0)**	**0 (0)**	**1 (100)**	**0 (0)**

Source: Academy of Business Studies, 2006. *FDI in the R&D Sector: Study for the Pattern in 1998-2003*, Technology Information, Forecasting, and Assessment Council (TIFACS), New Delhi.

of these companies have so far entered into any research contract with any local research organization neither that they have felt the need of any training programme for the R&D employee nor that they had any collaboration with any universities. These requirements seem to be varying with the specific sectoral characteristics. In sectors like Agriculture, Automobile and Chemical, firms in India have not found any need to engage in contract research with Indian clients. Training programmes were more common in Chemical sector than IT or Automobile sector and the need for training is also gradually reducing in the IT sector. It is also important note here that some of the interviews conducted by the author revealed that in the ICT sector some of the Asian companies had problems in recruiting or retaining middle level technical personnel. This problem could be categorized as the problem of high mobility of the sector or as some of the personnel reported that the management style of these companies did not provide adequate autonomy in decision-making as compared to other western companies.

6. Concluding Observations

The process of globalization has promoted greater complexities into the national innovation system and international cooperation. An element of fierce competition, nature of emerging technologies associated with greater risk and uncertainty, shortage of highly skilled S&T human resource and bio-resources are overshadowing other determinants like cost, geographic proximity and cultural affinities, market conditions. It seems that strengthening of the NIS and building up high-tech sector infrastructure will further the process of globalization rather than developing capacity to prevent it. Hence, it would be difficult to ignore the linkages between NIS and ISI. In the first two categories of exploitation and generation of technology, the process was partly facilitated by the nature of bilateral or multilateral cooperation. During these phases, the R&D component of TNCs tended to remain unfragmented or restricted to its adaptive nature and geographic spread. In particular, the globalization process has influenced the collaboration pattern by encouraging relatively wider geographical spread and the alliances in high-tech sectors have accelerated this process. In this context, the following observations are made regarding the changing nature of India's collaboration policy:

1. The nature of bilateral cooperation has undergone a transformation and has been extended to R&D based innovative activities and industrial application instead of remaining confined to scientific research. It seems that this type of collaboration is more diversified in terms of S&T areas and types of organizations. It seems that this type of cooperation will continue to play a significant role.

2. A need for collaboration is felt irrespective of size of the investing country or R&D. However, the R&D flows are directed towards countries with developed R&D infrastructure and availability of human resource irrespective of geographical proximity.
3. As far as FDI flow in R&D are concerned, these activities are not restricted to supporting domestic manufacturing but are extended to capacity building programmes like exports including R&D exports, training, contract research and have generated significant R&D employment.
4. The TNCs from the European and Asian countries are also forming global R&D network by partnering in India. Thus, geographical boundaries of the NIS are getting blurred.
5. The global share of Asia's S&T infrastructure (though hierarchical in nature) has been steadily increasing along with the increased intra-Asian inward and outward FDI flows.
6. The Asian TNCs had no training programmes for their R&D employees, which reflects the suitability of S&T human resource. However, compared to the developed country TNCs, these companies had limited interactions with the local R&D organizations in terms of contract research, collaboration with universities and firms.
7. Some significant knowledge spillovers are expected from this activity. To take advantage of these benefits, India will have to gear S&T policies towards facilitating such knowledge flows.

Notes

1. Some of the important organizations and institutions are for instance World Trade Organization (WTO), Trade Related Intellectual Property Rights (TRIPS), the Agreement on Trade-Related Investment Measures (TRIMS), the General Agreement on Trade in Services (GATS), Information Technology Agreement (ITA), Technical Barriers to Trade (TBT), Regional Trade Agreement, Free Trade Agreement, Bilateral S&T Agreements and even other agreements relating to environment, safety and standards.
2. Strategic FDI is defined here as investments that generate the greatest benefits in terms of innovation, capital investment, job creation and added value activities.

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