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Internationalisation of R&D and Global Nature of Innovation: Emerging Trends in India

V.V. Krishna
Asia Research Institute, National University of Singapore &
Centre for Studies in Science Policy,
Jawaharlal Nehru University, India

arivvk@nus.edu.sg; vkrishna16@hotmail.com

and

Sujit Bhattacharya
Centre for Studies in Science Policy,
Jawaharlal Nehru University, India

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Asia Research Institute
National University of Singapore
469A Tower Block #10-01,
Bukit Timah Road,
Singapore 259770
Tel: (65) 6516 3810
Fax: (65) 6779 1428
Website: www.ari.nus.edu.sg
Email: arisec@nus.edu.sg

INTRODUCTION

The last decade witnessed two rapidly increasing trends in the pattern of global science and technology system, namely, internationalisation of R&D and globalisation of innovation. The former signifies Foreign Direct Investment, foreign R&D affiliates of Trans National Corporations (TNCs) and other companies and international collaborations etc. Business and knowledge process outsourcing, R&D and technical services outsourcing, and moving other institutional and organisational operations to foreign locations also fall in this category (Turpin and Krishna 2007). The latter is a recent trend signifying innovation networks of companies stretching beyond in-house or home country locations into foreign locations. Innovation networks do not require co-location of R&D with either the consumer or the manufacturing facility. Global products can be created by driving greater integration of R&D across different locations thus efficiently combining multiple talents/capabilities of different economies[1]. There are a number of innovation chain network operations conducted or contracted to foreign locations which create new business opportunities. The corporate model of R&D pursued within home country locations within physical boundaries of the corporate firm is fast eroding (*The Economist* 3 March 2007). The internet and telecommunication revolutions have dismantled geographical barriers creating a new innovation potential at different levels of the value chain. This was mainly restricted to industrially advanced countries until about early 1980s, but during the last decade and a half this trend has spread into the developing countries (See Reddy 2005; Pearce 2005).

The Asia and Pacific region has come to occupy a significant space in these trends. Whereas Japan, Australia, South Korea and Taiwan have already made mark from the region; India and China have emerged as important players and destinations for internationalisation of R&D and globalisation of innovation during the last decade. As the World Investment Report (2005: 139) notes, 'the rise of developing Asia and Oceania has been the most dramatic development in the global landscape of R&D. Some economies in the region have been able to capture a broad range of R&D functions from Trans National Corporations (TNCs), including innovative R&D and basic research'. Further, as the data by WIR (2005) reveals, of the 885 R&D-oriented Greenfield Foreign Direct Investment (FDI) projects announced in 2002-04, 75% (723 projects) were cornered by India and China. These countries are host to some 800 leading global TNCs which are operating R&D centres or R&D-based firms mainly in ICT, biotechnology, pharmaceuticals, telecommunications and automobiles. During the last decade Bangalore, India's Silicon Valley, Hyderabad's high technology city, Beijing's Zhongguancun Science Park at Haidan District, and Shanghai's Pudong New District are host to some 500 global companies which have opened up R&D centres. These cities have emerged as global R&D and innovation hubs or networks with horizontal and vertical integration to globally dispersed TNCs. UNCTAD's survey of the largest R&D spenders confirmed the growing importance of Asian economies as the most favoured R&D destination of foreign locations. China (3rd position), Japan (5th), India (6th) and Singapore (9th) figured in the top 10 countries in this survey (see WIR 2005:133). In the latest survey by UNCTAD (World Investment Prospect, 2007-09), India emerges as the second most preferred destination after China for the location of FDI. In R&D activities, 47% (of the 191

[1] Radjou (Forrester Research, 2006) envisages Innovation Networks as the next big wave of outsourcing. In this new scenario, he posits that US firms will "source not simply low-cost talent, but 'invention services' (R&D services) in India and 'transformation services' (manufacturing services) in China to build products for a global economy.

companies that were part of this survey) were eager to internationalise, as compared with only 42% in 2006.

The objective of the paper is to explore three main issues in the Indian context. Firstly, to briefly review and trace developments in the Research and Development (R&D) related FDI in the developing countries. Secondly, to explore the structure of internationalisation of R&D in India. Here we will trace the growth of foreign R&D centres, spatial distribution, sectors and fields of operation and their activity structure, among other factors. Given the broad map of internationalisation of R&D, in the third section the paper will attempt to bring out the main implications of these trends from the perspective of globalisation of innovation in the last few years. What is the impact of R&D-related FDI? What is the direct and indirect impact? What is happening to Indian firms and how are they partnering with foreign R&D centres and firms? To what extent are Indian firms globalising? In doing so the paper will explore the context of innovation to see whether these trends signify a 'new international division of labour' between North and South or whether there is evidence to suggest a transformation towards a globalisation of innovation.

R&D RELATED FDI IN DEVELOPING COUNTRIES (DCS) – A FRAMEWORK

Internationalisation of R&D as understood in terms of firms operating with their affiliates and collaborations in foreign locations is indeed a very old trend which can be traced back to the colonial period in the DCs such as India. Influential writings from Reddy (1997, 2000 and 2005) and others draw our attention to the internationalisation of R&D in two phases during the 1960s and 1970s. Further, these studies draw attention to the third and fourth waves in the 1980s and 1990s, respectively, which are termed as globalisation of R&D[2]. While the firms performing R&D abroad in the 1960s are said to be relatively small and much of the R&D undertaken abroad is characterised as technology transfer units linked to local adaptation, the decade of the 1970s witnessed the trend of going beyond technology transfer of earlier phases to performing R&D abroad by firms in a somewhat significant way. Even indigenous firms and institutions in DCs enhanced their local and national technological capabilities to absorb foreign technology and reverse engineer into useful products and processes. In India, policies of self-reliance and import-substitution led to strengthening of local and national S&T capacities beginning with the Indian Patent Act of 1970, India's first S&T Plan of 1974 and the Technology Policy Statement (1983) in the early 1980s.

The third phase is seen to witness the extension from internationalisation of R&D to the Globalisation of R&D[3], wherein, 'higher-order R&D, such as regional technology units, global technology units and corporate technology units, had been located abroad in what can be regarded as the third wave of globalisation of R&D' (Reddy 2005: 95). Furthermore, the main forces that are driving this phenomenon are identified as:

- Global basis of competition coupled with convergence of consumer tastes and preferences worldwide are creating a need for learning;

[2] Reddy (2005) cautions us not to view the periods or phases as water-tight compartment but to see them as just indications. Hence when we transpose these phases to the Indian context we will see that the assumed phases stretch much beyond the decade identified. Much of the framework for four phases is drawn from Reddy (ibid).

[3] Kindly note 'Globalisation of R&D', not Globalisation of innovation.

- Increasing science-base of new technologies which demand multi-sourcing;
- Rationalisation of TNC operations which assigned a specific role to their affiliates.

The rise of information and communication technologies and the new structure of science based technologies were seen to foster the de-linking of R&D and manufacturing activities in the decade beginning in the 1980s. The decade since the 1990s is seen to have paved the way for the fourth wave. In India this phase witnessed the introduction of new economic reforms, which promoted liberalisation and FDI for both financial and R&D related components.Number of other international developments characterise the fourth wave such as a) Increasing demand for skills in industrially advanced countries; b) widening of research network of firms to tap into geographically dispersed sites; c) rising wages in the North and availability of highly skilled human resources in India and China and other DCs; and d) considerable enhancement of science and technology capacities for innovation in the Indian context.[4]

In this phase, the sector of Business Process Outsourcing (BPO) and Knowledge Processing Outsourcing (KPO) activities found firm roots in India. Coupled with the ICT revolution, these activities accelerated the earlier trend of de-linking manufacturing and R&D to pave the way for R&D networking on the one hand, and opened up a vast 'window of opportunity' for Indian software firms to partner with global firms, on the other hand.

Whilst the frameworks put forward by Reddy and others are quite useful to explore the growth and structure of R&D-related FDI in terms of the four phases and waves reviewed above, they do not however explicitly bring in the changing context of innovation and link up with the trends in internationalisation of R&D. In other words, strictly speaking, 'globalisation of R&D' is not the same as 'globalisation of innovation' even though it is closely associated with it. As the context of global innovation is changing rapidly, it is more meaningful to talk about dispersed or networked innovation in which firms and R&D institutions in DCs are assuming the role of partnerships in both knowledge production and its use. It is the objective of this paper to go beyond the rich perspectives and literature on internationalisation of R&D and globalisation of R&D to explore emerging trends in the globalisation of innovation from an Indian perspective. What Pearce (2005: 29-30) says in this regard seems quite relevant:

> …single most important element in the changing ….TNCs… has been the perception of a breakdown in such an immutable home-country orientation of creative activity and moves towards globalised programmes of innovation and R&D. … to see TNCs organisational structures as predominantly hierarchical has been replaced by attempts to analyse them in terms of heterarchy or as differentiated networks.

Even though R&D is an important component of innovation it is appropriate to distinguish between the two. The notion of innovation draws attention to technological, changes both radical and incremental, inventions and other R&D related activities undertaken at the laboratory level which find relevance in the industry or market of commercial or non-commercial types. In this sense, the globalisation of innovation relates to various components of knowledge production and consumption chains which are not hierarchical but are

[4] Reddy's (2005) period of different waves or phases since the 1960s can be extended a decade further in the Indian context.

horizontally connected networks and geographically dispersed across various actors, agencies and regulated by institutions at different levels and locations. As Ernst (2005: 73) observes, even big firms like IBM are in no position to 'mobilize all the diverse resources, capabilities and bodies of knowledge internally'. Firms need to tap knowledge inputs from trans-border locations. Furthermore, scholars such as Chesbrough (2003) already drew our attention to what is termed as the 'model' of 'open' innovation system.

Contemporary development of horizontally networked, geographically dispersed and partnered innovation process which is shifting away from industrially advanced countries (US and Western Europe) into India, China and other DCs is closely associated with the rise of science, technology and innovation capacities of these latter countries. The nature of R&D and knowledge related links, partnerships, working relationships between Indian firms, knowledge institutions (both private and public research systems) with Indian based foreign TNCs, their subsidiary R&D units and laboratories assumes considerable significance to explore the development of globalisation of innovation from Indian experience. Further, Reddy (2005) and others draw our attention to the fact that there is a whole range of impact-related factors of TNC operations in developing countries which point towards spin-offs, spill overs among others which seem very relevant.[5]

The other important development in India during the last decade since the late 1990s has been the rise of what may be termed as Indian TNCs or enterprises and firms (both public and private) which operate and carry out business in more than two to three countries and are involved in the knowledge production and linked to knowledge consumption for a range of sectors from engineering, medical, ICT related to legal and social services and manufacturing on a global scale. For example Tata Consultancy Services, Infosys, Wipro, Ranbaxy, Reddy Laboratories each of them operate in over a dozen foreign locations or countries. Further, leading Indian software firms provide high technology knowledge based services to at least 400 of the FORTUNE 500 firms. As Bowonder (2001) implies in the case of WIPRO, Indian software forms since the 1990s begun to acquire global status in three ways, namely, a) global contract research in information services; b) moving up the research value chain; and c) expanding with research centres in India and foreign locations (mainly USA in the case of WIPRO). Kash et al. (2004) study of two Indian companies (TCS and Infosys) shows that a growing portion of the services they are providing is at the upper end of the value chain, and these services are taking on the characteristics of complexity. The same can be said about the leading Indian software firms by adding a fourth factor of research partnerships with global TNCs. This indeed is emerging as the other main feature of globalisation of innovation from an Indian perspective. Taxonomy of internationalisation of R&D to globalisation of innovation as given in the literature may be summarised as in Table-1:

[5] Refer to Reddy (2005) who has given a number of good examples of spin-offs and spill overs in the Indian context. Here in this paper we wish to go beyond the globalisation of R&D to explore the emerging trends in globalisation of innovation.

Table 1: A Taxonomy of Internationalisation of R&D to Globalisation of Innovation

Reddy (1997 and 2005)	**Archbugi and Michie (1995)**	**Proposed framework for the Indian situation**
First wave 1960s – Internationalisation of R&D: Focus on Technology Transfer	*International exploitation of nationally produced innovations*: focus on exports and foreign production of goods	1960s and 1970s: phase of international technology transfer
Second wave 1970s – Internationalisation of corporate R&D in host countries	*Global generation of Innovations*: R&D and innovation in home and host countries	1980s: Emergence of Internationalisation of R&D
Third wave 1980s: Globalisation of R&D – global role to TNC affiliates in host countries	*Global Techno-Scientific Collaborations*: focus on joint research projects and science exchanges	1990s: Globalisation of R&D with TNCs and local institutions participating in R&D
Fourth wave 1990s: Globalisation of R&D – shortages of skills and widening research networks to tap geographically dispersed talent	Continuation: focus on joint ventures for specific innovative projects	2000 and beyond: Globally Dispersed Networked Innovation and Internationalisation of Indian firms (mergers and acquisitions abroad)

MAPPING INTERNATIONALISATION OF R&D IN INDIA SINCE 1990S

The period since the late 1990s witnessed proliferation of foreign TNCs in parallel to the rise of Indian TNCs. FDI surveys by agencies such as McKinsey and Indian Federation of Chambers and Commerce were undertaken which throw ample light on the extent of R&D related FDI in India since the 1990s. Whilst the information in these surveys tilt more towards financial and other aspects than on R&D related FDI, the Indian government funded Technology, Information, Forecasting and Assessment Council (TIFAC) of the Department of Science and Technology (DST) carried out a survey on *FDI in the R&D Sector – Study for the Pattern in 1998 -2003* in 2004 and published the report in 2006 (hereafter TIFAC Survey 2006). This survey gave out results of the structure of FDI related R&D in India for over 145 foreign TNCs which we will use here to map the internationalisation of R&D in India.

Growth, Location and R&D Areas of Foreign R&D Units/Laboratories

Texas Instruments was the first foreign firm to set up an R&D unit in India in 1985 but it was not until the late 1990s the trend gained momentum as shown in Table-2. As this table shows, about 35 to 40 R&D centres were set up each year from the turn of the Century. The type of firms that were being established from 1999 onwards also significantly changed in structure and composition with ICT being the dominant sector in which foreign R&D centres were getting established. In terms of location, more than 90% of the Centres are established in mainly five major city regions in India, namely Bangalore, Hyderabad, Chennai, National

Capital Region (Delhi), Pune-Mumbai as shown in Table – 3. As expected, Bangalore is the most preferred destination of foreign R&D centres which accounts for 45% of the firms, followed by NCR (Delhi) with 22% of the centres. Further, major R&D segments for R&D related FDI from the TIFAC Survey of 145 centres is shown in Table –4.[6] The data from 145 TNC R&D centres show that an R&D investment of 1.35 billion US$ (approx) came into India in the period from 1998 to 2003. About 24398 R&D professionals were engaged in research in these 145 centres dominated by USA (15901) followed by Germany (2050), UK (954), France (970), Canada 594), Korea (650) etc. These figures also correspond to number of TNC R&D centres dominated by USA to the extent of 53% (See TIFAC Survey 2006). The last few years witnessed unprecedented inflow surge of FDI related R&D. According to a source, total of 8.6 billion US$ investment is pledged by TNCs such as Microsoft (1.7), Intel (1.0), Cisco Systems (1.1) and IBM (6.0).[7]

Analysis of various newspaper reports show that many of the established R&D centres are significantly scaling up their investments. For example, Maruti Suzuki India Ltd has announced an investment of $1.8 billion in its research and development facility. Among the firms that are opening up their R&D centres, for many it is their first R&D centre outside their home country. Among them are Rs 1 trillion US-based science and technology company E.I. du Pont (this centre will be involved in high end R&D in different sectors), Axiom Design (embedded design applications), Vanu Inc (complex switching systems).

Table 2: Growth of Foreign R&D Centres in India

Year	No of R&D Centres
1985	3
1995	19
1999	49
2000	64
2005	145
2006-07	200*

Note: TIFAC Survey (2006) data is restricted to 2005
Source: TIFAC Survey and CSSP/JNU Data base.

[6] It can be observed that the foreign R&D centres are addressing a number of sub-domains/target areas that are critical and highly advanced. Kindly note that we have used these figures for TNC R&D centres from TIFAC 2006 report. This report provides detailed statistics for 100 centres (used to construct Table 3); additional 45 centres with some what scattered data and information (used to construct Tables 2 and 4); and 115 centres (used for Table 5).

[7] See, Raja M.Mitra (2007), *India's Emerging as a Global R&D Center*, Working Paper, Swedish Institute for Growth Policy Studies, R2007:012, Ostersund, Sweden.

Table 3: Location of Foreign R&D Centres in India

Region	No of Centres
Bangalore	45
NCR (Delhi)	22
Pune-Mumbai	17
Hyderabad	7
Chennai	4
Other regions	5

Source: TIFAC Survey (2006)

Table 4: Major R&D Segment of FDI Firms in India

Major R&D Segment (Target areas of application)	Number of Companies
Software development (software applications for different sectors, networking tools, multi-media applications, CAD/CAM tools, multimedia tools)	34
Hardware-computer/telecommunications and embedded tools (chip designing-aerospace/mobile, optical switching systems, broad band system)	19
Automotive sector (vehicle and component design, embedded control system, safety systems)	14
Pharmaceuticals (formulations, intermediaries, vaccination, drug discovery)	13
Agro-chemicals (insecticide, hybrid seeds)	11
Chemical (coating, basic inorganic chemicals, polymers and synthetic materials, tanning agents, textile chemical)	11
Consumer products	11
Engineering goods(Medical equipments, textile machinery, electrical test equipments, compressors, motors)	9
Biotechnology (Genomics, bio-informatics)	6
Food industry (fermentation, processed foods)	4

Source: Constructed from TIFAC Survey (2006)

Having mapped the foreign R&D centres during the last decade, it will be pertinent here to explore the types of activity carried out by these TNC centres in India.

Types of R&D Activity of TNC Centres in India

Influential writing from Pearce and Singh (1992) and Pearce (2005) draw our attention to three types of TNC-related R&D activities in foreign locations. The first is the support laboratories which facilitate 'effective transfer and application of group's already successful technologies embodied in the current product range' (Pearce 2005: 35). Comparative advantages of lower costs to carry out R&D, foreign country's innovation capacities, its market and adaptation of technology processes, among other factors, characterize these *support laboratories*. In one form or other these laboratories are seen to provide international competitive edge in the medium or longer time periods for the parent firms. In Table-5, TIFAC's category of 'Only Offshore R&D for In-house R&D' is equated with the Pearce category of support laboratories, (with 54 i.e. 47% of the sample of TNC centres) as most of these firms have R&D centres which fall in the second type (locally integrated laboratories) indicating technology transfer processes from parent firms in one form or other. For example, the US software giant Oracle, has three R&D centres in Bangalore and Hyderabad employing 4000 professionals who create products for Oracle's global business and customers. However, Oracle also has 6 offices spread in India which works in banking and insurance, telecommunications, manufacturing and air ports, among other sectors such as police departments in three states.

The second type are the *locally integrated laboratories* which go beyond the first type to develop links with the local firms and innovation systems. This type of laboratories are also involved in the production and consumption of R&D for local/national and global markets, links with manufacturing and marketing. This type of laboratories is also seen to have all the signs to contribute positively to the host economies. The third type of laboratories are what are termed as *internationally independent laboratories* linked to international interdependencies between independent TNC labs which are more focused on autonomous path of more basic and pure sciences.

Whilst the first two (support and locally integrated laboratories) seem more relevant to Indian situation, the other form or type of TNCs operation in India can be differentiated as *Collaborative R&D Centres* which develop partnerships and collaborative projects with public and private firms, enterprises and government based labs and universities. Such type is also distinguished by Zhou Yuan (2005) in the case of internationalization of R&D in China. In the light of the above brief discussion and TIFAC Survey of 145 TNC centres, three types of R&D activity can be identified in the Indian context.

Table 5: Types of R&D Activity of TNC Centres in India

R&D Activity Type from TIFAC Survey	Pearce (2005) R&D Type Activity	Collaborative R&D Type	Number of TNC Centres (%)
Only Offshore R&D for In-house R&D (ie parent TNC R&D)	Support Laboratories	-	53 (47%)
R&D exports + domestic marketing	Locally Integrated Laboratories		23 (20%)
R&D exports + local manufacturing	-do-	-	19 (16%)
Contract research	-	Collaborative R&D	20 (17%)
Total			**115 [8](100%)**

EMERGING STRUCTURE WITH LOCAL FIRMS AND INSTITUTIONS

The role of TNCs and their operations in host developing countries has been the subject of discourse and considerable research interest for quite some time now. At one extreme one can find the positive view of R&D related FDI being beneficial in varying forms and at the other extreme there are counter views. We will however attempt to address these issues in the concluding discussion after we explore the impact of TNC R&D centres and their links with the local firms and institutions. Reddy (2005), draws attention to *direct effects, spin-off effects and spillover effects.*[9] Whilst these three features reflect the impact on host country situation, the fourth feature which has emerged and is evolving is the *transnational innovation networks*. However, here we will explore: a) two-way knowledge transfer; b) collaborative R&D innovation; c) globally dispersed networked innovation; and d) rise of Indian firms and institutions at the global level.

Two-Way Knowledge Transfer between Home and Host Country TNCS

TNCs as one of the main sources of international technology transfer to developing countries, is a very old subject but the type and nature of the technology transferred is still an issue of discourse. Much of the earlier writings deal with firms and are not necessarily R&D related. However, here we are concerned with links between parent and off shore R&D centres of TNCs. It has been observed that there is a wide range of technology development, knowledge generation and transfer between different types of TNC centres as depicted in Table-5. For instance big TNCs such as IBM, Oracle, General Electric, Intel, Texas Instruments, Bell Labs, Philips International, among others, operate in all types of R&D shown in Table – 5 and are involved in the technology and knowledge transfer. What is rather 'new' is that the development of technology, knowledge production and its transfer is not one sided but operates in both ways in an interactive fashion that is often linked with the local host country

[8] Note: Actually 15 centres were involved in multiple types of activities and hence the figure escalates to 115 instead of 100.

[9] As noted above we will focus more on the globalisation of innovation.

knowledge institutions. Let us consider some examples of TNC R&D centres and the nature of work carried out by these labs in India.

IBM is an appropriate example. For instance, out of 8 IBM R&D centres in the world, it maintains two in India where more than 300 professionals are working along with 73,000 workers (of the 250,000 workforce globally). IBM projected to have 100,000 workers in India by 2010 – a quarter of its global workforce.[10] India Research Laboratory (IRL) of IBM was established in the Indian Institute of Technology, Delhi campus, initially in 1998 and moved to its own premises in New Delhi. In 2006 it opened its second R&D centre in Bangalore. IRL is working on a number of conventional areas of adaptive research such as information and knowledge management, interaction and collaboration technologies, systems management, software engineering, analytics and optimizations, services innovation, telecommunications research and industrial research among many others. In almost all these areas the knowledge transfer is both ways between Indian and home country R&D centres. However, what is also notable is that IRL in India is in a large measure involved in the cutting edge research of distributed and high performance computing which is linked to IBM's BlueGene/L supercomputer installed at the Lawrence Livermore National Laboratory, USA. This is the fastest supercomputer in the world in 2007. Two key research papers published by the Indian lab in 2006 won two international awards which are closely linked to BuleGene/L computing. IRL team has been working in close collaboration with IIT, Delhi and IISc, Bangalore on the cutting edge computing research and other management institutions such as ISB, Hyderabad, in evolving first of its kind management course on ‘service science management engineering’.[11] Another instance of how cutting edge human – computer interaction research linked to local adaptation is the work going on in new generation speech, grammar, pronunciation, recognition computers in local languages and translation devices for user friendly mediums.[12]

IBM India has been cited as the only centre in the world working on ‘solution accelerators’ and has developed over 120 solution accelerators for 17 verticals that help cut short overall development of technology and business solutions (Business Line, December 19, 2007). These solutions draw upon IBMs domain knowledge of consultations provided to clients world-wide.

The second good example is that of Intel corporation of USA based in Oregon which has a Development Centre in Bangalore where 2900 R&D professionals are working. It is reported that a significant proportion of researchers in Intel’s Indian Development Centre worked on logic, circuit and physical design of the Intel's recently announced the development of a "teraflop research chip" which crams 80 core chips (100 million transistors in one core chip) on a fingernail size device.[13] Significant parts of the Intel’s first low powered chip with sub-1 watt to 2 watts power for mobile internet devices and phones was developed at Intel India.

[10] This issue was raised by the US Committee on Science and Technology (See OECD discussion paper on ‘OECD Global Forum on Trade, Innovation and Growth’, OECD, Paris, presented at a meeting during 15-16 October 2007)

[11] http://www.research.ibm.com/irl/distributedcomp.html. Much of the information on IBM labs in India is drawn from the website.

[12] http://www.research.ibm.com/irl/knowledgeim.html.

[13] It is the first programmable chip to deliver more than one trillion floating point operations per second (1 Teraflops) of performance while consuming very little power. See, http://techresearch.intel.com/articles/Tera-Scale/1449.htm

This chip has achieved a major technological challenge for Intel as it meets low power requirements of hand held devices and opens a new product segment for Intel[14]. The center's rate of innovation compares favorably with Intel's mature development centers in the United States, observes Mr. Sampat, the Intel president in India, who holds six patents for his work in the United States.[15] Intel has formed R&D and technology alliances with 3 IITs in Delhi, Chennai and Mumbai, IISc, Bangalore and with the National Centre for Software Technology, Mumbai. Companies like Cisco Systems, I.B.M., Intel and Texas Instruments and others (GE and Motorola) who have filed more than 1,000 patent applications with the USPTO by 2007 have established R&D units in semiconductors mainly undertaking the work of advance chip designing. As the Managing Director of Texas Instruments India recently observed, the 'semiconductor ecosystem in India has reached a stage of maturity where design engineers are playing a key role in designing for world and India market'[16].

Another good example is that of ADOBE India Ltd. Indian operations, spread across two centres located in Noida and Bangalore, currently employing about 900 people out of Adobe's 6,000 employees worldwide. ADOBE has developed a number of products fully engineered from India. Contribute 4.0, Captivate 2, Premier Elements 3.0, Page Maker 7.0, Frame Maker, RoboHelp, PostScript, Acrobat Reader on handheld devices, Acrobat Reader on Linux, Photoshop Album Starter Edition and Premiere Elements.

Similarly we have the case of CISCO's R&D operations in India. Cisco Systems, Inc. the worldwide leader in networking for the Internet first established operations in India in 1995 and today employs over 1400 people in the country in its Global R&D center in Bangalore and offices in New Delhi, Mumbai, Bangalore, Chennai, Kolkatta, Pune, Hyderabad. CISCO plans to invest US $1.1 billion for R&D in India for three year period. Cisco Systems India Private Limited (CSIPL) is the largest research and development (R&D) center established by Cisco outside of the US.[17]

Small Network Management Solution (SNMS) was conceived and developed entirely in India. This is a Web-based network management solution that provides monitoring, configuration, and management tools to simplify the administration of small to medium business networks and work groups. It can be used in networks that feature both Cisco and non-Cisco devices. Another product coming out of India is the Cisco Emergency Responder (CER) - part of IP telephony solutions.[18]

[14] Quoted by Justin Rattner, Intel's chief technology officer (Mint 2-4-08)

[15] See the website http://www.ti.com/in/news_detail_tidccurtain.htm Mr Sampat observed this on 27 Nov 2006.

[16] See http://www.ti.com/in/news_detail_tidccurtain.htm

[17] Six individual technology groups operating in India: Routing Technology, Voice Technology, Optical Networking, Internet Switching Technology, IOS Technology Division, and Network Management. On-going development of the 7500 router platform primarily takes place in India.

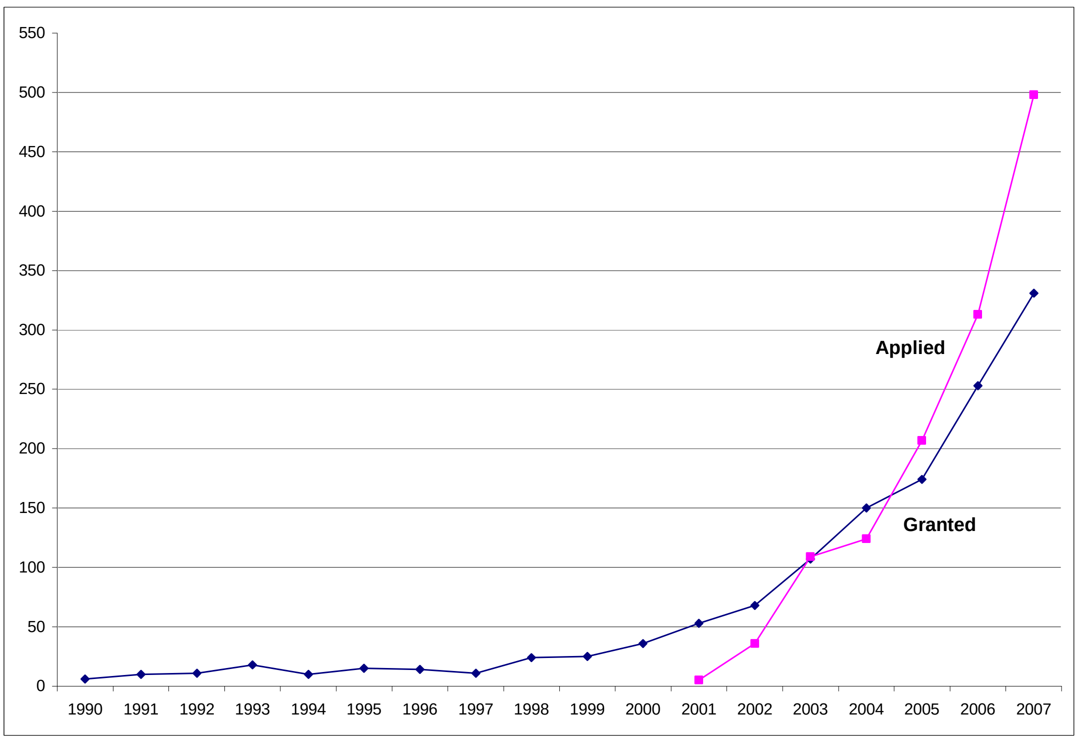
[18] Enhancing the existing E911 functionality of Cisco Call manager, CER enables emergency agencies to identify the location of 911-emergency callers. This product provides customers around the world with caller location and on-site alerting to security operations, even when public infrastructures do not support these services.

Examples of IBM together with big firms such as Texas Instruments, GE, Intel, Adobe and other big TNCs signify a 'new threshold' of TNCs operation in India at the cutting edge of R&D and innovation[19] linked to global production. There is however considerable evidence to suggest the knowledge transfer between home and host country TNC R&D centres in new equipment and instrumentation, engineering know-how, research methodologies, and knowledge management mechanisms, among other elements.

Knowledge Production by TNCs

Two way knowledge transfers between Indian and home country TNCs is closely connected with the feature of knowledge production which in fact precedes knowledge transfer. If we consider foreign firms in India obtaining US patents as one good indicator for knowledge production by TNCs, then the data available (See Figure 1) shows a significant increase in pace during the last few years[20].

Figure 1: Patenting in the USPTO by Foreign Entities in India



[19] For example, Texas Instruments India has just released the `world's first floating point digital signal controller ' - a chip completely designed and developed by its India-based engineers. The product has applications in solar and other un-interruptible power supplies.

[20] Followed the USPTO (United States Patent and Trademark Office) convention of attributing the invented patent to a country/location based on the address of the first inventor (thus in our case all patents from a foreign firm in which the first inventor had an Indian address was attributed to patent emerging from its Indian R&D Centre)

Table 6 Foreign Firms Granted More Than 10 Patents by the USPTO: 1990-2007

Organizations/ Industries	90-92	93-95	96-98	99-01	02-04	05-07	Cumulative (1990-2007)
Texas Instruments Incorporated		3	11	18	47	101	180
International Business Machines Corporation		1		8	52	88	149
General Electric Company			2	15	32	92	141
STMicroelectronics Ltd.				1	15	72	88
Hoechst Aktiengesellschaft	9	15	5	4	-	-	33
Cisco Technology					3	27	30
Hewlett Packard				1	15	14	30
Veritas Operating Corporation					2	27	29
Broadcom Corporation					3	24	27
Cypress Semiconductor Corp.			1	2	14	10	27
GE Medical System Global					10	17	27
Honeywell International Co.					2	24	26
Unilever Home & Personal Care				6	12	4	22
Intel Corporation				1	3	17	21
Freescale Semiconductor, Inc					1	14	15
Sun Microsystems, Inc.					1	13	14
Analog Devices			2		3	8	13
Novell, Inc					3	10	13
Novo Nordisk A/S				4	8		12
Cirrus Logic, Inc.				1	5	5	11

Source: Constructed from USPTO database (accessed via Delphion)

Table 7: Foreign Firms Applied for More Than 10 Patents in the USPTO: 2001-2007

Company	01	02	03	04	05	06	07	TOTAL
Texas Instruments	0	0	18	28	32	44	42	164
International Business Machines	1	16	19	15	25	30	55	162
General Electric	0	0	1	19	29	37	58	148
Honeywell	0	2	15	4	7	25	69	121
Cisco Technology	0	0	0	1	5	15	28	49
Oracle	0	0	0	12	5	18	18	44
Unilever Home & Personal Care	0	8	9	2	5	15	4	43
Microsoft	0	0	0	0	2	15	25	42
Hewlett-Packard	0	0	0	1	6	13	15	35
Sun Microsystems	0	0	6	11	12	1	5	35
Broadcom	0	0	2	2	8	6	12	30
Intel	0	0	1	1	15	5	8	30
SAP Aktiengesellschaft	0	0	0	0	2	1	19	22
Samsung Electronics	0	0	1	0	3	6	11	21
STMicroelectronics	0	0	9	6	3	4	3	21
Koninklijke Philips Electronics	0	0	1	0	0	3	8	12
Analog Devices	0	0	1	2	2	5	1	11

1316 patents were granted to foreign entities by the US Patent Office (USPTO) from the research work undertaken by them in India during the period from 1990-2007. The patents cover a wide range of technological areas. The period from 1990-2007 reveals a technological shift in the types of firms involved and the types of patents that were granted[21]. Pharmaceutical, chemical and consumer goods firms were predominantly involved in patenting activity before 1995, whereas from 1995 onwards ICT firms were more involved in this process. This has a strong correlation with the R&D centers that are opening in India over the period. It may be noted that patenting in software is only a recent trend. Much of the R&D work carried out in India in software, though of high quality, is of contractual nature feeding into parent companies. The established practice of the software firms was to obtain 'protection' through copyrights.

[21] Examining the data from 1971 to 1989 further underscores the significant shift that has taken place in comparison to patents granted to foreign MNCs after 1995. Two pharmaceutical MNC, Ciba-Giegy (23 patents) and Hoechst (13 patents) were actively involved during this period i.e. 1971 to 1989. The other firms that were granted patents were mainly consumer goods firms.

Table-6 shows firms/organizations that accounted for maximum number of patents in the USPTO of the research work undertaken in India. Examination of patents of these organizations reveals important insights of the technological complexities. Patents being granted in the cutting edge high technological areas by the US patent office provide a strong indication of the advance level research work being undertaken by them in India. One can also observe that the Indian entities of these foreign firms are building up ‘portfolio’ of key patents covering a specific technology. ICT was the main domain in which patents have been granted. The examination of the patents show that the patents cover present high end applications (for mobile phones, routers, digital signal processors, RF sensors) as well as future technologies (cover inter-operability/scalability of devices and applications through building ‘adaptive’ wireless solutions — driven by software rather than confined by hardware specifications). These patents are emerging from R&D centers of IBM, GE, Texas Instruments, CISCO (‘world technology leaders in ICT’). GE Medical has obtained patents covering the healthcare domain targeting medical instruments. A number of patents have been obtained in ‘X-ray systems’ covering improved diagnostic precision, lower radiation dosage, high image quality.

STMicroelectronics, Intel, Lucent have obtained patents in VLSI, micro-processor controlled applications, etc.

1292 patent applications were filed during the period 2001 to 2007 by the foreign firms in the USPTO. Table 7 exhibits the firms actively filing patent applications during this period. It is interesting to note the differences with the firms that were granted patents (refer Table 6). However, further introspection by taking account of the datedness of the granted data[22] reveals a much closer correspondence. Except for Honeywell (involved in Aerospace R&D) and Unilever (consumer goods) the other firms are ICT based entities, this mirrors the firms granted patents during the period 2001-2007.

Collaborative R&D and Innovation

There are different forms of collaborative R&D (sponsor research, research alliances subcontracting, consultancy and through exchange of human resources etc) wherein host country institutions and firms and TNCs participate in the knowledge production and transfer to its user. As Table-5 shows, in our sample of 115 TNC R&D centres 17% are involved in contract R&D. Closer scrutiny reveals that most of these contracts concern pharma, software, agri-biotechnology etc. Much of the contract research in the pharmaceutical industry is now gaining momentum in the domain of clinical research, drug screening and testing related activities which is estimated at over 2 billion US$ currently. What is new, however, are the collaborative ventures between TNC R&D centres and Indian institution which is now a part and parcel of the global research and innovation system. For instance, GE Healthcare which is operating in India since the mid-1990s has opened up Integrated Development Centre at Manipal Hospital in Bangalore which will participate in the global multi-country clinical studies in the US, European Union and other countries. While the local hospital and patients benefit from state of the art techniques and technology with access to global advances in diagnostic imaging and medical needs in oncology, neurology and cardiology.

[22] Granted data is dated to the extent of three to four years i.e. the average time it takes for a patent to be granted after filing.

At a more sophisticated and high technology end, public research laboratories are leveraged by TNCs for basic oriented research and commercialisation which are more R&D intensive and focus on oriented or directed basic research (See Table 7). A good example of this new development is the collaborations between National Chemical Laboratory (NCL), Pune, and more than 20 TNCs such as Du Pont, Ciba Geigy, Dow Chemicals, Eastman Chemicals, General Electric, Parke Davis, Pfizer Research Center, Polaroid, Nestle, Rhone Poulenc from France, Specs and Biospecs from Netherlands, Unilever etc., in polymers, process chemistry, Anti-HIV drugs, designed organic synthesis, titanium technologies, several drug molecules and development of synthetic methodologies.

NCL was able to obtain highly complex patents on its work in the area on polycarbonates in the early 1990s. This work attracted the attention of GE, global R&D leader in this domain and led to an alliance of NCL with GE in 1993. This alliance had been beneficial to both the partners. GE got assignment rights to a number of patents created by NCL. It has been estimated that US $8.5 million has been given by GE to NCL. One of the important outcome of this alliance was the development of proprietary process for THPE [1,1′,1′′-Tris(4′-hydroxyphenyl) ethane], a branching agent used in the synthesis of high grade polycarbonates with properties of high transparency, good mechanical and high parison strength. Patent applications were filed in India and abroad. This broke the monopoly of a single supplier, Hoechst Celanesa, USA. THPE valued at around Rs 300 millions over a three year period were exported by from 2001 to 2003. NCL has received US$ 50,000 as license fee and royalty payment of around US $ 100,000. Similarly, large Indian drug firms such as Biocon, Dr Reddy Labs, Ranbaxy have entered into R&D collaborations for drug development and innovation processes as shown in Table – 8.

Table-8: Collaborations of Select Indian Firms in Pharma and other Institutions

Indian Private R&D Laboratory		
Biocon	**Dr Reddy's Labs**	**Ranbaxy Labs**
• Center of Molecular Immunology, Cuba, to develop first anti-cancer drug • Vaccinex, Inc to discover and co-develop antibodies for cancer • Karolinska Inst, Sweden – product development • Deakin Univ. Australia in bio-processing • Bentley Pharma in insulins • Syngene and Innate Pharma, Sweden for viulence blockers in diarrhoeal disease. • Syngene and Bristol Meyers Sqiubb in R&D services and drug development	• Clintec International for co-development of anti cancer drug • Merc to produce generic version of Proscar and Zocor for the treatment of benign prostatic hyperplasia. • Rheoscience, Netherland for the diabetes drug • Roche acquisition and development of 18 products including steroids	- Ciprofloxacin (Cipr OD) technology licensed to Bayer for about 40$million – blockbuster antibiotic - Static molecule licensed to world's top contract research organization in USA – PPD for developing, marketing world wide. • **-** Benign prostrate hyperplasia (BPH) – asthma molecule licensing, drug development and marketing negotiations with 3 major firms.[23]

[23] http://www.blonnet.com/2002/06/03/stories/2002060301900300.htm

Indian Public R&D Institution		
Indian Institutes of Technology	**Indian Institute of Science, Bangalore**	**National Chemical Laboratory, Pune**
• IIT, Kharagpur: Motorola, Compaq, Oracle and GE Caps • IIT, Chennai: HP joint laboratory, • IIT, Bombay: Intel, Lever • IIT, Delhi: IBM, Intel, Samsung	• Intel Techology lab • Texas Instruments runs a digital Signal Processing labs • Hindustan Lever • IBM labs • Hewlett Packard (HP)	• 20 TNCs collaborate on R&D with this lab. They include:Du Pont, Ciba Geigy, Dow Chemicals, Eastman Chemicals, General Electric, Parke Davis, Pfizer Research Center, Polaroid, Nestle, Rhone Poulenc from France, Specs and Biospecs from Netherlands

Knowledge links are getting further institutionalized with collaborative agreements being signed for joint research. Among the big names is the recent agreement between Boeing with the Indian Institute of Science (IISc), Wipro Technologies and HCL Technologies to develop wireless and other network technologies for aerospace-related applications (Business Line-Jan 30, 2008). The agreement forms the Aerospace Network Research Consortium (ANRC), which a statement issued by Boeing states, is the country's first public-private aerospace research consortium.

Collaborative Partnerships between Indian and Foreign Entities Leading to Patented Technology

Many Indian firms had varied types of linkages with international firms. Some of these linkages had translated into development of novel products/processes. Patents are a strong assertion of the ‘novel’ technology being created. Joint assignment thus indicates that co-assignee firms had strong R&D partnership. However, co-assignment that shows collaboration in technology development is only a partial indicator of collaboration in R&D. For example, major Indian software firms such as Infosys, Wipro, TCS are under contractual obligations to transfer the ownership of intellectual property created to the host organisation. In general MNCs use collaboration at a later stage to avoid possible infringements. These collaborations are in terms of cross-licensing, patent pooling (pooling patents in a given field and license them as package) etc. (The Economist, 2001). Thus in spite of these caveats, patents that are co-assigned with foreign entities is a good indicator of high level technology partnership. Table-9 below shows the Indian firms and organisations that were involved in technology development with foreign partners leading to the patent(s) granted by the US patent office (USPTO).

Table -9: Indian Firms and Organisations Developing Technology with Foreign Entities leading to Patent Grant by USPTO: 1990-2006

Organisation	**No. of patents*** (Collaborative patents)	**Foreign Partners** Number [Foreign partners]
Council of Scientific & Industrial Research	898 (35)	5 [General Electric Company (3); University of California (1); Laboratoire des Materiaux Organiques a Proprietes Speciques (1); Bar-Ilan University (1)]
Ranbaxy Laboratories	78(1)	1 [Toyonoma Chemical Co. Ltd]
Dr Reddy's Research Foundation	65(10)	10 [Novo-Nordisk A/S (10)]
Department of Biotechnology	27(9)	1[University of Maryland, Baltimore]
Indian Petrochemicals Corporation Limited	14(2)	2 [Korea Institute of Energy Research (2)]
Indian Herbs Research & Supply Company Ltd.	8 (8)	8 [Natreon Inc. (8)]
Defense Research & Development Organisation	6(1)	1 [Societe Nationale d'Etude et de Construction de Moteurs d'Aviation and Association pour la Recherche et le Development des Methods et]
Vittal Mallya Scientific Research Foundation	5(2)	2 [The University of Leicester (1); Renaissance Herbs, Inc. (1)]
Indian Institute of Technology	5(4)	Intel Corporation (2)
Exide Industries Ltd.	3(2)	Shin-Kobe Electric Machinery Co. Ltd (2)
Sami Chemicals & Extracts	2(1)	Sabinsa Corporation (1)
Sami Labs LTD	1(1)	Sabinsa Corporation (1)
National Institute of Immunology	1(1)	1 [International Centre for Genetic Engineering and Biotechnology]
Satyam Enterprise Solutions Limited	1(1)	1 [In Touch Technologies Limited]
Tata Institute of Fundamental Research	1(1)	1 [NEC Research Institute, Inc. and TPPED Technical Physics and Protype Engineering Division]
Indian Statistical Institute	1(1)	1 [Intel Corporation]
Purna Global Infotech, Ltd	1(1)	QSSolutions, Inc (1)

Note:
*Collaborative patents were defined as patents that were assigned to more than one entity. Thus 'monopoly' rights to the patented invention are jointly owned by the collaborative partners. Patents in joint assignment with a firm's own subsidiary were not counted as collaborative patents.

Table constructed from Bhattacharya et al. (2006); Updated using Dolphion and USPTO web sites.

Trend in the Patenting Activity of Indian Firms and Institutions

Concurrently with the rise of Indian firms and growing influence of knowledge production of TNC R&D centres in India, the last decade witnessed an increase pace of Indian firms and institutions obtaining US patents as shown in Table-9. Patenting by Indian firms has significantly increased in domestic as well as foreign patent systems. Pharmaceuticals and Chemicals have been the two broad areas were Indian patenting activity is primarily concentrated. Biotechnology and telecommunications are among the emerging areas were patenting is significantly increasing (Bhattacharya et al. 2007). These firms are developing ‘portfolios’ in ‘novel drug discovery’ covering various pharmaceutical product groups, herbal formulations, industrial catalysts, high-tensile fibers, etc. Obtaining patents in US provides them with ‘monopoly’ rights to exploit their invention in the US market. Patenting by Indian firms such as Ranbaxy, Reddy Labs, CSIR and pharma-based firms is closely associated with network partnerships for drug development and marketing at the global level.

Table 10: Patent Activity of Select Indian Firms and Organisations in the USPTO (1990-2006)

Organizations/ Industries	1990-94	1995-98	1999-2002	2003-04	2005-06	Cumulative Patents
Council of Scientific & Industrial Research (CSIR)	29	71	278	272	248	898
Ranbaxy Laboratories Limited	7	9	23	20	19	78
Dr. Reddy's Research Foundation	-	3	32	15	15	65
Dr Reddy Labs	3	7	1	-	-	11
Dabur Research Foundation	-	-	15	10	9	34
Dabur India Ltd	5	5	6	1	2	19
Indian Oil Corporation Limited	-	2	16	7	6	31
Orchid Chemicals & Pharmaceuticals	-	-	2	11	5	18
Lupin Laboratories Limited	-	7	4	1	4	16
Panacea Biotech Limited	-	2	11	1	1	15
Indian Petrochemicals Corporation Limited	***1***	2	4	3	4	14
National Institute of Immunology	1	2	10	-	-	13
Wockhard Limited				6	6	12
Aurobindo Pharma			2	3	4	9
Bicon India Limited			1	5	3	9

GLOBALLY DISPERSED NETWORKED INNOVATION

Beyond cost and size of market in countries such as India and China, what is driving internationalization of R&D via TNCs are the speed of innovation and quantity of innovation (B A Hamilton and INSEAD 2006).[24] Coupled with this, the emergence of science and technology capacities in new technologies and its potential for innovation is dispersed across the globe (See Ernst 2005 and Chesbrough 2003). A good example can be drawn from the new development that while India commands certain expertise in the software, China does the same in hardware and manufacturing. Rather, software and embedded software and its design has become generic in varying forms and mediums and an important component of innovation in high technology fields as much as in non-technology markets, financial and global operating systems. The other important aspect is the convergence of technologies, fields of research with non-science and technology factors in the domain of finance, banking, social, cultural, among other factors. All crucial components or factors of innovation are becoming impossible to locate them in one place or location in the corporate home country R&D sites in North America and Western Europe. Innovation is more and more come to be seen in the footprint of networks whose actors are rather dispersed. As INSEAD Survey 2006, draw our attention and imply, 'optimising the configuration and integration of R&D networks' (p.7) is becoming crucial for improving the speed of innovation for global TNCs. Whilst the demands of speed and quantity of innovation for global competition is driving TNCs to enter into new form of strategic partnerships and collaborations, countries such as India and China, have come to occupy a significant position in the globally dispersed networked innovation. The basis of this development is not merely the low cost skill base which was the case initially in the 1980s and early 1990s, but the development of increasing national innovation capacities and endowment of highly trained human resources and R&D institutional base as evident from the results of INSEAD Survey 2006 as shown in Table – 11. This Survey covered 186 global companies in 19 countries (which spent 76 $billion in R&D in 2004) operating in 17 sectors. The survey asked companies to respond as to what is driving their future R&D sites.

Table 11: Drivers of Future R&D Sites
(figures in % in responses from 186 global firms)

	China	India	Brazil	USA
Qualified Workers	12	25	21	17
Technology Cluster and Academic institutions	13	13	14	27
Low cost skill base	24	30	11	3
Proximity to production facilities	17	11	18	12
Others(business/markets)	34	21	36	41

[24] Hereafter will be referred to as INSEAD Survey 2006.

As Table 11 shows, qualified workers and academic institutional cluster account for 38% for India and 25% for China more than the feature of low cost skill base. Further, the INSEAD Survey 2006 revealed that global firms would like to strengthen their 'optimally configured' R&D network over the next five years by opening up new R&D sites in China (22%), India (19%), USA (19%) and Western Europe (13%). These developments are also closely related to plan growth pattern of R&D human resources. By the end of 2007, the Survey indicated that India (contributing 23%) and China (contributing 16%) will account for a total 39% of global R&D staff, up from 19% (India 14% and China 5%) in 2004.[25] Another important finding from the Survey relates to the insight that **45% of foreign R&D sites** are seen to be important (by 186 global TNCs) due to core technology research and full development capabilities; **and 55% of R&D foreign sites** due to specific development capabilities coupled with customization for local markets.

Innovation networks are increasingly being used in ICT for client tailored innovation services — to design custom chips and supply chain software algorithms. Indian firms are trying to exploit the opportunities of innovation networks by focusing on 'product engineering services' such as innovation of ASIC chips[26] . Except the final fabrication, the full R&D work related to the functionality of the chip is being undertaken by Indian firms.

This development of networked innovation is very much in alignment with the features of *two way technology transfer* (particularly the case of IBM in India) and *collaborative R&D and innovation* briefly discussed above. Multiple technology partnerships are also evolving (see for example the case study below of WIPRO's PES innovation network). This is due to the fact that knowledge supply chain and consumption in these processes are directly or indirectly linked to global operations of TNCs involved in the specific cases. For example, IBM's research and knowledge inputs from India, feeds into global business operations of the firm. In the light of this, let us look into some concrete examples of Indian firms for specific globally dispersed networked innovation.

Case 1: Infosys with its 75000 professionals world wide (13000 professionals in 30 centres outside India) has evolved into a global delivery model – a framework for globally dispersed project management and multi-location execution of R&D and services for innovation. It provides 'end-to-end business solutions that leverage technology… provide solutions for a dynamic environment where business and technology strategies converge…..work with large global corporations and new generation technology companies - to build new products or services …in today's dynamic digital environment'.[27] A good example where an Indian firm is a crucial player in the globally dispersed networked innovation is Infosys's participation in Automotive Open Systems Architecture – **Autosar**. It is a 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.[28] Further, Infosys formed a 'product lifecycle and engineering solutions' (PLES) group to focus on developing

[25] It is rather interesting to note that China increases its R&D staff by three times compared to India during 2004 and 2007.

[26] 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.

[27] http://www.infosys.com/about/default.asp

[28] http:///www.domain-b.com/companies/companies_i/infosys/20050328_consortium.html

embedded solutions, product design and PLM solutions for the automotive sector. It works in close collaboration with Autosar to develop the protocols and standards for the next generation automotive electronics.[29]

Case 2: The second example of an Indian firm which plays a crucial role in the networked innovation is Tata Consultancy Services (TCS) – with 89000 IT professionals operating in 47 countries with revenues around 4.3 billion US$ in 2007. It develops software solutions for American Express, Microsoft and General Motors among others. TCS initiated what is known as 'global co-innovation network' with firms, research and academic institutions around the world to partner for developing advanced software systems and solutions for global customers. A case in point is its collaboration with University of Massachusetts, Amherst's laboratory for advanced software engineering research (LASER). Different sectors in which the above two companies operate and partner in the globally dispersed networked innovation is given in table – 12.

Table 12: Areas of Operation and Select global Clients of Two Indian Firms

Infosys	**Tata Consultancy Services**
Aerospace and defense, automotive, banking and capital markets, communication services, consumer discrete manufacturing, education, energy , healthcare , high technology , hospitality and leisure, insurance and life Sciences and Media and Entertainment.	Aerospace, automotive, chemicals, pharmaceuticals, industrial machinery, high technology, minerals and metals, oil and gas, power water, medical devices, finance and insurance etc.
Network Partner Firms - select examples	**Network Partner Firms- select examples**
Aerospace and defense: Boeing (787);Airbus 380 Freighter; National Oceanography Centre, UK *High technology*: Cisco, Apple, Oracle, Telecom Australia; Toshiba; and Siebel CRM solutins *LifeScience and Health Care*: Global Contract Research Organisations/firms	*Telecom*: Hutchison 3G Austria; Motorola; Sonofon; *Manufacturing*: Philips semiconductors *Banking and Insurance*: Aviva; ABN Amro; American Express *Information Technology*: ABN Amro in Brazil, UK, France, Germany, Hong Kong, Switzerland and Netherlands.

Kash et al. (2004) has earlier undertaken a case study of these two firms. Their paper shows how these two firms have progressed over the years. Learning and incremental innovations have helped these firms transition to complex technologies. Evidences from above show the next stage of their evolution; becoming partners in global innovation networks.

Case 3: Another firm that is increasingly participating in 'electronics innovation network' is Wipro Technologies, the global IT services business of Wipro. It is partnering with major firms and providing them 'product engineering services' (PES). PES generated 28 per cent of Wipro Technologies' $1.35 b revenues last year. Wipro has also partnered with Semiconductor Manufacturing International Corporation (SMIC), Taiwan Semiconductor Manufacturing Company (TSMC), and United Microelectronics Corporation (UMC) that would help it bring in-house designed chip in the market.

[29] ibid

Rise of Indian Firms

The last decade witnessed a new trend of Indian firms expanding their business and getting integrated into the global production networks (GPNs) beginning with the Lakshmi Mittal group based in UK which acquired the European steel giant Arcelor. The pace of Mergers and Acquisitions (M&A) route to expand business in foreign locations and take part in the GPNs has increased in the last four years. However, going beyond business operations several Indian software firms have begun to use their human resource base in knowledge, software, R&D and engineering services to expand their operations at the global level. In fact there is a two way process of knowledge transfer and technological capability building that can be observed in this new development. While hard core engineering firms in steel and automotive (Mittal Steel, Tata Steel, Bharat Forge and Tata Motors for instance) stand to benefit with new technological innovations and manufacturing processes through M&As, software and knowledge based service oriented firms are likely to provide their highly skilled software knowledge services and design capabilities across a large number of sectors ranging from banking and finance to power and aerospace industries. Whilst the actual quantity and type of knowledge transferred and the way in which it gets into production and consumption at the global level is open to empirical investigation via case studies, the present trend of local firms participation in GPNs signals a new indicator of global nature of innovation from an Indian perspective. Table – 12 indicates the emerging structure of top Indian Firms in M&As during the last few years.

Table 12: Major Overseas Acquisitions by Indian firms (2000-2007)[1]

Indian Firm[2]	Target Firm	Country	Year	Deal value (US $million)	Sector
ONGC Videsh Ltd	Petrobras	Brazil	2006	1,400	Petroleum
	Greater Plutonic Project	Angola	2004	600	Petroleum
	Greater Nile Oil Project	Sudan	2002	760	Petroleum
	Sakhalin-I PSA Project	Russia	2000	323	Petroleum
Dr Reddy's Laboratories	Betapharm Arzneimittel	Germany	2006	572	Pharmaceutical
Suzlon Energy Ltd	Hansen Transmissions International	Belgium	2006	565	Energy
Ranbaxy Laboratories Ltd	Therapia S.A.	Romainia	2006	324	Pharmaceutical
Opto Circuits India	Eurocor GmbH	Germany	2005	600	Medical equipments
Kraft Foods	United Biscuits	UK	2006	520	Food & beverages
Tata Tea	Tetley	UK	2000	407	Food & beverages
Tata Motors	Daewoo Commercial	South Korea	2004	465	Automotive
VSNL	Teleglobe	Canada	2005	239	Telecom
Tata Chemicals	Brunner Mod	UK	2005	798	Chemicals
Tata Steel	Corus Steel	UK	2007	12100	Steel
	PT Bumi Resources Tbk	Indonesia	2007	1100	Power
	Millenium Steel	Thailand	2006	404	Steel
	Natsteel	Singapore	2005	285	Steel
Tata Coffee	Eight O' Clock	US	2006	220	Food & beverages
Hindalco	Novelis	Canada	2007	5892	Aluminum
Videocon	Daewoo Electronics	Korea	2005	729	Electronics
Videocon	Thomson SA	France		290	Electronics
Ispat Industries	Finmetal Holdings	Bulgaria	2005	300	Steel
Bharat Forge	Swedish Imatra Kilstra AB	Sweden		1300	Automotive
Reliance Ind.	Flag Telecom	Bermuda	2003	212	Telecom
HPCL	Kenya Petroleum	Kenya		500	Oil and Gas
Matrix Laboratories	Docpharma NV	Belgium	2005	235	Pharmaceutical
Ballarpur Industries	Sabah Forest Industries	Malaysia	2006	209	Pulp and paper
Sasken Communications	Bornia Hightec	Finland	2006	210	Information Technology
Essar Steel	Algoma	Canada	2007	1600	Steel

[1] Deal Value at least 200 million US$; [2]Firms belonging to a group are kept in a single row. Source: Various websites – http://track.in/Tags/Business/category/mergers/; Wall Street Journal; http://ibef.org; Prowess database (CMIE), Nayyar (2007), Mitra (2007), Jha (2006), Newspaper reports.

Range of underlying factors has driven the outward FDI (Nayar 2007; Jha 2006). Increasing competitiveness, market access for exports, capturing international brand names, access to technology, sourcing raw materials, distribution networks, skills were some of the strategic considerations that has driven Indian enterprises to expand abroad. Acquisitions were mainly in the manufacturing (40%) and IT sector (30%); 80% of the acquisitions were in the industrialized countries, 15 firms mainly responsible for nearly one-third of the total acquisitions (Nayar, 2007).

DISCUSSION AND CONCLUDING REMARKS

The theme of internationalization of R&D and global nature of innovation in emerging economies such as India and China provide a new context for exploration. More than anything else, this new context directs our research attention to the ways in which economies are getting integrated not by just economic and financial means but through knowledge-based institutions and innovation systems which are now geographically dispersed. The domination of a centralized corporate R&D and innovation by TNCs mainly based in home countries is fast breaking down. Disintegration of the production of knowledge and innovation into discrete networks has been further exacerbated by the impact of the information and communication revolution coupled with the generic nature of software technology. It is becoming more meaningful to talk about globally dispersed networked innovation. The changing locus of R&D and innovation structures of TNCs and the growing importance of foreign locations for knowledge and R&D are at the 'centre of gravity' of this emerging globalization of R&D and horizontal nature of innovation.

Influential writings from Archibugi and Michie (1995, 1997) and Reddy (2000 and 2005) have shown, in varying ways, the progress of internationalization and globalization of R&D by global TNCs being mainly confined to industrially advanced countries in Western Europe and North America with the possible exceptions of Japan and South Korea in Asia. As some other studies argued, even if TNCs moved to developing countries in the around mid 1990s, their operations were confined to 'one way technology transfer' or oriented towards 'adaptive R&D' rather than 'creative R&D'. In the specific case of India, an influential study by Kumar and Aggarwal (2000: 22) reflect a similar view when they observe, 'MNE affiliates focus on a customization of their parents' technology for the local market or on exploiting the advantages of India as an R&D platform for their parents (now referred to as home-base augmenting R&D)'.[30]

Studies based on patenting behavior of TNC's provide further insights of the changing trends. Pavitt and Patel (1999) do not contest the internationalisation of R&D but question whether globalization of technology has taken place. By analyzing US patenting activities of 569 firms (based on 13 countries and in 17 product groups) they show that firms primarily undertake patenting in their home locations. Carlsson (2006) while reviewing the literature of innovation systems (citing the works of Meyer-Krahmer 1999; Cantwell and Santangelo 2000; Le Bas and Sierra 2002 among others) finds changing patenting behavior of TNC's from 1990 onwards. The reason for this change is attributed by them to speeding of the rate of technological change that made it extremely difficult for large firms to diversify their home technology base at a sufficient pace and thus compelling them to exploit the competence of

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[30] See http://www.gdnet.org/pdf/827_Agarwal_rev.pdf for Nagesh Kumar and A.Aggarwal (2000)

foreign locations. However, all these patent based studies again show that these activities are confined to the 'triad' of the United States, Europe and Japan.

Our database and study reveals that during the last decade this situation has changed significantly. India emerged as an important destination for 200 global TNC R&D centres (see Table 2). A closer scrutiny of 115 TNC R&D centres reveals that over 53% of these centres are either 'locally integrated labs' or with collaborative R&D projects (see Table 5) with local Indian firms and institutions. A closer examination of selective cases in other segment of 'support laboratories' (as shown in Table 5), reveals that much of the R&D work carried out in these labs is not without local linkages and spillover effects. The way in which knowledge is tapped and drawn from their Indian affiliates closely feeds into their parent, home country TNCs and often integrated with global production networks. The nature of the R&D undertaken by Microsoft, Intel and IBM labs, among others, in India are typical examples of this kind. The point of research relevance to local and global (to home country centres) is due to the fact that such big TNCs in India have centres and units oriented to different needs and demands with links between research personnel and projects in these units. Patent statistics also showed the changing trend (see for reference Figure 1 and Tables 6, 7 and 8). Foreign TNC R&D centres located in India were granted 1316 US patents in the last decade (90% of these coming in the last 7 years). 1292 patent application were filed by Foreign TNC R&D centres during the period 2001-2007, reflecting significant positive trends. Information presented in Tables 8 and 9, on the other hand, show the emergence of partnerships. What is of significance here is the new development of collaborative R&D and innovation between TNCs and Indian firms and institutions, particularly in biopharmaceuticals and ICT.[31]

There is enough evidence to suggest that the R&D undertaken by TNCs in India and its collaboration with Indian firms and institutions cannot be described solely in terms of either 'home base augmenting R&D' or 'home based exploiting site' reflective of the situation in the1990s, even though they still find relevance.[32] Indian R&D and innovation threshold has quite dramatically moved up in the last decade to transform from 'one way' to two way knowledge transfer as argued in this paper. Research carried out at IBM's Indian labs in advance computing; and collaborations between Indian firms (such as Biocon, Reddly Labs and Ranbaxy) and the TNCs in drug discovery and its commercialisation are examples of the nature of research in computing and biopharmaceutical fields. Together with the patent data presented, the paper reveals the emerging trend of TNC R&D centres towards 'creative R&D' linked to global competition.

ICT is a major driver of the world economy. One can discern from the foreign R&D centers establishing in India, a large number of firms in ICT based applications primarily involved in chip design. Indian firms such as TCS, WIPRO are also trying to address various functionalities associated with chip design. The missing link i.e. fabrication (chip manufacturing) is being addressed by the innovation network involving other manufacturing locations such as China or Taiwan for fabrication. The empirical findings support Rajdou's observation that India is getting recognition as a base for semiconductor chip design. On the

[31] As such, 17% of 115 TNCs are characterized as falling in the category of collaborative R&D by the TIFAC Survey 2005. Collaborations in ICT is discussed in other sections of this concluding discussion.

[32] For instance, India will take advantage of its high skilled and low wages human resources in various sectors but at the same time the nature of R&D threshold is moving up in pharma, ICT software, chip designing, auto etc.

other hand China boasts world-class electronics manufacturing capabilities embodied in its semiconductor firms like Semiconductor Manufacturing International Corporation (SMIC) and Grace Semiconductor. The result: India and China combined will become a major hub in the global electronics Innovation Networks - a fluid market structure that matches global innovation demand with worldwide supply of talent and capabilities.

A parallel development is taking place to complete the full product cycle within India with big investments in fabrication (for example $3billiom SemIndia project, $4 billion fabrication project of Hindustan Semiconductor Manufacturing Company, a consortium of NRIs). These are new initiatives after the setback of Intel withdrawing their proposed chip-manufacturing facility in India. The new fabrication units will have to confront established fabrication centers. Whether these units can integrate successfully with chip design that is undertaken in India is a question that remains to be answered.

Our exploration of TNCs and their impact in the Indian context advances the view that India is emerging as an important partner in the globalization of innovation. For instance, big Indian software firms have become important actors in the globally dispersed networked innovation processes in a number of high technology areas such as aerospace, automotive, telecommunications, banking and finance etc. In varying ways, Indian developments reveal the changing structure of TNCs in the context of 'new approach' which 'moves towards globalized programmes for innovation and R&D' or 'dynamic differentiated networks' (Pearce 2005:29,30). As Ernst (2005: 61) says, TNCs are 'increasing their overseas investment in R&D, while seeking to integrate geographically dispersed innovation clusters into global networks of production, engineering, development and research'. Our exploration in this paper advances this view of Ernst and Pearce to some extent. Further, the INSEAD Survey 2006, based on the responses from 186 global firms, also lends support to this view of India assuming some importance in the globally dispersed networked innovation. As this Survey clearly reveals, even though India continues to enjoy the comparative advantage of low wage and highly skilled human resources, India has emerged as an important destination for TNCs with the growing threshold of its R&D and innovation base. The patent data of select Indian firms and institutions presented in Table -9 supports this view. In the case of ICT software, in parallel to software services to over 400 global firms from India, big firms such as TCS, Infosys, Wipro are now closely linked to globally dispersed innovation networks. The situation has changed during the last seven years compared to 1980s and 1990s of 'body shopping era'.

Another important trend of globalization and the global nature of innovation emerging is the rise of Indian firms which expand business and link up with the global production networks as depicted in Table 12. Much of this development is closely associated with economic and market growth of Indian firms over the years which are now entering a phase of M&As. This appears to be another important route for technology acquisition at global level for firms such as Tatas and Bharat Forge in engineering and manufacturing; production, commercialisation and marketing of new molecules and generic drugs for pharmaceutical firms; and partnering in the globally dispersed innovation networks for software firms.

All these insights advanced in this section however deserve further research to validate our initial findings.

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