Foreign R&D Centres in India: An Analysis of their Size, Structure and Implications

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Foreign R&D Centres in India: An Analysis of their Size, Structure and Implications[1]

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Abstract

The study measures the contribution of MNCs to the generation of innovations from India. The focus is on innovations that are carried out in foreign R&D Centres. After having mapped out the size of this sector, the study develops a way of classifying them into two categories on the basis of their actual record with respect to performance of innovations. Further we survey the policies that are available in India to promote FDI in R&D services. The study also identify the characteristics of these foreign R&D centres in terms of a number of indicators like their, size, domain expertise, physical location and then it distils out the interaction of these centres with India's National System of Innovation. The latter is carried out through a primary survey. The contribution of this study is an identification of the size of foreign R&D Centres in India from official sources of data and its actual working. The study has thus a number of pointers for public policy for promoting this activity so that it is beneficial to the host economy of India.

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Contents

Introduction

China and India are two of the fastest growing economies of the world. Their continued surge in economic growth both before and after the recent (2008) global financial crisis has further lent credence to the hypothesis that the economic growth registered by the two countries is sustainable as it is based more on technological improvements rather than by using more factor inputs such as labour and capital. Recent estimates of total factor productivity growth lend some empirical support to this hypothesis. Both the countries have also been receiving sizeable chunks of FDI in R&D by MNCs. There are also press reports of a number of innovations emanating from the two countries although systematic empirical evidence on this issue is found wanting in the literature[2]. One of the avowed objectives of economic reforms in both the countries (embracing of market socialism in China since 1979 and economic liberalization in India since 1991) was to promote competition between firms. Along with the possibility of increased competition, one also sees that both the countries have become increasingly integrated with rest of the world although on these counts China has a better record than that of India. All these factors may pave the way for both the economies to invest in innovative activities as the firms in both the countries are no longer concerned with competition in their respective domestic economies, but internationally as well. In the context, the objective of the present paper is to compare the emerging role of MNC R&D centres in India in the backdrop of her innovation record since the onset of the reforms in the two countries which, as argued, earlier should have facilitated this process to flourish.

The paper is structured into seven sections. The first section maps out the larger context in which this study is conducted. The second section focuses on the growing importance of foreign companies in the generation of innovations in India. The third section engages with

[2] For a detailed count of these see, Business Week, http://www.businessweek.com/magazine/toc/05_34/B3948chinaindia.htm (accessed April 5 2010)

the small but growing literature on foreign R&D centres especially in India. The fourth section measures the size of this activity. The fifth section surveys the public policy with respect to FDI in R&D and the sixth section distils out the results from a primary survey of foreign R&D centres in India. Three characteristics are highlighted here: determinants, structure and scope of R&D activity, and the nature of linkages that these centres have with the rest of India's national system of innovation. Finally, the seventh section sums the main findings of our study.

I. The Larger Context

In this section we present the larger context against which one may analyse the nature and extent of innovative activities in these two fast growing economies in the world. The context has four components: (i) China and India are the fastest growing economies in terms of efficiency of resource use; (ii) There has been considerable improvement in China and India's rank summary measures of global innovation; (iii) There has been a perceptible increase in the knowledge-intensity of China and India's manufactured and service exports; and (iv) Both the countries have achieved international competitiveness in high technology areas such as astronautic technology. In what follows we elaborate on these four areas.

(i) Fastest growing economies in terms of efficiency of resource use: Productivity growth is well recognized as a measure of an economy's health. This is because an economy may show rapid growth by increasing the level of investments in the key factor inputs of capital and labour. But what is more important is the efficiency with which these factor inputs are combined to produce an increasing level of output. Economists usually measure this efficiency of resource by computing a summary measure such as total factor productivity growth (TFPG) although the empirical measures of TFPG is subject to the quirks of methodology and the type of data used. Among the various empirical exercises comparing

TFPG in China and India, two of the recent and more systematic studies are by Bosworth and Collins (2008) and Cates (2009), Bosworth and Collins (2008) examines the sources of economic growth in the two countries over the 25 year period 1978-2004 using a simple growth accounting framework that produces estimates of the contribution of labor, capital, education, and total factor productivity for the three sectors of agriculture, industry, and services as well as for the aggregate economy. Their analysis incorporates recent data revisions in both countries and includes extensive discussion of the underlying data series. The growth accounts, derived by the authors, show a roughly equal division in each country between the contributions of capital accumulation and TFP to growth in output per worker over the period of analysis, and an acceleration of growth when the period is divided at 1993. However, the magnitude of output growth in China is roughly double that of India at the aggregate level, and also higher in each of the three sectors in both sub-periods. In China the post-1993 acceleration was concentrated mostly in industry, which contributed nearly 60 percent of China's aggregate productivity growth. In contrast, 45 percent of the growth in India in the second sub-period came in from services. A second study is by Cates cited in Economist (2009) who computed the TFPG in emerging economies over the period 1990-2008. See Figure 1 for the results of this study. According to this study, China had the fastest annual rate of TFP growth at around 4 per cent per annum closely followed by India at around 2.5 per cent per annum during this period. Now the important question is to explain the determinants of this fast productivity growth. The three determinants that Cates identify are: (i) rate of adoption of existing and new technologies; (ii) the pace of domestic scientific innovations; and (iii) changes in the organization of production. Using a composite index of technology diffusion and innovation, Cates finds a strong correlation between the rate of increase in an economy's technological progress and its productivity growth. In other words the study also points to an increase in the rate of innovations in the two countries although this is not exactly probed in to in detail in the study.

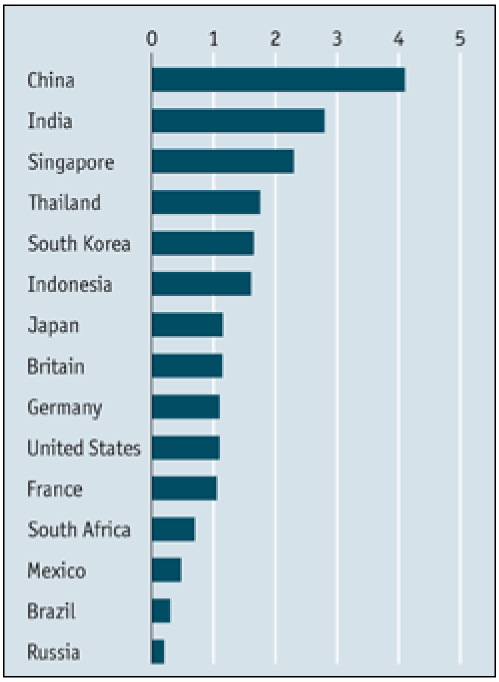

Figure 1: Total Factor Productivity Growth in China and India, 1990-2008
Source: Cates cited in Economist (2009)

(ii) Improvements in global innovation ranking: A number of composite indices of global innovation are available these days. One such index is the 'EIU Innovation Index' by the Economist Intelligence Unit[3]. Between 2002-06 and 2004-08, China rose from 59th to 54th in this index. This is most impressive as the prediction was that this sort of a moving up in the ranking will occur only within five years. One reason for the jump is that China is making a

[3] The Economist Intelligence Unit's Innovation Index analyses the innovation performance of 82 economies. It is based on countries' innovation output, as measured by the number of patents granted by the patent offices of the US, European Union and Japan, and innovation inputs, based on the Economist Intelligence Unit's Business Environment Ranking (BER) model. The Index measures the following direct innovation inputs: R&D as a percentage of GDP, the quality of local research infrastructure, the education of the workforce, technical skills, the quality of information and communications technology infrastructure and broadband penetration. The innovation environment includes political conditions, market opportunities, policy towards free enterprise, policy towards foreign investment, foreign trade and exchange controls, taxes, financing, the labour market and infrastructure.

concerted effort to build a more innovative economy by investing heavily in R&D and education. India, on the contrary is, advancing at a steady pace up the innovation ranks as the number of patents granted increases and both innovation-specific and broad environmental factors improve. From 58th in 2002-06 it advanced to 56th in 2004-08. In 2009-13, it is forecast to reach 54th[4].

(iii) Increasing technological intensity of exports: By applying the UNIDO (2009) definition of high technology products to the UN Comtrade data (according to the SITC, Rev. 3 classification system) on manufactured exports from China and India during the period 1988-2008, we derived the manufactured exports from China and India. This is presented in Table 1. It shows that the high tech export intensity of both the countries have doubled during the period under consideration. If one undertakes a detailed decomposition of the components of these high technology exports then it can be seen that China is specializing in electronics and telecommunications equipments, while in the case of India the most important high technology manufactured product are pharmaceutical products.

China has in fact become the largest exporter of telecommunications equipments in the world: its share of the world market has actually increased from 2.36 per cent in 1992 to about 23 per cent in 2008. The above focus on manufactured products may actually underestimate the technological content of exports as far as India is concerned as the country is now increasingly diversifying into exports of services. Approximately 40 per cent of India's exports are in the form of services. Within the service exports, we denote the following four as knowledge-intensive services, namely (i) IT services; (ii) R&D services; (iii) Architectural, engineering and technical services; and (iv) Communications services. The

[4] See Economist, http://www.economist.com/node/13562333?story_id=13562333 (accessed on January 26, 2012)

combined share of these four in India's services exports have increased from about 55 per cent in 1999-2000 to about 80 per cent in 2007-08.

Table 1: High-technology intensity of manufactured exports from China and India, 1988-2008
(High technology exports as a per cent of manufactured exports)

	China	**India**
1988		7.32
1989		10.12
1990		9.17
1991		9.16
1992	20.09	6.86
1993	22.76	7.21
1994	23.91	7.50
1995	25.77	8.95
1996	30.59	10.16
1997	32.44	10.23
1998	36.19	9.15
1999	38.68	9.28
2000	39.59	9.59
2001	40.92	12.34
2002	43.71	12.17
2003	47.33	12.04
2004	48.16	11.90
2005	48.42	11.12
2006	47.65	13.41
2007	46.72	14.54
2008	44.59	16.94

Source: Computed from UN Comtrade

A mere increase in the technology content of exports and especially manufacturing does not necessarily mean that the country is becoming innovative if this increased exports are merely based on imported components and if the country in question does not have a clear record with respect to objective definitions of innovative activity in these products. It may well be the case that the country is merely importing components and parts, assembling them and exporting the finished product with very little local value addition.

(**iv) International competitiveness in certain high technology areas such as astronautic technology:** Both China and India have an active space research programme, spend considerable amount of public funds on space research and have increasingly demonstrated technological capability in designing satellites and satellite launch vehicles and even undertaking commercial launches of satellites on behalf of other countries. In order to measuring the external competitiveness of the astronautic sector of China and India among other space-faring nations, we rely on the space competitiveness index (SCI) computed by Futron Corporation (2009). The SCI evaluates the space faring nations across 40 individual metrics that represent the underlying economic determinants of space competitiveness. These metrics assess national space competitiveness in three major dimensions: government, human capital, and industry. The ranks obtained by the ten major space faring nations are presented in Table 2.

Table 2: India's Rank in the Space Competitiveness Index in 2008 and 2009

Rank	Country	Government	Human Capital	Industry	2009 Score	2008 Score(Rank)
1	U.S	38.42	13.96	37.94	90.33	91.43(1)
2	Europe	19.32	9.03	18.46	46.80	48.07(2)
3	Russia	18.57	3.04	10.83	32.44	34.06(3)
4	Japan	15.80	1.72	3.65	21.16	14.46(7)
5	China	12.42	2.98	4.06	19.46	17.88(4)
6	Canada	12.89	3.42	1.82	18.13	16.94(6)
7	India	12.24	1.71	1.39	15.34	17.51(5)
8	South Korea	8.39	1.34	2.31	12.03	8.88(8)
9	Israel	6.72	0.56	1.42	8.70	8.37(9)
10	Brazil	6.10	0.49	0.50	7.08	4.96(10)

Source: Futron Corporation (2009)

India was ranked 5 in 2008. Her rank has since slipped to 7 out of 10, although her score is better than Brazil- a country that is very strong in the aeronautical sector.

Thus on all these four broad indicators of innovation outcomes, both China and India show considerable improvements over time.

II. Role of Foreign Companies in the Generation of Innovations from India

FDI inflows to India have increased rather significantly since the relaxation of rules governing FDI inflows set into motion since the announcement of the "New Industrial Policy Statement' of 1991.Rules governing FDI inflows have been relaxed at several occasions over the last two decades and the inflows currently account for as much as 3 per cent of India's

GDP or even 8 per cent of total investments. See Table 3. It is generally believed that foreign companies or FDI companies[5] (as is usually referred to in India) occupy a relatively speaking more important role in China's economy than that of India's. For instance, a large proportion of exports of manufactures from China is contributed by MNCs operating from China. This is unlikely to be the case of India although there is now some evidence to show that MNCs share of domestic production is increasing although concentrated in specific industries such as the automotive industry, for instance.

Newspaper reports and some recent studies (Mrinalini et al, 2010 and Reddy, 2011) refer to the growth of foreign companies in outsourcing R&D activities to their own affiliates and to other domestic companies specialising in the performance of R&D in India. However, these studies provide us with no quantitative estimates of the growing importance of foreign companies in the performance of innovative activity in India.

Table 3: Growing importance of FDI in India
(Values are in Millions of US $)

Fiscal year ending	FDI Inflow	FDI Stock	FDI Inflow/Gross Domestic Product (%)	FDI Inflow/Gross Fixed Capital Formation (%)
1991	75	1732	0.039	0.154
1992	252	1984	0.063	0.260
1993	532	2516	0.154	0.622
1994	974	3490	0.258	1.101
1995	2151	5641	0.458	1.890
1996	2525	8166	0.675	2.513
1997	3619	10630	0.807	3.189
1998	2633	14065	0.950	3.786
1999	2168	15426	0.653	2.647
2000	3585	17517	0.527	2.061
2001	5472	20326	0.956	3.852
2002	5627	25419	1.395	5.439
2003	4323	31221	1.091	4.219
2004	5771	38183	0.781	2.883
2005	7606	44458	0.917	2.925

[5] According to the Reserve Bank of India a FDI company, is one where 10 per cent or more of the voting stock of the local company is held by a foreign company. This definition conforms to what is contained in Balance of Payments and International Investment Position Manual, Sixth, Edition (BPM6) of the IMF.

2006	20336	70282	1.172	3.546
2007	25127	105429	2.607	7.668
2008	34835	123288	3.053	8.522
2009	37838	159300*	3.249	9.593
2010	37763	182100	2.930	8.914
2011	30380	211200		5.964

Source: Reserve Bank of India (2011) and UNCTAD (various issues)

Although both the Secretariat of Industrial Assistance (SIA) and the Reserve Bank of India publishes data on industry-wide distribution of FDI in R&D, both the sources have started publishing it only since 2005. See Table 4. While the SIA reports FDI in R&D, the RBI source clubs education and R&D together. The series, admittedly only for a few years, does not show any trend and the magnitude of FDI in R&D is less than a per cent of total FDI inflows to India.

In order to measure the growing importance we examine the share of foreign companies performing innovations in India by tracking the usual input and output indicators for measuring innovative activity, namely R&D expenditures and patents. There are, of course, several difficulties of an empirical nature. These could be enumerated as follows. While it is, relatively speaking, a straight forward exercise in the case of patents as the data sources allow us to measure the share of foreign companies in patents granted to Indian inventors in both abroad and in India, this is not that straightforward or direct in the case of R&D expenditure data. With these caveats, we analyse the growing importance of foreign companies in the performance of R&D and in patenting. We begin with the R&D expenditure data.

Table 4: Differing estimates of FDI in R&D (Millions of of US $)

According to SIA		According to RBI	
2005	22		
2006	36.9		
2007	73	2006-07	43
2008	433.3	2007-08	156
2009	na	2008-09	243
2010	52.59	2009-10	91
		2010-11	56

Source: Secretariat of Industrial Assistance (various issues); Reserve Bank of India (2011), Table 19.

Role of Foreign Companies in Inputs to innovations in India: Some Indications from the Analysis of R&D Estimates

R&D in India's innovation system is performed by at least three broad actors: government (includes government research institutes), business enterprises and in the higher education sector. Table 4 provides a sector-wide distribution of R&D in both China and India. Even now, in India the government accounts for over 63 per cent of the total R&D performed within the country although the share of government has tended to come down over time. This has been accompanied by an increase in R&D investments by business enterprises which now account for about 30 per cent- a significant increase from just 14 per cent in 1991. For China the similar percentage is about 71 per cent by business enterprises and research institutes (read government) account for only 19 per cent: China has actually gone through an elaborate process of paring down the role of governmental research institutes in the performance of R&D by converting a large number of these institutes into business enterprises. As a result the number of government research institutes (GRIs) in China reduced significantly from 5867 in 1991 to about 1149 GRIs in 2004[6]. Increase in the share of R&D performed by business enterprises is generally considered to be a desirable trend as they tend to implement or productionise the results of their research rather quickly than the government

[6] For detailed account of this see Gu and Lundavall (2006) and Schaaper (2009)

sector where much of the research does not fructify into products and process for the country as a whole[7].

Table 5: Evolution of the Chinese and Indian National Systems of Innovation, 1991-2007
(Sector-wide performances of GERD, Figures are percentage share of each sector in total GERD)

	Government		**Business Enterprises**		**Higher Education**	
	China	**India**	**China**	**India**	**China**	**India**
1991	51.6	86.16	39.8	13.84	8.6	
1996	44.9	78.26	43.2	21.74	11.8	
2000	31.2	77.21	60.3	18.46	8.6	4.33
2007	19.2	67.91	72.3	27.71	8.5	4.38

Source: OECD (2008) and Department of Science and Technology (2009)

The business enterprise sector is now emerging as the core of the NSI in both the countries although it is much more pronounced in the case of China than in India. In China, the business sector has become the largest R&D performer in terms of S&T inputs and outputs. According to these indicators, the business sector plays a dominant role in the S&T development of China. However, due to various historical and structural reasons, the efficiency and the innovation capacity of the business sector is still insufficient, despite a large and rapid increase in scale and scope.

The R&D expenditure of the business enterprise sector of both the countries has risen, once again the Chinese annual growth rate at 31 per cent is much higher than that is recorded for India and as a result the R&D expenditure of Chinese enterprises is almost 16 times that of its counterparts in India. It must however be noted that both Chinese and Indian firms spent only less than a per cent of their sales turn over on R&D.

It looks as if the business enterprises in both China and India are becoming the core of both country's NSI. However OECD (2008) remarks that "it would be wrong to conclude that

[7] Governmental R&D in India is expended by atomic energy, defense, space, health and agricultural sectors. The spillover of government research to civilian use is very much limited in the Indian context although in more recent times conscious efforts have been made by the government is slowly beginning to produce results. This especially so in the area of astronautic research. For details see Mani (2010b).

firms already form the backbone of the Chinese NIS. To a significant extent, the rapid increase in business sector R&D has resulted mechanically from the conversion of some public research institutes into business entities often without creating the conditions for them to become innovation oriented firms.

We now come to the issue of R&D expenditure by foreign companies operating from India. The biennial R&D surveys conducted by the Department of Science and Technology and published in its *Research and Development Statistics* do not report R&D expenditure by MNCs separately. It has only a category called 'private sector' which may include those incurred by foreign companies as well. The only source of data on R&D expenditure by foreign companies is by the successive surveys titled 'Finances of Foreign Direct Investment Companies'. Although the RBI has been reporting this survey for quite some time, it is only since 2002-03 that it has started reporting the R&D expenditure incurred by what it refers to as FDI companies which in essence are foreign companies. See Table 6.

Table 6: R&D expenditure by FDI companies in India (Rs in Millions)

	FDI Companies	Total private sector companies	Share of FDI companies (%)
2002-03	2860	34983	8.18
2003-04	3100	44713	6.93
2004-05	3570	60390	5.91
2005-06	5290	74442	7.11
2006-07	6680	91281	7.32
2007-08	22230	111929	19.86
2008-09	26010	NA	NA
2009-10	28830	NA	NA

Source: Reserve Bank of India (various issues) and Department of Science and Technology (2009)

In an absolute sense the R&D expenditures, by FDI companies, has shown a robust increase from Rs 2,860 million in 2002-03 to Rs 28,830 million in 2009-10 and the share of foreign companies in total R&D has risen to around 20 per cent according to the most recently available estimates (Table 5). However, this increase is fairly recent as the R&D expenditures by FDI companies jumped dramatically in 2007-08; for the earlier period, their share stagnated around 7 per cent. So the role of foreign firms in the R&D undertaken in India seems to have increased but since the changes have been sudden and we have data on R&D expenditures only for a limited number of years, we are not in a position to draw any firm conclusions about the increasing share of foreign companies in the generation of innovations.

A further indicator of the growing importance of MNCs in the performance of R&D is the growth of R&D in India by affiliates of MNCs from the USA. See Figure 2. The R&D investments by these MNCs have shown sharp increases since 2004, coinciding with the growth of foreign R&D centres in the country. While the increase in 2004 does not show up in Table 5, the increase in 2007-08 is consistent with the estimates presented there.

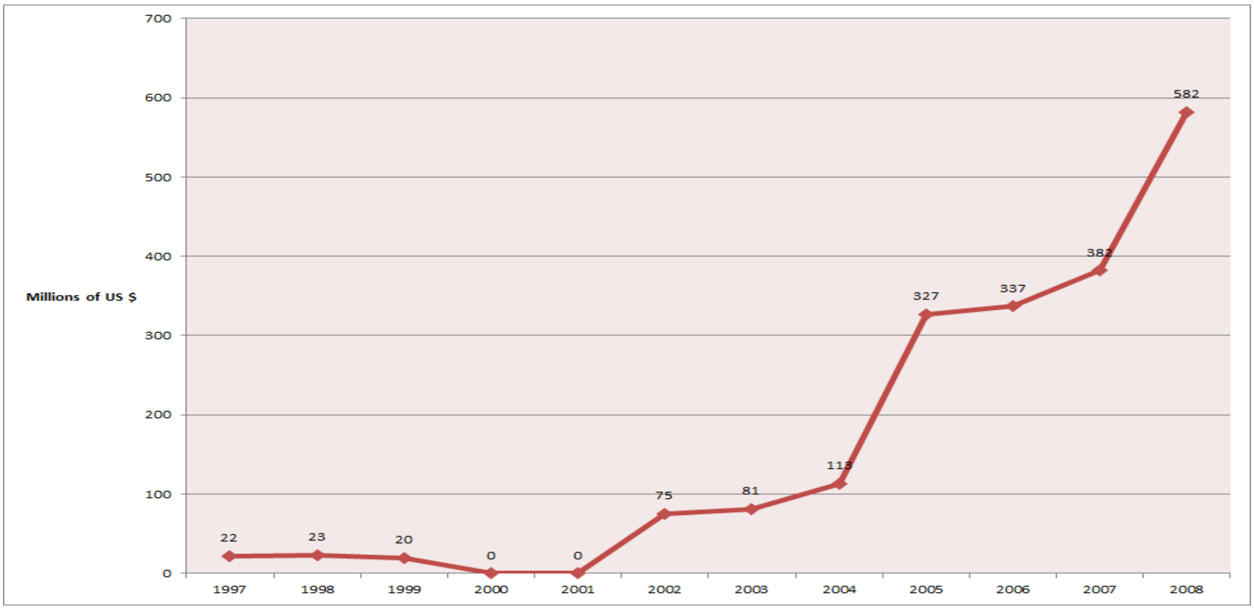

Figure 2: R&D Investments in India by Affiliates of US MNCs
Source: National Science Board (2012)
Note: Data for 2000 and 2001 are not reported

Role of Foreign Companies in Innovative Outputs India: Analysis of Patenting Data

R&D investment is basically an input measure of innovation while patents are an output measure. There are three different types of patents, namely patenting by Chinese and Indian inventors in the US, Triadic patents and national patents in both China and India. We examine the record of the two countries in each of these. We begin with the US patenting record of the two countries. Both the countries have improved their US patenting record since the onset of reforms (Table 7), again China having more patents than India.[8] In fact, the difference between the two countries' record with respect to patenting has increased over time. China moved rapidly ahead of India in utility patents in 2004 and increased the gap significantly in 2008, while the same trend was observed in the case of design patents since the year 2000.. But there is an important difference between the two countries. India has, relatively speaking, more utility patents; the share of design patents of India's total US patents being rather low. Increasingly, a large share of the Chinese US patents are design patents accounting for as much as one third of the total patents.

Broadly, a "utility patent" protects the way an article is used and works, while a "design patent" protects the way an article looks, or the look and feel of the product. In that sense utility patents can be viewed as representing 'new inventions' while design patents protect the ornamental appearance for an article that includes its shape/configuration or surface ornamentation or both. Both design and utility patents may be obtained on an article if invention resides both in its utility and ornamental appearance as articles of manufacture can possess both functional and ornamental characteristics. Therefore, it is possible that many of the design patents may be on the same inventions for which product patents have been filed.[9]

[8] Both China and India together account for much of the patents that inventors from the BRICs have secured in the USA

[9] For details see, http://www.uspto.gov/web/offices/pac/mpep/documents/1500_1502_01.htm

Table 7: Trends in US patenting by Chinese and Indian inventors

(Number of patents granted by the USPTO)

	Utility patents			Design patents			Total Patents			Ratio of utility to total patents		
	Total world	China	India	Total world	China	India	Total world	China	India	Total world	China	India
1979	48854	0	14	3119	0	0	51973	0	14	0.94		1
1980	61819	0	4	3949	0	0	65768	0	4	0.94		1
1981	65771	2	6	4745	0	0	70516	2	6	0.93	1	1
1982	57888	0	4	4944	0	0	62832	0	4	0.92		1
1983	56860	0	14	4563	0	0	61423	0	14	0.93		1
1984	67200	2	12	4938	0	0	72138	2	12	0.93	1	11
1985	71661	1	10	5066	0	0	76727	1	10	0.93	1	1
1986	70860	7	18	5518	0	0	76378	7	18	0.93	1	1
1987	82952	23	12	5959	0	0	88911	23	12	0.93	1	1
1988	77924	47	14	5679	1	0	83603	48	14	0.93	0.98	1
1989	95537	52	14	6092	0	1	101629	52	15	0.94	1.00	0.93
1990	90365	47	23	8024	1	0	98389	48	23	0.92	0.98	1.00
1991	96511	50	22	9569	2	1	106080	52	23	0.91	0.96	0.96
1992	97444	41	24	9269	0	0	106713	41	24	0.91	1.00	1.00
1993	98342	53	30	10630	0	0	108972	53	30	0.90	1.00	1.00
1994	101676	48	27	11095	0	1	112771	48	28	0.90	1.00	0.96
1995	101419	62	37	11712	1	1	113131	63	38	0.90	0.98	0.97
1996	109645	46	35	11410	2	1	121055	48	36	0.91	0.96	0.97
1997	111984	62	47	11414	4	1	123398	66	48	0.91	0.94	0.98
1998	147517	72	85	14766	16	7	162283	88	92	0.91	0.82	0.92
1999	153485	90	112	14732	9	1	168217	99	113	0.91	0.91	0.99
2000	157494	119	131	17413	42	0	174907	161	131	0.90	0.74	1.00
2001	166035	195	178	16871	70	1	182906	265	179	0.91	0.74	0.99
2002	167331	289	249	15451	101	6	182782	390	255	0.92	0.74	0.98
2003	169023	297	342	16574	127	7	185597	424	349	0.91	0.70	0.98
2004	164290	404	363	15695	192	9	179985	596	372	0.91	0.68	0.98
2005	143806	402	384	12951	163	16	156757	565	400	0.92	0.71	0.96
2006	173772	661	481	20965	309	19	194737	970	500	0.89	0.68	0.96
2007	157282	772	546	24062	462	24	181344	1234	570	0.87	0.63	0.96
2008	157772	1225	634	25565	647	37	183337	1872	671	0.86	0.65	0.94
2009	167349	1655	679	23116	613	38	190465	2268	717	0.88	0.73	0.95
2010	219614	2657	1098	22799	645	37	242413	3302	1135	0.91	0.80	0.97

Source: Computed from USPTO

It is important to note while India is still focusing on the ‘technical’ the Chinese have learnt to play the patenting game in the ‘ornamental’ segment as well. Arguably, the difference in the share of the design patents in the two countries is also affected by the sectoral distribution of patents these two countries own; while India focuses on pharmaceuticals and chemistry related technologies, China has an important share of electronics and telecommunications, areas that are more amenable to design innovations.

A still another important issue is of the ownership of these patents. In India, the share of foreign companies has increased, quite significantly, over the years. In fact, Mani (2009) had argued that the surge in Indian patenting in the US is to be attributed to the activities of foreign R&D centres. As such these increase in patenting behavior does lead one to infer that India has become innovative rather it has become an important location for innovative activity to occur (See Figure 3). We observed a similar trend for China as well although it may be argued that a lot of the foreign companies patenting from China are of Taiwanese origin[10].

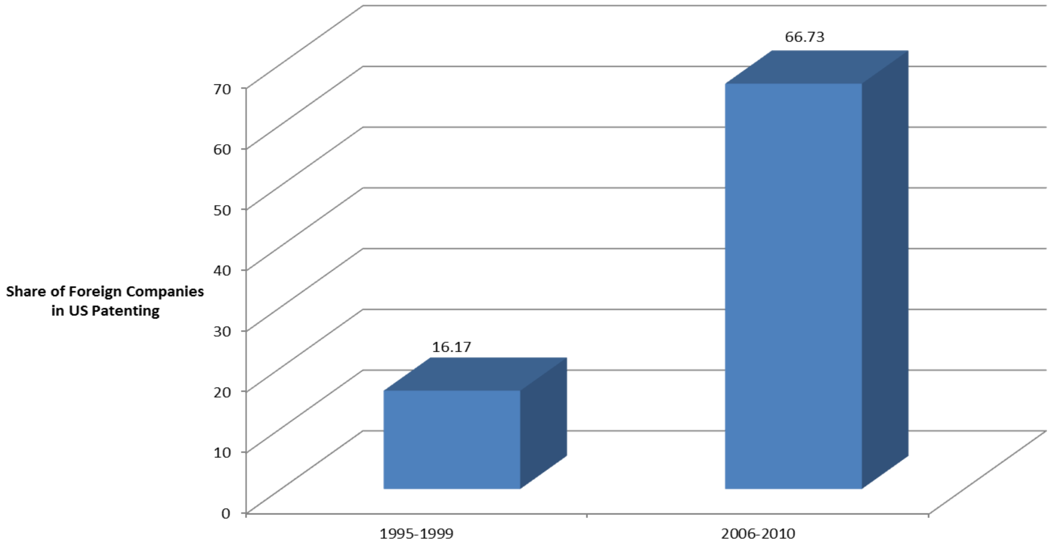

Figure 3: Growing Share of Foreign Entities in US Patenting by Indian Inventors
Source: Computed from Mani (2002) and USPTO

It is interesting to find out the details of the foreign companies that are active in patenting from India**.** During the five year period 2006 through 2010, we could identify 59 companies (See Table 8). A number of important inferences can be drawn from the Table 8. First, almost all the companies are ICT ones of US origin. Second, although India has a fair amount of innovation capability in pharmaceutical research, the only company that has patented the

[10] The two companies that account for a significant portion of Chinese patents in the US are Hong Fujin Precision Industry and Hon Hai Precision. Both are part of the Foxconn Technology group.

output of its research from India is the hitherto Indian company, Ranbaxy. Since 2008, it is part of the Japanese pharmaceutical MNC, Daiichi Sankyo and therefore is not exactly a representative of a foreign R&D centre as it has become foreign purely due to change of ownership. It is interesting to note that despite India's full compliance with the provisions of TRIPS in January 1, 2005, outsourcing of patenting yielding R&D projects by MNCs are yet to be conducted in India. There are of course a number of international pharmaceutical companies outsourcing portions of a large R&D project to Indian entities. Clinical trials are the most frequently encountered pharmaceutical R&D outsourcing type that is found in India. The sheer number of MNCs operating in the ICT area confirms the oft repeated popular impression that India has a fair amount of innovation capability in the ICT software and in some cases hardware too (especially of the embedded software type). More specific details on the scope of these R&D projects are not known.

Table 8: Foreign companies based in India active in US patenting, 2006-2010

	Foreign Company	**Industry**	**Cumulative patents granted 2006-2010**
1	International Business Machines Corporation	ICT	250
2	Texas Instruments, Incorporated	ICT	211
3	General Electric Company	Electronics and Medical Devices	193
4	Stmicroelectronics Pvt. Ltd.	ICT	135
5	Honeywell International Inc.	ICT	93
6	Intel Corporation	ICT	92
7	Cisco Technology, Inc.	ICT	91
8	Symantec Operating Corporation	ICT	91
9	Broadcom Corporation	ICT	60
10	Hewlett-Packard Development Company, L.P.	ICT	57
11	Microsoft Corporation	ICT	49
12	Sun Microsystems, Inc.	ICT	43
13	Sabic Innovative Plastics, Ip Bv	Chemicals	39
14	Freescale Semiconductor, Inc.	ICT	35
15	Sap Aktiengesellschaft	ICT	31
16	Cypress Semiconductor Corp.	ICT	28
17	Adobe Systems, Inc.	ICT	27
18	Oracle International Corporation	ICT	27

19	Veritas Operating Corporation	ICT	26
20	Ranbaxy Laboratories Limited	Pharmaceutical	24
21	Ge Medical Systems Global Technology Company, Llc	Electronics and Medical Devices	23
22	Novell, Inc.	ICT	23
23	Yahoo, Inc.	ICT	22
24	Redpine Signals, Inc.	ICT	17
25	Analog Devices, Inc.	ICT	16
26	National Semiconductor Corporation	ICT	16
27	Oracle America, Inc.	ICT	15
28	Cadence Design Systems, Inc.	ICT	14
29	Gm Global Technology Operations, Inc.	Automotive	13
30	Lsi Corporation	ICT	11
31	Teva Pharmaceutical Industries, Ltd.	Pharmaceutical	11
32	Infineon Technologies Ag	ICT	10
33	Symantec Corporation	ICT	10
34	Netapp, Inc.	ICT	9
35	Nxp B.V.	ICT	9
36	Agere Systems Inc.	ICT	8
37	Emc Corporation	ICT	8
38	Genesis Microchip Inc.	ICT	8
39	Alcatel-Lucent Usa Inc.	ICT	7
40	Amazon Technologies, Inc.	ICT	7
41	Hellosoft Inc.	ICT	7
42	Nvidia Corporation	ICT	7
43	Samsung Electronics Co., Ltd.	ICT	7
44	Sicronic Remote Kg, Llc	ICT	7
45	Usv Limited	ICT	7
46	Airtight Networks, Inc	ICT	6
47	Kyocera Corporation	ICT	6
48	Motorola, Inc.	ICT	6
49	Synopsys Inc.	ICT	6
50	Tektronix Inc.	ICT	6
51	Cirrus Logic, Inc.	ICT	5
52	Commvault Systems, Inc.	ICT	5
53	Koninklijke Philips Electronics N.V.	ICT	5
54	Osram Sylvania Inc.	Lighting	5
55	Stmicroelectronics Asia Pacific Pte Limited	ICT	5
56	Symbol Technologies, Inc.	ICT	5
57	Thomson Licensing	ICT	5
58	Transwitch Corporation	ICT	5
59	Virage Logic Corporation	ICT	5
	Total		**1969**

Source: Compiled from USPTO

Most MNCs distribute their R&D activities across a range of countries and the prime reason for choosing a specific location is essentially dictated by the availability and cost of the human resource. So in order to find out the importance of the research done in India to their global research operations and patenting, we computed the share of Indian patents in the total US patents that each of these companies have been granted. The larger the share of Indian patenting larger will be the importance of Indian R&D activity to a particular MNC. See Table 8. Data on only 49 out of 59 MNCs (as reported in Table 9) are available as the USPTO does not report the patenting activity of the parent companies of the remaining companies. The 49 companies are arranged in a descending order. Some of the companies are related to each other. For instance Symantec has actually taken over Veritas in 2005. On an average, the India R&D outfit of the MNCs is increasingly contributing to the US patenting performance of their respective parent company. There are of course considerable variations across the companies ranging from as much as 46 per cent in the case of Symantec to as little as 0.042 per cent in the case of Samsung. But for almost all the companies the share of India based patenting activity has actually shown an increase.

In both the countries there has been a tremendous surge in the number of national patents granted but national patenting is still dominated by foreign inventors although the share of domestic inventors has been showing some fluctuations. Of the two, the share of domestic inventors is higher in China and in the case of India although the share of domestic inventors kept on rising (with some fluctuations) until 2005, it has started declining since that year. Mani (2012, *forthcoming*).

Table 9: Importance of India in the US patenting of MNCs

Name of MNC	Percentage Share of Patents emanating from Indian R&D operations					
	2006	2007	2008	2009	2010	Total
Symantec Operating Corporation	0.000	5.882	40.625	19.298	24.848	22.980
Veritas Operating Corporation	18.033	22.642	50.000	66.667	0.000	21.667
STMicroelectronics Pvt. Ltd.	10.588	22.785	20.000	16.993	15.607	17.003
Sabic Innovative Plastics, Ip Bv		33.333	9.375	16.495	15.323	15.234
Novell, Inc.	7.317	9.091	8.333	2.083	15.517	8.812
Teva Pharmaceutical Industries, Ltd.	0.000	0.000	9.091	6.250	10.526	5.851
Texas Instruments, Incorporated	4.432	5.073	5.695	5.547	6.651	5.466
GE Medical Systems Global Technology Company, Llc	7.143	7.692	3.409	4.348	1.639	5.275
Cypress Semiconductor Corp.	0.621	4.348	9.434	6.452	5.839	4.819
Adobe Systems, Inc.	0.000	1.786	4.651	3.425	7.489	4.729
Yahoo, Inc.	3.333	0.000	0.000	6.400	4.483	4.074
General Electric Company	3.045	3.952	4.391	3.279	4.337	3.806
Netapp, Inc.			0.000	4.000	4.082	3.797
Amazon Technologies, Inc.	0.000	0.000	18.750	4.348	1.695	3.684
Oracle America, Inc.					3.348	3.348
Cadence Design Systems, Inc.	2.564	0.000	4.348	2.174	4.688	3.011
Honeywell International Inc.	0.894	1.859	2.908	3.817	4.248	2.911
Tektronix Inc.	2.703	2.041	0.000	4.878	4.545	2.752
Analog Devices, Inc.	1.418	2.113	2.459	0.000	5.634	2.536
Symantec Corporation	0.000	8.824	0.000	1.754	3.030	2.525
Oracle International Corporation	1.724	0.595	2.488	2.463	3.495	2.415
Cisco Technology, Inc.	1.849	1.724	2.557	1.972	2.962	2.298
Cirrus Logic, Inc.	7.500	1.613	0.000	0.000	2.273	2.262
Sap Aktiengesellschaft	0.000	3.333	1.626	4.199	0.930	2.099
Freescale Semiconductor, Inc.	2.787	0.932	2.795	1.087	2.249	1.957
Osram Sylvania Inc.	0.000	5.970	0.000	2.632	0.000	1.845
Synopsys Inc.	0.000	4.110	0.000	1.299	2.381	1.770
Broadcom Corporation	0.909	2.814	2.022	1.961	1.253	1.710
Lsi Corporation	0.000	0.704	0.000	1.212	3.902	1.682
Sun Microsystems, Inc.	0.644	1.148	3.340	1.961	1.515	1.620
National Semiconductor Corporation	0.772	1.322	1.571	2.000	1.961	1.480
Kyocera Corporation	0.000	0.000	0.000	1.923	3.101	1.399
International Business Machines Corporation	0.718	1.152	0.911	1.310	1.466	1.154
Intel Corporation	0.102	0.644	1.242	1.043	2.421	1.048
Nxp B.V.	0.000	0.000	1.042	0.000	2.917	1.014
Symbol Technologies, Inc.	0.826	0.000	0.855	0.971	1.905	0.876
Nvidia Corporation	0.000	0.000	0.571	0.369	2.183	0.791
Alcatel-Lucent Usa Inc.			0.000	0.484	1.089	0.777
Agere Systems Inc.	0.000	0.000	0.000	1.905	1.702	0.755
Emc Corporation	0.000	0.000	0.000	0.800	1.954	0.739
Hewlett-Packard Development Company, L.P.	0.286	0.409	0.563	0.867	1.757	0.737
GM Global Technology Operations, Inc.	0.000	0.000	0.000	0.190	1.277	0.647
Thomson Licensing	0.851	0.483	0.000	0.000	0.763	0.463
Microsoft Corporation	0.137	0.183	0.296	0.552	0.713	0.441
Motorola, Inc.	0.347	0.000	0.857	0.295	0.000	0.290
Infineon Technologies Ag	0.000	0.000	0.371	0.672	0.393	0.256

Koninklijke Philips Electronics N.V.	0.112	0.000	0.207	0.198	0.302	0.162
Samsung Electronics Co., Ltd.	0.000	0.000	0.000	0.028	0.133	0.042

Source: Compiled from USPTO

One hypothesis could be that with the TRIPS compliance of Indian patent regime since January 1 2005, MNCs have shown a rush to patenting in India so that Indian companies and especially the pharmaceutical ones may find it difficult to do incremental innovations.

It is also possible for foreign companies to do research in India and then patent the output of that research at the Indian Patent Office (officially known as Controller General of Patents, Designs and Trademarks). However, the Indian patent office does not publish the list of all foreign companies located in India that patent their research output in India, but does publish a list of top ten foreign companies resident in India and patenting in India, although the data are reported only for the latest period. See Table 10.

It is interesting to note that while almost all the foreign companies based in India and patenting their research output in the US are in the ICT industry, while those patenting in India are in the electronics industry. This is because computer software can be more easily patented in the US while it cannot be patented in India where one needs to show embodiment. Another interesting finding is that the two groups of foreign companies are mutually exclusive with some notable exceptions.

Table 10: Foreign companies based in India and patenting in India (As on 2009-10)

Sl No	Name of foreign company	Industry	Number of patents granted in 2009-10
1	Qualcomm	ICT	230
2	Samsung Electronics	Electronics	79
3	BASF	Chemicals	66
4	Siemens	Electronics	65
5	Thomson Licensing	Service	62
6	Motorola	Electronics	52
7	Philips	Electronics	49
8	LG Elctronics	Electronics	49
9	Honda Motor	Automotive	47
10	LM Ericsson	ICT	41

Source: Controller General of Patents, Designs and Trademarks (2010)

In sum, based on our analysis of both R&D expenditure and patents, it is more or less clear that MNCs are increasingly conducting a portion of their R&D activity in India. This is accomplished through a variety of formats ranging from setting up of their own branches (in the case 100 per cent of the equity of the Indian affiliate is owned by the parent company) to a purely Indian company specializing in R&D outsourcing (such as WIPRO or HCL). We pick up this issue again in IV where we discuss the size of this activity.

III. Engagement with the Literature on Foreign R&D Centres

As discussed earlier, an increasing share of global R&D is being undertaken in developing countries. MNCs from the Western World, European Union, US and Japan, are carrying out R&D in several developing economies. However, such R&D is predominantly located in East and Southeast Asia, India and a few countries in Eastern Europe; this phenomenon has largely bypassed the remaining part of the developing world. What factors have contributed to this process of 'decentralizing' R&D activity? Several studies in recent years have explored the determinants of foreign R&D in developing countries. These determinants have been variously called as 'push and pull' factors or 'demand and supply' factors.[11]

The push factors include increasing competitive pressures that firms in developed countries have to face. These include increase in international competition and increased importance of product performance and quality based competition. There are also pressures to shorten international product penetration of new products and need to launch products in different markets simultaneously. Such competition seems to be accompanied by simultaneous processes that not only increase product differentiation but also homogenize markets globally. Such changes require firms to innovate rapidly and at lower costs but the costs of

[11] For recent reviews see Mitra (2007) and Krishna and Bhattacharya (2009). Schmiele and Mangelsdorf (2009), and He (2007) provide useful empirical analysis. For an excellent review of studies before early 1990s, see Granstrand et al (1993).

R&D in developed nations are on the rise and at times relevant scientific manpower is simply not available. With the increase in technology intensity and complexity of innovative products, processes and services and the multi-disciplinary nature of R&D activity, firms find internal capabilities to be either inadequate or too expensive.[12] The sharp declines in product (service) life cycles also enhance the need to reduce costs and increase the speed to market. Decentralization of R&D is seen as a response to these competitive and associated pressures. The emergence of ICT that facilitates rapid and meaningful interaction across geographies has also enhanced the potential of decentralization. Changes in technologies and use of ICT also create opportunities for increasing modularity of innovation and different modules can potentially be developed in different locations.

Given the 'push' factors, availability of R&D skills at competitive wages, a well-developed national innovation system, globalization of production requiring R&D in proximate regions, market demand for R&D based products can act as pull factors for R&D activity in a specific region. For example, Mitra (2007) argues that salaries of researchers account for about 45 per cent of total R&D expenditure in the US and if the same is undertaken in India, the costs can be much lower. Based on the information available to him for the year 2005, his estimates suggest significant cost savings:

> 'In India, the annual salary of an electronic circuit engineer with a Master's degree and five years of working experience is about 18,000 dollars, compared to 84,000 dollars in the US; a senior engineer in India would earn between 30,000 to 40,000 dollars, compared to 150,000 to 200,000 dollars in the US…*This generally translates into a savings of 30 to 40 per cent, even after accounting for the hidden costs of managing offshore R&D units*…Additionally, *Indian graduates work the longest hours*, on average 2,350 hours a year as compared to their US and German counterparts, who work 1.900 and 1,700 hours respectively. *Indian graduates are*

[12] Increasing technology inter-relatedness among products and technologies along with the increasing tendency towards technology specialization at the firm level also results in a situation that firms, even large MNCs' are not self-sufficient in knowledge resources.

> *more geographically mobile* than their colleagues in other countries' (Mitra, 2007: 45-46, emphasis ours)

Moreover, some estimates also suggest that construction and overhead costs are much lower in India. These constitute about 4 and 17 per cent respectively of the total R&D costs in the US. Savings on construction costs can be in the range of 25-30 per cent while support staff expenses related savings are in the range of 60-70 per cent (Mitra, 2007). Despite recent increases in costs, India is still cost-competitive.

The desire to supply to large emerging markets that requires adaptation of products to local needs results in setting up R&D centers in physical proximity to the manufacturing bases. Early studies identified a link between foreign production and R&D essentially because adaptation to local conditions was required (Granstrand et al, 1993). Such strategies to locate R&D centers close to manufacturing bases and developing country markets were seen as 'knowledge exploiting' strategies of MNCs in the developed countries. Such MNC entry strategies into developing countries were in line with the earlier hypotheses linked to technology life cycle (TLC) ideas that argued, a la Vernon that technologies would be transferred to developing countries in the later stages of the TLC and might need adaptation at that stage. These strategies can be seen as being driven by the 'pull' factors as MNCs *seek markets* in developing countries. The 'push' factors can similarly be equated to *resource seeking'* strategies of MNCs whereby inexpensive knowledge and infrastructure resources are being sought by the investing firms. This resource seeking behaviour can also be termed as a 'knowledge augmenting' (as against knowledge exploiting) strategies as MNCs seek to augment their knowledge bases. This strategy has been on the rise with the development of global innovation networks (Schmiele and Mangelsdorf, 2009).

Another way of broadly dividing the forces that result in geographical decentralization of R&D can be 'demand' and 'supply' factors. Among *demand* based factors proximity to 'host' country markets probably is the most dominant which is required to understand local customers, essentially to adapt technologies to suit local conditions. As mentioned, decentralization may also be undertaken to tap into the scientific and technological infrastructure of host countries to reduce R&D costs and access new knowledge, in other words driven by *supply* of technological resources. Reduction in technology gaps across nations and firms and internationalization of firms through acquisition have made the supply side factors somewhat more prominent in recent years. Granstrand et al (1993) have argued that decentralization to satisfy demand related needs is generally small and does not really 'replace' the R&D done in the home country. However, decentralization of R&D driven by supply side factors may replace home country R&D activities.

Overall, therefore, a large variety of factors have been identified by earlier studies that might influence the incidence and extent of R&D undertaken by foreign firms in developing countries. These factors can be broadly divided into two broad categories:

1. *Pull* factors that are essentially driven by *demand* in host (developing) countries and lead to the use of *market seeking* or *knowledge exploiting* strategies of MNCs; and
2. *Push* factors that are driven by lack of adequate *supply* of knowledge and other resources in home countries while such resources are available at competitive rates in host nations. As a consequence, MNCs employ *resource seeking* or *knowledge augmenting* strategies as they undertake R&D in developing nations.

In the final analysis, which of these factors dominate in a specific situation is an empirical question. Very few studies, however, have explored these issues empirically. Available studies, however, give mixed results. While Schmiele and Mangelsdorf's (2009) results suggest that knowledge exploiting strategies dominate for setting up R&D centers in developing countries, He (2007) finds resource seeking to be more dominant, although market seeking is done simultaneously.

Some Organizational Imperatives: Granstrand et al (1993) show that at the organizational level, early work on MNCs essentially focused on the relationship between headquarter and the subsidiary. Recent literature, however, has more or less moved away from this focus and explores the network character of MNCs. As a consequence, the problems and opportunities associated with the exploitation of a global organization as an integrated whole are being increasingly emphasized. Granstrand et al (1993) also make this interesting point that in the context of international R&D, an increase in 'organizational centralization' is often a response to geographical decentralization. We shall revert to this issue later.

More generally, centralization of R&D organization is a result of diversity of forces and if decentralization does take place, the benefits of centralization will need to be compensated. Centralization, for example, avoids leakages and facilitates protection of firm specific knowledge of MNCs. Besides technological characteristics like tacitness and complexity may require a centralized structure to develop and share knowledge 'internally'. Insofar as centralization in the 'home' country sustains advantages of being in proximity of the home market through better understanding of the market and at the same time help reap economies of scale and scope (through cross-fertilization) in R&D activity, it makes strategic and economic sense. Concentration of R&D also makes sense from the point of view of reducing transaction costs; the costs of co-ordination and control. At the firm level, there was also some evidence of links between 'age, size and stage of corporate development' and extent of internationally performed R&D (see later discussion).

The organizational imperatives mentioned above would not only influence the structure and scope of foreign R&D activity in developing nations like India but would also determine the nature of linkages foreign R&D centers have with domestic entities in these nations.

India specific literature on foreign R&D centers, it is of very recent origin. The earliest work can be traced to Reddy (1997). The study focused on the determinants of FDI in R&D. According to Reddy, the primary driving forces behind such a move by TNCs are technology-related i.e. to gain access to science and technology (S&T) resources and cost-related i.e. to exploit the cost differentials.

Main findings of the TIFAC (2006) wrt FDI in R&D

- R&D Services has emerged as the third segment in Export of IT Services- it occupies a share of 18.4% of software exports accounting for an annual value of $2.3 bn (during 1998-2003)
- R&D investment worth of $1.13 billion has flowed into India during the five year period 1998-2003
- US is the largest investor followed by Germany and Korea, France and Japan. China too has established centres in India
- The study identified 100 R&D centres employing 22980 scientists and engineers
- Lower costs and availability of scientists and engineers are the main determinants
- IT and Telecom, followed by pharmaceutical, auto and chemicals in general are the major industries attracting FDI in R&D
- Nearly half the FDI companies are cases of relocation of inhouse R&D in home country to offshore location in India
- Partnerships with local companies are good at the start but partnerships are not forever – 56 percent of FDI companies prefer to work alone in India, with 100% foreign equity without local partners in equity

Source: TIFAC(2006)

In sum, the existing literature on foreign R&D centres have touched upon the following issues: (i) size of R&D outsourcing activity in India primarily in terms of its physical number; (ii) industry-wide distribution of this activity; (iii) determinants of FDI in R&D; and (iv) the connectedness or otherwise of these with India's National System of Innovation (NSI).

IV. Size of R&D Outsourcing to India

We consider two dimensions of size: (i) physical size in terms of the number of R&D centres; (ii) financial size of this activity.

Number of foreign R&D centres: R&D off-shoring started in India way back in 1984 with Texas Instruments setting up its first R&D center in Bangalore. China's R&D offshoring trend began in the early 1990s with Motorola being the first company to take advantage of the local talent and low cost in China. No precise estimates of the size of this sector in both the countries exist. According to some private estimates[13] there exist 920 MNCs having 1,100 R&D centers in China. The number till December 2010 for India was about 851[14] . Recently a number of estimates on the size of this sector have been made by TIFAC funded studies, the TIFAC itself and by the private consultancy agency, Zinnov. But none of these studies use a clearly identifiable methodology for identifying foreign R&D centres. There is a clear problem of identification here. The two indicators that are used for measuring the size are: (i) the physical number of R&D centres; and (ii) size of R&D activity in money terms. Sometimes a finer distinction is made between number of MNCs and number of foreign R&D centres the latter being higher than the former as one MNC may have more than one R&D centre. All the available studies have focused more on arriving at the number of R&D

[13] http://zinnov.com/blog/?p=160 (accessed on November 23, 2011)

[14] See Zinnov (2011a), p. 11

Centres. However in the absence of objective indicators for identifying foreign R&D centres, the estimates arrived at are mere guestimates and there is nothing sacrosanct about the precision of these numbers. We ourselves have relied on the estimates arrived by Zinnov Management Consulting, as its estimates are now widely used, albeit, in the popular press. It is our understanding that Zinnov itself has identified a centre as a foreign R&D one on the basis the foreign equity holding in the centre, i.e., if it exceeds 10 per cent or more, although this is not made very explicit. Further, we compared the list of centres arrived at by Zinnov with those arrived at by the original 2006 TIFAC study. So the total number of foreign R&D centres operating from India is reckoned to about 639 as on January 2010 although according to Zinnov (2011) this is about 871 by December 2010. A recent TIFAC sponsored study (Mrinalini et al, 2010) arrives at a total number of 700 although even in this study the criteria for identifying the R&D centres is not spelt out in explicit terms. In sum all estimates of the number of foreign R&D centres are mere guestimates and its exactness may not be taken for granted but only as a broad approximations. The Department of Industrial Policy and Promotion (DIPP), which is charged with the responsibility of compiling and publishing data on FDI inflows to India does not identify R&D services while it reports on sector-wide distribution of FDI equity inflows[15]. TIFAC is the only official agency that has attempted to quantify the size of this activity.

Value of R&D services: The *National Accounts Statistics* (Central Statistical Organization, 2011) publishes data on domestic value added of R&D Services[16] since 2004-05 (Table 10).

[15] See 'India FDI Fact Sheet', Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, http://dipp.nic.in/fdi_statistics/india_fdi_index.htm (accessed on January 3, 2012)

[16] According to Central Statistical Organization (2007), this include Research and development, market research and public opinion polling, business & management consultancy, architectural, engineering & other technical activities, advertising and business activities n.e.c. excluding auctioning (NIC-98 codes 73, 7413, 7414, 742, 743, 749(-)74991).

On an average, the domestic value added of R&D services, stood at about 78 per cent of the Gross Expenditure on R&D (GERD). Even during the five year period under consideration, the activity has increased almost four fold. These R&D services are done by both Indian and foreign entities. Since R&D services done by the latter are almost entirely (if not entirely) are exported to their respective parent entities, one can obtain precise estimates of it on the basis of an analysis of detailed Balance of Payments tables published by the Reserve Bank of India (RBI)[17]. Here we present two such estimates: first one refers to R&D services strictly defined and this is of course the narrow definition. The second one refers to architectural, engineering and technical services. The total of these two gives us a broader definition of R&D services. The RBI has been reporting these two since 2004-05. The two categories show us two different trends (Table 11).

Table 11: Trends in Value Added and Exports of R&D Services (in Millions of US $)

Year	**Domestic Value Added of R&D services (Current Prices)**	**Exports**			
		R&D services	Architectural, Engineering and Technical Services	Total R&D Services	Share of Exports in Value Added (%)
2004-05	3644.66	221	1417	1638	44.94
2005-06	4574.52	395	3193	3588	78.43
2006-07	5687.99	760	3457	4217	74.14
2007-08	8117.84 (93)	1335	3144	4479	55.17
2008-09	9288.72	1385	1766	3151	33.92
2009-10	12122.13	565	4738	5303	43.75

Source: Central Statistical Organisation (2011); Reserve Bank of India (various issues) Reserve Bank of India (various issues)

Three conclusions emerge from an analysis of the size of R&D outsourcing to India. First, it was growing very rapidly until the financial crisis of 2008. Thereafter the growth has actually declined by a significant amount; while the exports of ‘pure’ R&D services have not picked up in 2009-10, on observes an increase in architectural and technical services. Second, the

[17] In fact since the very recent change over to the presentation of BoP data according to BPM6 format, data on both receipts and payments of R&D services are directly reported under ‘Business Services’. See Reserve Bank of India (2011).

size of this activity, although, increasing is much less than what is claimed by trade circles[18] even if one takes the broader definition of including engineering and technical services. Third, on an average, only 57 per cent of domestic production of R&D services (broadly defined) is actually exported. This may mean at least two things. Firstly, it may be that there is actually an underestimation of the exports data. In fact, the RBI series of R&D services *per se* does show some indication of this underestimation. This belief is based on an analysis of the mirror statistics of imports of R&D services from India by one of the leading importer's of R&D services from India, namely the United States. This is further explained below (See also Figure 4). Secondly, the domestic market for R&D services is quite huge. In fact the RBI's data also show that the payments for R&D services increased from 57 million US $ in 2004-05 to 318 million US$ in 2009-10. Consequently the net balance on this account may not be much.

United States is one of the leading importers of R&D and testing services from India. The US data on imports of R&D, and testing services are regularly collected by its Bureau of Economic Analysis (BEA). The National Science Board (2012) , based on the BEA data has tracked the imports of R&D, and testing services from all countries including that from India during the period 2006 through 2009. Based on the original BEA source, we have added the data for 2010 as well and this is presented in Figure 4. The series show a similar trend, excepting for 2010, as reported in Table 10 above. In fact according to National Science Board (2012), India has become leading supplier of R&D services to the US accounting for as much as 9 per cent of its total imports of this form of service. A still more important

[18] The R&D outsourcing market for IT in India is forecasted to grow from the present size of 1.3 billion dollars in 2003 to $9.1 billion in 2010 at a compounded annual growth rate of 32.05 per cent, Frost & Sullivan, which undertook the study for the department of IT, said in its report. According to another estimate arrived at by Zinnov, the market for R&D offshoring to India, which stood at $11.8 billion in 2010, is expected to grow to $13.1 billion in 201. See Zinnov (2011b).

finding is that although China may have more number of foreign R&D Centres, she exports far less R&D and testing services to the US (especially during the period 2006 through 2010).

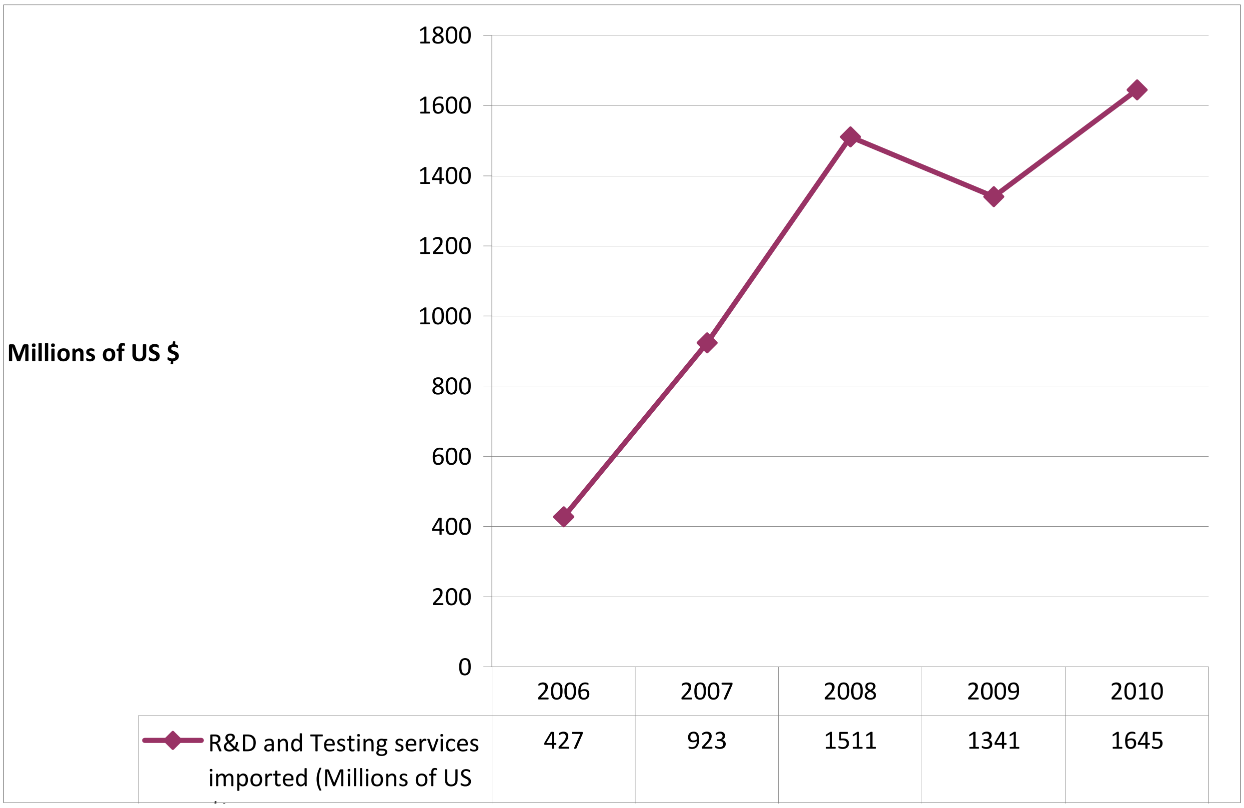

Figure 4: US Imports of R&D and Testing Services from India (Millions, US $), 2006-10
Sources: National Science Board (2012), Bureau of Economic Analysis, *Detailed Statistics for Cross Border Trade, Business, Professional and Technical Services*, Table 7a, http://www.bea.gov/International/International_services.htm#summaryandother (accessed on January 22, 2012)

Classification of Foreign R&D Centres: Our analysis so far shows that there are a wide variety of foreign R&D centres in India. In the general literature on globalization of innovation (Kuemmerle, 1999), these centres are normally categorized into two analytical categories on the basis of flows of information between the parent company and its foreign R&D centre into: Home-base Augmenting (HBA) and Home-base exploiting (HBE). The former is where technology actually flows from the foreign R&D centre to the home base in which the home base gets further strengthened, technologically speaking, on the basis of R&D conducted at the foreign centre. On the contrary, in the case of the latter (HBE) information and technology flows from the home base to the foreign R&D Centre. From the MNCs point of view it is beneficial to have more of the HBA variety which will go towards replenishing its technological capability while from the host country (especially developing host countries), it is more beneficial to have more of HBE type of foreign R&D centres. However a careful analysis of the definitions of these two categories show that no objective criteria are used to identify foreign R&D centres into either of the two categories. Very often the centres self-select themselves into one of these two categories during a survey of these centres. It is therefore necessary to have a more realistic analytical categorization of the R&D centres[19]. Such an exercise will be helpful for engineering spillovers from this activity to the host economy. We, therefore, attempt such an analytical classification.

As noted before, based on the combined TIFAC and Zinnov lists we could identify about 639 foreign R&D centres in India. Most of them are either branches (parent owns 100 per cent of the equity of the host firm) of the parent MNC while a few of them are subsidiaries (having foreign equity holding between 51 to 99 per cent). Still a few of them are purely Indian outsourcing companies (like WIPRO for instance) undertaking contract R&D on behalf of MNC clients abroad.

In terms of industry-wide distribution, most of these R&D centres are actually confined to certain high technology industries such as telecommunications equipment, information technology, pharmaceuticals and biotech industries.

[19] There is also a another categorization of foreign R&D centres on the basis of the nature of ownership of these centres into two categories MNC captives and Domestic R&D service providers. According to Zinnov (2011b), nearly two-thirds of the total number of centres belongs to the former and about one-third to the latter. WIPRO technologies, HCL technologies, Tata Consulting Serives, Infosys, Patni and Sakrn Communication are the leading domestic R&D service providers.

Of these 639, our understanding is that majority of the centres are only fulfilling a part of a large and globally distributed R&D project, which is carried out in a number of locations of which the Indian centre is one such location. However there are also a few of the total that are engaged in complete R&D projects. We denote the former category as *partial innovators* as the output of the R&D projects that they perform may not be patentable at all. Further we denote the latter category as *innovators* as they have developed patented technologies that can even be licensed to other companies and royalties earned.

Therefore all the MNCs that either takes a patent in the USPTO or at the Indian PTO is classified as innovators. These account for about 10.17 per cent of the total number of R&D centres. The remaining 89.93 per cent which does not have any patents, but an operation in the country are denoted as partial innovators. Needless to add this may be a conservative way of classifying the R&D centres as innovators and partial innovators, but it certainly is as objective as data would allow us to do. Given the fact that the latter are the majority, possible spillovers to the local economy from the operations of these Centers are limited[20]. We will examine this proposition, more rigorously, through the data generated through our field survey in the section VI below.

V. Public Policy and FDI in R&D

Although both FDI and R&D are promoted and incentivized by both the central and state governments, there is no explicit policy in attracting FDI in R&D. However, by analyzing the successive policy pronouncements with respect to the above two issues, we were able to identify the following two which have important bearing on encouraging FDI in R&D:

[20] In fact, available studies in the case of China (Lan and Liang, 2006) too has shown that foreign R&D centres are hardly connected with the national system of innovation of China as their linkages are often enough with their own parent firms abroad. This is likely to be the same for India as well.

- R&D Services *excluding* basic research and setting of R&D/ academic institutions which would award degrees/diplomas/certificates would be allowed 100 per cent foreign direct investments (FDI) under the automatic route;

- To further encourage R&D across all sectors of the economy, weighted deduction on expenditure incurred on in-house R&D has been enhanced from 150 per cent to 200 per cent. Weighted deduction on payments made to national laboratories, research associations, colleges, universities and other institutions, for scientific research has been enhanced from 125 per cent to 175 per cent. The income of such approved research association shall be exempt from tax, according to the union budget of 2010-11.[21] Since Trade Related Investment Measures (TRIMS) of the WTO requires a level playing field for both domestic and foreign companies, these incentives are applicable to both the sets of companies.
- Further, the government (through the newly established National Innovation Council) is examining a proposal to set up a venture capital (VC) fund for promoting drug discovery in the country. Earlier, the government had announced to set up an US$ 2.14 billion VC fund to finance drug discovery projects in India. The proposed funding of US$ 2.14 billion which includes substantial contribution from the private pharmaceutical industry under the public private partnership (PPP) model, is expected to provide favourable environment for drug innovation in the country and to make India a hub for new drug discoveries.

[21] See, Mani (2010a) for a survey of earlier policies used for in promoting R&D in India.

With such a liberal policy on the extent of FDI in R&D services, and a seemingly generous tax incentive scheme, along with the availability of well trained and relatively speaking cheaper human resource in science and engineering, one would assume that India has a fairly generous policy regime with respect to FDI in R&D.

VI. Determinants, Structure & Scope and Nature of Linkages of Foreign R&D Centres: Insights from a Primary Survey[22]:

A sample survey of foreign R&D Centers was undertaken by us. The data was collected through face-to-face interviews with senior managers. A comprehensive list of all R&D centers was first prepared on the basis of information provided by the firm Zinnov and TIFAC. This list included 639 firms. A sample of 120 firms was surveyed from this list. To the extent possible, efforts were made to cover firms of different sizes and in all locations. Given the lack of detailed data on all firms when the sample was drawn, we cannot claim that our sample is representative of the universe in a statistical sense. However, we are sure that it is representative enough to provide useful analytical insights that can be used to develop more detailed hypotheses that can be explored with more detailed data.

Sample Characteristics: As mentioned, a total of 120 firms were surveyed. Table 12 provides the geographic distribution of the surveyed firms. While these firms are spread over different parts of the country, 50 per cent were located in Bangalore. This was followed by the Delhi, Mumbai-Pune, Hyderabad and Chennai regions. If we compare the regional distribution of our sample firms with that of the firms identified by TIFAC in 2006, we seem to have done reasonably *well although Bangalore Hyderabad and Chennai are a bit over-represented at the cost of* Delhi and Mumbai-Pune. Since for a large number of firms in the Zinnov as well as TIFAC lists, addresses were not available, we are not in a position to

[22] The field survey was conducted during the period January through April 2010,.

ascertain if the geographical distribution has in fact shifted in favour of these 'over-represented' regions.

Table 12: Distribution of Surveyed Foreign R&D Centres by Geographic Location		
Location	**Number of R&D Centres**	**Share (%)**
Bangalore	60	50.0 (45)
Chennai	10	8.3 (4)
New Delhi (NCR)	21	17.5 (22)
Hyderabad	13	10.8 (7)
Mumbai	14	11.7 (17)*
Pune	2	1.7
Total	**120**	100.0 (100)

Source: Primary Survey
Note: Figures in parentheses in the last column report the percentage of R&D centers identified by TIFAC survey in these locations (TIFAC, 2006). * Estimate includes both Mumbai and Pune.

Earlier studies have shown that there was a spurt in the setting up of R&D centers in India in the 1990s and especially after the year 2000 (Krishna and Bhattacharya, 2009). In our sample only about 24 per cent firms were set up before 1990, about 31 per cent in the 1990s and about 37 per cent after the year 2000. For about 8 per cent of the firms this information is not available (Table 13). In general, therefore, bulk of the sample firms were set up after 1990.

Table 13: Distribution of Sample Firms by Year of Establishment	
Year	**Number of Companies**
Before 80	10 (8.3)
1980-85	9 (7.5)
1985-90	10 (8.3)
1990-95	12 (10.0)
1995-00	25 (20.8)
2000-05	27 (22.5)
After 2005	17 (14.2)
Not Known	10 (8.3)
Total	**120 (100.0)**

Source: Primary Survey

The information on the investments made in the R&D centers was not easily available. As many as 38 per cent firms did not disclose this information. But overall, most of the centers seem to be relatively small with investments of less than Rs 50 million (Table 14). Although the information seems meager on this issue, it would be safe to argue that India has not yet seen a situation where the bulk of R&D centers have been set-up with huge investments. As things evolve, we might see such developments.

Table 14: Distribution of Sample Firms by Capital Investment	
Initial Capital Investment (in millions)	**Number of Companies**
0-50	59 (49.2)
50-100	8 (6.7)
100-150	1 (8.3)
150-200	3 (2.5)
>200	3 (2.5)
Not Known	46 (38.3)
Total	**120 (100.0)**

Source: Primary Survey

The fact that on average the R&D centers are not large is also evident from the distribution of sample firms by number of R&D personnel (Table 15). About 42 per cent centers have less than 50 R&D personnel. The share of centers with less than 100 workers is almost 60 per cent; only about 11 per cent centers reported more than 500 R&D workers.

Table 15: Distribution of Sample Firms by Number of R&D Personnel	
R&D Personnel Total Number	**Number of Companies**
< 10	7 (5.8)
10-49	43 (35.8)
50-99	22 (18.3)
100-249	21 (17.5)
250-499	8 (6.7)
> 500	13 (10.8)
Not Known	6 (5.0)
Total	**120 (100.0)**

Source: Primary Survey

The other interesting feature of the foreign R&D centers is that only a small proportion has minority foreign ownership (Table 16). Almost all of them have more than 50 per cent foreign equity, the share of firms having more than 90 per cent foreign ownership is almost 50 per cent. Overall, what emerges from this simple description is that R&D centers in India are: (a) concentrated in Bangalore; (b) relatively young; (c) small with low average capital investment and small number of researchers; and (d) have foreign control with high equity share of MNCs.

Table 16: Distribution of Sample Firms by Foreign Ownership	
% of foreign ownership	**Number of Companies**
< 50	6 (5.0)
50-90	31 (25.8)
90-100	12 (10.0)
100	47 (39.2)
Not known	24 (20.0)
Total	**120 (100.0)**

Source: Primary Survey

Determinants of Foreign R&D Activity in India

As a part of our survey, we had collected information on the strategic objectives of doing R&D in India. The respondents were asked to rate various objectives on a seven point scale. Relative scores of different objectives signify their relative importance; a higher score implying higher importance. Table 17 reports these scores.

Table 17: Relative Importance of Various Objectives for Undertaking R&D in India	
Objectives	**Rating**
Utilizing local human resources	6.25
Reducing R&D cost	5.63
Developing new technology for world markets	5.74
Developing new technology for regional markets	5.68
Developing new technology for local markets	5.44
Modifying existing technology for local markets	5.13
Providing technology support for local manufacturing, marketing etc.	5.10
Tracking local technology development	5.22
Participating in national standards setting	5.15
Providing R&D on contract for multinationals/subsidiaries based in India	4.65
Providing R&D on contract for multinationals/subsidiaries not based in India	4.46

Source: Primary survey

As can be seen in Table 17, the listed objectives encompassed various determinants of foreign R&D discussed in the earlier section. While a more detailed analysis would be required to ascertain if the scores of different objectives are statistically significant from each other, a few interesting patterns can be highlighted:

1. Utilizing local resources is the most important objective which supports the *resource seeking* argument wherein the supply of knowledge resources is the key objective of decentralizing R&D to India;
2. Development of new technologies for different markets (especially world and regional markets) is more important than modifying existing technologies for local markets and/or providing support to local manufacturing. Thus, while both strategies co-exist, on average *knowledge augmenting* strategies seem more important than *knowledge exploiting* strategies in the investment decisions of R&D centers in India. This also gets reflected in the importance given to the objective of tracking technology development in India;
3. Provision of contract R&D to foreign and local subsidiaries, on average is not very important.

The relative scores of objectives do not change much when we look at centers of different vintages and sizes (Appendix Tables 1 and 2). A more detailed analysis may throw up some additional insights. However, some interesting patterns emerge when one compares with different degrees of foreign ownership (Table 18). On average, as compared to others, centers with 100% foreign ownership give more importance the objectives of utilizing local human resources, reducing R&D costs, developing new technologies for global and regional markets. In other words, centers having higher equity linked control are more geared towards resource seeking and knowledge augmenting strategies to serve markets outside India.

Table 18: Relative Importance of Various Objectives for Undertaking R&D in India Degrees of Foreign Ownership

Objectives	Rating (Foreign Ownership)			
	0-69	**70-99**	**100%**	**ALL**
Utilizing local human resources	5.97	6.00	6.45	6.25
Reducing R&D cost	5.44	5.70	5.81	5.63
Developing new technology for world markets	5.74	5.63	5.81	5.74
Developing new technology for regional markets	5.79	5.44	5.68	5.68
Developing new technology for local markets	5.74	5.19	5.38	5.44
Modifying exiting technology for local markets	5.47	4.96	4.98	5.13

Providing technology support for local manufacturing, marketing etc.	5.50	5.04	4.83	5.10
Tracking local technology development	5.68	4.63	5.18	5.22
Participating in national standards setting	5.65	5.04	4.95	5.15
Providing R&D on contract for multinationals/subsidiaries based in India	5.26	4.70	4.30	4.65
Providing R&D on contract for multinationals/subsidiaries not based in India	5.00	4.81	3.98	4.46
Others (please specify): ______________				

Source: Primary Survey

At a broader level, a hypothesis that emerges from this data is that higher control is sought in cases where the technologies being developed are for global markets. Interestingly, for tracking local technology development, higher control is not required. Given the skewed distribution of our sample in favour of centers that has majority equity owned by foreign firms, this hypothesis needs to be explored more carefully and systematically.

To explore the determinants of R&D location in India more directly, a question was asked about the factors that provide the local center a competitive edge. Table 19 provides a summary. Once again, the scores suggest that a multiplicity of objectives is being satisfied by setting up these centers. While cost considerations (low personnel and other costs) dominate as MNCs seek to meet competition, market demand, proximity to production facilities competence in specific fields of local entities were also quite important. Once again, both knowledge-augmenting as well as knowledge-exploiting strategies co-exist with the former being somewhat more important. The role of social networks also seems important but relatively less so as compared to other factors. This probably reflects the role of non-resident Indians in facilitating setting up of R&D centers in India, a feature that has been highlighted in a few studies (see, for example, Chakrabarti and Bhaumik, 2009).

Table 19: Factors for Providing Competitive Advantage to the Centre	
Factors	**Rating**
Lower Personnel Cost	6.02
Lower Overall Cost	6.08
Proximity to the Market Demand of India	5.42
Proximity to production facilities in India	5.21
Special Natural & Social Resources (e.g. species resources, Language)	5.00
Competence in certain technological field (horizontal specialization: e.g., in field of medicine R&D for heart disease, information privacy technologies)	5.23
Competence in certain R&D Stage (vertical specialization: e.g., in the stage of engineering implementation, Standardization)	5.31
Social Networks: Close personal relations with leaders in the headquarter	4.97

Source: Primary Survey

When one looks at factors that provide competitive advantage to the R&D centers by size of the center (Appendix Table 3) no clear pattern seems to emerge. However, the importance of some factors seems to differ by age of the establishments and the degree of foreign control (Appendix Table 4). The following patterns seem interesting and require more exploration, including a better understanding of their implications (as mentioned earlier, more systematic analysis to test the statistical significance of these ratings/scores would help gain some more concrete insights):

1. The relative importance of proximity to production facilities, market demand, special resources, competences and networks is less for younger R&D centers, especially those that were set up after year 2000. This suggests that younger centers are more geared for global needs and less dependent on NRI and other networks. This makes intuitive sense. However, the decline in the importance of specific resources and certain competences needs some exploration;
2. The relative importance of proximity to production facility, some competences and social networks is also less for centers that are fully owned by MNCs. Once again while the relative unimportance of production facilities and social networks makes some intuitive

sense as fully owned R&D centers may not be driven mainly by these factors, the smaller role of some competences needs to be explored further.

To further explore the determinants of R&D location in India another direct question was used to collect information on the relative roles of different factors. Respondents were asked to rate the relative importance of various factors in influencing the decision to set-up R&D in India. Once again the broad patterns observed earlier are evident: market and resource seeking opportunities are being exploited through the location of R&D in India (Table 20). Large and growing market, high quality human resources and availability of technological resources along with S&T institutions have contributed to this location decision. At the policy level, IP policy and R&D related incentives seem important and the state is considered to be reasonably efficient but the firms do not feel that they can influence policy making as much by being part of India's R&D system.[23]

Table 20: Factors Influencing Decision Regarding Location of R&D Center (Activity)

Factors	Rating
India's economic development, market size and opportunities	6.11
Availability of technological resources of India's related industries	5.95
Level of science and education (including basic facilities of scientific research)	5.76
Acquisition of high quality human resources	5.80
Availability of infrastructural and other facilities	5.67
Protection of Intellectual Protection Rights	5.42
Favorable policies attracting R&D investment (tax and other incentives)	5.43
Efficiency of government departments (Registration, clearances etc.))	5.12
Ability to participate in policy making, science and technology projects, etc.	4.88

Source: Primary Survey

Are the factors affecting location decisions different for firms of different types? A preliminary analysis of the data (see Appendix Tables 5-7) does not suggest any differences across size of centers, their age and the extent of foreign ownership. A more detailed statistical analysis might bring out some useful patterns.

[23] The empirical results of He (2007) also showed that at the cross-country level, stronger IPR regimes and good contract enforcement has a positive impact on decisions to set up R&D centers in developing countries.

Structure and Scope of Foreign R&D Activity in India: The type of activity undertaken at the Centers in India would also reflect the strategic intent behind setting up these centers. To get an idea of this, the respondents were required to rate the importance of different types of research in their centers. Table 21 provides a summary of responses. Once again, what is striking is that the centers undertake all kinds of research activity and their activity is not restricted to adaptation or improvement of products and processes. In fact, new product development, basic and advanced research is reported to be the three most important foci of work in these centers. Product design and new process development are also quite important. The importance of technology support as a function is also quite important and in fact, may not be statistically different from the top three areas of focus.

Table 21: Relative Importance of Various Types of R&D Activity in the R&D Centers

	Rating
Basic Research	5.90
Advanced Research	5.83
New Product Development	6.03
Product Design	5.77
New Process Development	5.65
Engineering Research, Engineering Implementation	5.29
Product Improvement	5.37
Process Improvement	5.57
Software Architecture, Software Tools Design	5.37
Middleware, Applied Software, Software Module Development	5.15
Software Programming and Testing	5.41
Technology Data Collection, Analysis, and Testing	5.39
Technological Support	5.53

Source: Primary Survey

While the relative importance of different types of research is difficult to estimate, these patterns are consistent with the descriptions of R&D undertaken by R&D centers in India; these descriptions highlight the fact that research can range from low end activity to very complex almost state-of –the-art work (See Krishna, 2009 for some interesting descriptions of work undertaken by different centers).

A systematic analysis of the relative importance of different research activities across various types of centers, a preliminary analysis provides some intriguing patterns (Appendix Tables 8 and 9). Both technology support as well as basic/advanced research seems to have higher importance among centers set up before 1990 as compared to centers of more recent vintages. This suggests that a focus on basic/advanced research may not have been a recent phenomenon. Less importance given to basic/advanced research and product design in the smallest size centers is understandable.

While the research activity at these centers may encompass a wide variety, the time horizon is clearly for short-duration projects, with the emphasis on research output that can be used immediately or within 2 years; long range research that requires research outputs to be used after 5 years is clearly not on the priority list of these centers (Table 22).

Table 22: Time Horizon of Research Undertaken in India

Time Horizon of Research	Rating
A. Research output to be used immediately	5.79
B. Research output to be used in 1-2 years	5.43
C. Research output to be used in 3-5 years	4.33
D. Research output to be used in more than 5 years	3.83
E. Not known – Choice left to contracting organization	

Source: Primary Survey

Appendix Tables 10-12 show that the relative importance of long term research is low in centers of all sizes, age and degree of foreign ownership; in general research outputs that provide immediate utility or within a short period of time are preferred over long term research projects. Interestingly, the importance given to long duration projects (more than 5 years time frame) is the highest for centers with the least share of foreign ownership (Appendix Table 12). However, such differences need to be statistically tested before meaningful conclusions can be drawn.

The relatively short-term focus of the R&D undertaken in the centers is also evident by the average duration of the majority of the R&D projects undertaken by these centers; sixty per cent of the projects undertaken are of less than 2 year duration. Interestingly, projects of less than one year duration are not popular.

Moreover, the average size of the R&D projects undertaken by these centers, both in terms of investments as well as R&D personnel, are generally small; almost 80 per cent of the centers reported the average project investment to be less than US $ 100,000 (Table 23) and about 63 per cent centers reported the average size of the R&D team to be less than 10 persons (Table24).

Overall, while the projects undertaken by the R&D Centers in India cover a wide range of activities including basic research and product development, the R&D projects undertaken are small in terms of investment and team size with a relatively short time horizon of less than two years. Larger and long duration projects are not very common.[24]

Table 23: Distribution of Sample Centers by Average Size of Investment in R&D Projects

Average R&D investment of one project (US $ 000)	**Number of Companies**
<50	60 (50.0)
51-100	35 (29.2)
101-200	10 (8.3)
201-500	10 (8.3)
>500	4 (3.3)
Not Known	1 (0.8)
Total	**120 (100.0)**

Source: Primary Survey

[24] The finding that on average the R&D project size is relatively small in India is in line with the findings of Mrinalini et al (2010)

Table 24: Distribution of Sample Centers by Average Number of R&D Personnel in a Project	
Average No of R&D personnel involved in a project	**Number of Companies**
< 5	31 (25.8)
6-10	44 (36.7)
11-25	29 (24.2)
26-50	10 (8.3)
> 50	6 (5.0)
Total	**120 (100.0)**

Source: Primary Survey

Finally, another way to ascertain the nature of R&D activity is to look at the outcomes of the R&D activity. The survey collected data on the relative importance of different R&D outputs (Table 25). Interestingly, patents in the home and the host country are on top the list along with new and modified products. The patents can relate to both products and processes and in that sense, the importance given to new/modified products and processes is consistent with the importance given to patents in home and host countries.

Table 25: The Relative Importance of Various R&D outputs	
Main R&D Outputs	**Rating**
Home Country Patents	5.56
Host Country Patents	5.28
Other Country Patents (e.g. USPTO patents)	4.53
Papers	4.79
Technology Reports	4.95
Prototyping	4.93
Technology Standards	5.08
New/Modified Products	5.37
New/Modified Processes	5.04
Technology Services	4.87

Source: Primary Survey

Nature of Linkages Fostered by Foreign R&D Centers in India: The impact of R&D centers on host country economies is largely seen through the lens of linkages these entities build with local enterprises and institutions. Larger and deeper these linkages, higher are the possibilities of positive spillovers and associated learning. In the context of India Mrinalini and Wakdikar (2008) and Mrinalini et al (2010) have explored this issue at length. It has been pointed out that FDI in R&D results in higher demand for S&T manpower and the competition to attract good R&D personnel between domestic and foreign entities increases with such entry. Mrinalini et al (2010) also find evidence for similar tendencies. Apart from the 'interaction' through the labour market, there is limited evidence of linkages with local entities. In fact, of the 706 identified R&D Centers, Mrinalini et al (2010) found that only 118 had any linkages. And even these linkages were geared to attract skilled manpower. There were few cases foreign R&D centers helped develop curriculum in some educational institutions, awarded fellowships, undertook training and also, in few cases did collaborative projects. Moreover, linkages differed by sector, the interaction being higher in IT as compared to pharmaceuticals and auto and there have been few linkages with national laboratories and very few spinoffs from R&D centers. So, overall, there has been a positive impact of the R&D centers, the extent has not been very large.[25]

Our survey did not collect detailed data on the nature of linkages from the responding firms. In order to get a relative picture, the importance of both local and foreign linkages was sought to be ascertained. Table 26 provides a summary of the responses. Evidently, linkages with other R&D centers of the parent company (in and outside India) and other global business units of the parent company were much more important than local linkages with buyers, suppliers and local educational institutions.

[25] See Mrinalini et al (2010) for detailed data on 38 R&D centers that were surveyed by the authors.

Table 26: Importance of Various Linkages and Channels for Foreign R&D Centers	
Linkages with	**Rating**
Other R&D Centers of the Parent Company (excluding those in India)	5.79
Other R&D Centers of the Parent Company in India	5.58
Global Business Units of the Parent Company	5.63
Subsidiaries of the Parent Company in India	5.23
Local (Indian) Universities & Institutions	4.97
Local (Indian) Suppliers of machinery and inputs	5.02
Local (Indian) Buyers	5.13
Other Indian Companies in the Same Industry	5.09
Foreign-based contracting organizations for whom other services provided earlier	4.83
India-based contracting organizations for whom other services provided earlier	4.92

Source: Primary Survey.

A preliminary analysis of the reported importance of different linkages for different types of centers reveals that the relative importance does not change much with size and vintage of the center. However, as one would expect, parent company related linkages are more important for entities that are fully owned by MNCs as compared to those which have lower foreign equity. (Appendix Tables 13-15).

Based on the type of research activity undertaken by the R&D centers, these have been categorized as *support labs* (off-shoring of R&D by the parent company), *locally integrated labs* that involve R&D exports and local manufacturing and marketing activities, *collaborative labs* that collaborate with local entities and *internationally independent labs* whose research agenda is not driven by the parent companies (Krishna, 2009). Based on our data, one can argue that the R&D centers are essentially 'support labs' catering to needs of the parent company and their 'local integration' through 'collaborative activities' is limited. Such labs are unlikely to be 'internationally independent' but to ascertain the nature of autonomy these centers enjoy we asked questions about the process of selecting research projects and nature of interaction that these centers have with various entities as they implement these projects.

Interestingly, despite the fact that the R&D activities in the R&D centers surveyed are largely geared towards the needs of the parent company, researchers at the centers remain the most important sources of R&D project ideas, followed by global and local business units of the parent company (Table 27). Appendix Table 16 does not suggest that the importance of various sources of R&D project ideas varies systematically by size, age or degree of foreign ownership of the center. However, a feature worth noting and may need to be explored further: researchers at the center and local businesses are more important sources of project ideas for older centers and for those where foreign ownership is the lowest.

Table 27: Relative Importance of Various Sources of R&D Projects

Source of R&D Projects	Rating
Proposed by researchers at the Center	5.78
Global Business Units of the Parent Company (Contracted projects)	5.63
Local Business Units of the Parent Company (Contracted projects)	5.32
Other companies with no base in India (Contracted projects)	4.54
Other companies with a base in India (Contracted projects)	4.64

Source: Primary Survey

The increasing role of local researchers in the R&D activity is also reflected in the pattern of patenting. As was mentioned earlier, patents were seen as very important research outputs by the sample centers. Chakrabarti and Bhaumik (2009) find that collaboration between Indian and non-Indian researchers is used only by foreign entities in India. Interestingly, in recent years, foreign companies (including R&D centers) have also increased the use of all-Indian teams. This gets reflected in the teams of researchers mentioned as inventors in the patent applications filed by foreign firms in India and abroad in recent years. The authors argue that this trend suggests maturing of Indian researchers as does the fact noted earlier that local researchers are the most important sources of ideas for R&D projects in the centers surveyed by us.

Table 28: Frequency of Communication of Center with Various Entities	
Organizations	**Rating**
R&D headquarter of the parent company	4.24
Other R&D organizations of the parent company	3.84
Manufacturing companies of the parent company in India	3.38
Enterprises in India (suppliers or customers)	3.61
Universities or academies in India	3.09

Source: Primary Survey

During the implementation of the projects, researchers clearly communicate more frequently with the R&D headquarters of the parent company or other R&D centers of the company. Relatively limited communication with the manufacturing units of the parent company presumably implies that few R&D projects focus on modifying or adapting technologies for local production units. It is noteworthy that the frequency of communication is the least with the local educational institutions (Table 28). This reaffirms the earlier finding that the links with local universities are weak. The nature of communication does not seem to vary systematically across centers of different sizes and age, but firms with lower foreign ownership seem to interact more frequently with local entities as compared to those centers which are either fully owned by foreign entity or have a very large foreign ownership. (Appendix Table 17).

The strength of linkages is not only determined by the frequency of interaction but by the criticality of different 'partners' in resolving problems. The survey responses suggest that even in the resolution of research problems, the R&D centers in India are dependent more on R&D headquarters of the parent company or other R&D centers of the parent firm (Table 29). However, other local entities are also used to resolve problems. This implies that some spillover benefits would be accruing to these entities through the variety of interactions that are required to take care of problems.

Table 29: Relative Importance of Various Entities in Resolving the R&D Problems	
Entities	**Rating**
R&D headquarters of the parent company	6.06
Oversea R&D organizations of the parent company	5.49
Universities or academies in India	4.61
R&D organizations of other MNCs	4.52
R&D organizations of Indian companies	4.54
Professional research or technology references	4.83
Contracting organization	4.48

Source: Primary Survey

The estimates of relative importance of different entities in resolving R&D problems for centers of different sizes and age do not show a clear pattern. But once again centers with lower foreign equity rely less on the R&D centers of the parent company and use local entities more to sort out R&D related issues.

VII. Summing up

The paper seeks to analyse the role of MNC R&D centers in India in the context of the emerging NIS in the post reform. While part of the paper based on the survey data is exploratory a few interesting (but many of which tentative) conclusions emerge. Some of these may form useful hypotheses for future research in this area.

1. There is enough quantitative evidence to show that number of foreign R&D Centres in India have shown significant increases in the post reform period although there exists some doubts on the financial size of R&D services that are exported from the country. Data drawn from detailed Balance of Payments Indicate that the size of R&D services exported are only 10 per cent of its estimates arrived at industry sources;
2. Majority of the R&D Centres are either subsidiaries or branches of US-based MNCs and one industry where they are extremely active is the ICT sector;

3. MNC R&D centers in India seem to fulfill multiplicity of objectives. The analysis of the survey data suggests that the primary objective of MNC R&D centers in India is not market seeking; the resource seeking dimension seems to dominate. Development of new technologies for global and regional markets is more important for these centers than modifying/adapting technologies for local market needs or manufacturing requirements. In that sense, the activities of these R&D centers are more ‘knowledge augmenting’ than ‘knowledge exploiting’. Availability of quality scientists and engineers at considerably reduced compensation levels compared to their home countries is one of the important determinants of their location in India;
4. All kinds of research in being performed in the MNC R&D centers in India including high end work in basic research, product design and development and the with a focus on outputs in the form of patents and new and modified products. Over time much (ranging from 50 to 66 per cent of the total based on US patenting) of the industrial innovations recorded in India are the result of R&D projects conducted by these centres Therefore it is certainly not a low end operation. It is possible, however, that most of the R&D centres are primarily performing the more labour-intensive parts of a large R&D project with only a few implementing the entire R&D projects;
5. As a corollary of (1v) the foreign R&D centres seem to have become the locus for creating ‘reverse innovations’-defined as innovations that are first created in India by these centres and then exported back to their parent firms for use both in developed and developing country markets. An industry where this is clearly visible is in medical devices;
6. The projects performed in these centers are small, on average, with short-term horizons of less than 2 years. But local researchers seem to get a fair bit of autonomy in terms of

contributing research ideas; they are most important source of research ideas followed by global business units of the MNC;

7. The linkages of these R&D centers with local enterprises and institutions are rather limited; both for performing R&D and for solving research problems, they seek significantly more support from the global business units of the MNC. So knowledge spillovers for the local economy emanating out of the activities of these centers may not be non-existent but remains rather limited;
8. Finally India does not have any explicit policies to promote FDI in R&D although there exists in the country a number of policy instruments, fiscal and otherwise, for promoting FDI and incentivising the conduct of R&D. One needs to explore how other countries have used policy instruments to enhance the spillover benefits of MNC R&D activities in India.

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Appendix Table 1: Relative Importance of Various Objectives for Undertaking R&D in India by Size of the Center

Objectives	Number of Employees					
	< 50	50-99	100-249	> 250	Not Known	ALL
Utilizing local human resources	6.24	6.50	6.33	6.29	5.00	6.25
Reducing R&D cost	5.76	6.27	5.48	5.24	4.17	5.63
Developing new technology for world markets	5.82	5.95	5.76	5.38	5.50	5.74
Developing new technology for regional markets	5.70	6.00	5.71	5.33	5.33	5.68
Developing new technology for local markets	5.52	5.73	5.57	5.00	4.83	5.44
Modifying exiting technology for local markets	5.12	5.36	5.14	5.14	4.17	5.13
Providing technology support for local manufacturing, marketing etc.	5.02	4.95	5.29	5.33	4.83	5.10
Tracking local technology development	5.38	4.95	5.12	5.29	5.00	5.22
Participating in national standards setting	5.16	5.11	5.55	4.86	4.83	5.15
Providing R&D on contract for multinationals/subsidiaries based in India	4.46	4.68	5.05	4.71	4.50	4.65
Providing R&D on contract for multinationals/subsidiaries not based in India	4.30	4.82	4.95	3.90	4.67	4.46

Appendix Table 2: Relative Importance of Various Objectives for Undertaking R&D in India by Age of the Center

Objectives	Year of Establishment				
	Before 1990	1990-2000	After 2000	Not Known	ALL
Utilizing local human resources	6.34	6.40	6.33	5.00	6.25
Reducing R&D cost	5.83	5.79	5.56	4.70	5.63
Developing new technology for world markets	5.72	5.76	5.82	5.40	5.74
Developing new technology for regional markets	5.97	5.81	5.46	5.10	5.68
Developing new technology for local markets	5.45	5.60	5.46	4.70	5.44
Modifying exiting technology for local markets	5.55	5.26	4.69	5.00	5.13
Providing technology support for local manufacturing, marketing etc.	5.59	5.29	4.67	4.60	5.10
Tracking local technology development	5.50	5.50	4.82	4.80	5.22
Participating in national standards setting	5.40	5.51	4.64	4.90	5.15
Providing R&D on contract for multinationals/subsidiaries based in India	5.07	5.02	4.00	4.40	4.65
Providing R&D on contract for multinationals/subsidiaries not based in India	4.55	4.95	3.85	4.50	4.46

Appendix Table 3: Factors Providing Competitive Advantage to the Centre by Size of the Center

Factors	Number of Employees					
	< 50	**50-99**	**100-249**	**> 250**	**Not Known**	**ALL**
Lower Personnel Cost	5.88	6.55	6.33	5.76	5.00	6.02
Lower Overall Cost	6.14	6.36	6.19	5.81	5.00	6.08
Proximity to the Market Demand of India	5.46	4.86	6.00	5.33	5.33	5.42
Proximity to production facilities in India	5.38	4.91	5.29	5.14	4.83	5.21
Special Natural & Social Resources (e.g. species resources, Language)	4.98	4.73	5.00	5.38	4.83	5.00
Competence in certain technological field (horizontal specialization: e.g., in field of medicine R&D for heart disease, information privacy technologies)	5.28	5.36	5.43	4.90	4.83	5.23
Competence in certain R&D Stage (vertical specialization: e.g., in the stage of engineering implementation, Standardization)	5.30	5.27	5.76	5.10	4.67	5.31
Social Networks: Close personal relations with leaders in the headquarter	5.02	4.77	5.52	4.67	4.33	4.97

Appendix Table 4: Factors Providing Competitive Advantage to the Centre by Year of Establishment and Degree of Foreign Control

Factors	Year of Establishment				
	Before 1990	**1990-2000**	**After 2000**	**Not Known**	**ALL**
Lower Personnel Cost	6.21	6.12	6.10	4.70	6.02
Lower Overall Cost	6.17	6.05	6.31	5.00	6.08
Proximity to the Market Demand of India	5.41	5.86	5.13	4.70	5.42
Proximity to production facilities in India	5.24	5.55	4.92	4.80	5.21
Special Natural & Social Resources (e.g. species resources, Language)	5.28	5.24	4.59	4.80	5.00
Competence in certain technological field (horizontal specialization: e.g., in field of medicine R&D for heart disease, information privacy technologies)	5.59	5.19	5.10	4.90	5.23
Competence in certain R&D Stage (vertical specialization: e.g., in the stage of engineering implementation, Standardization)	5.90	5.21	5.08	4.90	5.31
Social Networks: Close personal relations with leaders in the headquarter	5.48	4.83	4.82	4.60	4.97
Factors	**Foreign Ownership**				
	0-69	**70-99**	**100%**	**ALL**	
Lower Personnel Cost	6.15	5.89	6.11	6.02	
Lower Overall Cost	6.24	5.96	6.19	6.08	
Proximity to the Market Demand of India	5.68	5.33	5.13	5.42	
Proximity to production facilities in India	5.38	5.41	4.96	5.21	
Special Natural & Social Resources (e.g. species resources, Language)	5.00	5.15	4.81	5.00	
Competence in certain technological field (horizontal specialization: e.g., in field of medicine R&D for heart disease, information privacy technologies)	5.47	5.30	4.96	5.23	
Competence in certain R&D Stage (vertical specialization: e.g., in the stage of engineering implementation, Standardization)	5.59	5.15	5.23	5.31	
Social Networks: Close personal relations with leaders in the headquarter	5.50	4.52	4.91	4.97	

Appendix Table 5: Factors Influencing Decision Regarding Location of R&D Center (Activity) by Size of Firm

Location of R&D Center (Activity)	Number of Employees					
	< 50	50-99	100-249	> 250	Not Known	ALL
India's economic development, market size and opportunities	6.16	6.36	6.24	5.86	5.17	6.11
Availability of technological resources of India's related industries	5.90	6.27	5.86	5.95	5.50	5.95
Level of science and education (including basic facilities of scientific research)	5.76	6.05	5.62	5.81	5.00	5.76
Acquisition of high quality human resources	5.78	5.82	6.10	5.62	5.50	5.80
Availability of infrastructural and other facilities	5.70	5.95	5.90	5.24	5.00	5.67
Protection of Intellectual Protection Rights	5.62	5.55	5.33	5.14	4.50	5.42
Favorable policies attracting R&D investment (tax and other incentives)	5.58	5.68	5.38	5.10	4.67	5.43
Efficiency of government departments (Registration, clearances etc.))	5.29	5.23	5.14	5.00	4.50	5.12
Ability to participate in policy making, science and technology projects, etc.	4.90	5.27	4.86	4.67	4.17	4.88

Appendix Table 6: Factors Influencing Decision Regarding Location of R&D Center (Activity) by Year of Establishment

Location of R&D Center (Activity)	Year of Establishment				
	Before 1990	1990-2000	After 2000	Not Known	ALL
India's economic development, market size and opportunities	6.28	6.14	6.23	5.00	6.11
Availability of technological resources of India's related industries	6.14	5.90	6.05	5.20	5.95
Level of science and education (including basic facilities of scientific research)	6.00	5.86	5.56	5.40	5.76
Acquisition of high quality human resources	5.83	6.00	5.72	5.20	5.80
Availability of infrastructural and other facilities	5.69	5.69	5.87	4.70	5.67
Protection of Intellectual Protection Rights	5.41	5.33	5.67	4.80	5.42
Favorable policies attracting R&D investment (tax and other incentives)	5.41	5.31	5.64	5.20	5.43
Efficiency of government departments (Registration, clearances etc.))	5.34	4.90	5.33	5.00	5.12
Ability to participate in policy making, science and technology projects, etc.	5.03	4.62	5.08	4.80	4.88

Appendix Table 7: Factors Influencing Decision Regarding Location of R&D Center (Activity) Degrees of Foreign Ownership

Location of R&D Center (Activity)	Foreign Ownership			
	0-69	**70-99**	**100%**	**ALL**
India's economic development, market size and opportunities	6.21	5.93	6.04	6.11
Availability of technological resources of India's related industries	6.03	5.74	6.00	5.95
Level of science and education (including basic facilities of scientific research)	5.88	5.33	5.96	5.76
Acquisition of high quality human resources	5.71	5.26	6.11	5.80
Availability of infrastructural and other facilities	5.50	5.15	5.89	5.67
Protection of Intellectual Protection Rights	5.44	5.07	5.53	5.42
Favorable policies attracting R&D investment (tax and other incentives)	5.59	5.15	5.38	5.43
Efficiency of government departments (Registration, clearances etc.))	5.64	5.04	4.94	5.12
Ability to participate in policy making, science and technology projects, etc.	5.32	4.81	4.64	4.88

Appendix Table 8: Relative Importance of Various Types of R&D Activity in the R&D Centers by Size and Year of Establishment

	Number of Employees					
	< 50	**50-99**	**100-249**	**> 250**	**Not Known**	**ALL**
Basic Research	5.60	6.23	6.38	5.95	5.33	5.90
Advanced Research	5.80	6.23	5.57	5.90	5.33	5.83
New Product Development	5.86	6.18	6.10	6.33	5.67	6.03
Product Design	5.68	6.05	5.43	6.14	5.33	5.77
New Process Development	5.54	5.68	6.00	5.71	5.00	5.65
Engineering Research, Engineering Implementation	5.14	5.41	5.52	5.62	4.17	5.29
Product Improvement	5.12	5.41	5.48	5.71	5.67	5.37
Process Improvement	5.58	5.41	5.67	5.48	6.00	5.57
Software Architecture, Software Tools Design	5.36	5.00	6.10	5.29	4.50	5.37
Middleware, Applied Software, Software Module Development	5.16	4.91	6.00	5.00	3.50	5.15
Software Programming and Testing	5.32	5.27	5.86	5.57	4.50	5.41
Technology Data Collection, Analysis, and Testing	5.22	5.41	5.76	5.43	5.33	5.39
Technological Support	5.40	5.45	6.14	5.57	4.50	5.53

	Year of Establishment				
	Before 1990	**1990-2000**	**After 2000**	**Not Known**	**ALL**
Basic Research	6.14	5.84	5.74	6.10	5.90
Advanced Research	6.21	5.88	5.55	5.60	5.83
New Product Development	6.07	6.07	6.13	5.40	6.03
Product Design	6.00	5.95	5.50	5.30	5.77
New Process Development	5.93	5.74	5.63	4.50	5.65
Engineering Research, Engineering Implementation	5.41	5.60	4.92	5.00	5.29
Product Improvement	5.76	5.56	4.89	5.20	5.37
Process Improvement	5.97	5.70	5.24	5.10	5.57
Software Architecture, Software Tools Design	5.48	5.51	5.11	5.40	5.37
Middleware, Applied Software, Software Module Development	5.14	5.53	4.74	5.10	5.15
Software Programming and Testing	5.79	5.53	5.08	5.00	5.41
Technology Data Collection, Analysis, and Testing	5.76	5.42	5.16	5.10	5.39
Technological Support	5.93	5.63	5.29	4.80	5.53

Appendix Table 9: Relative Importance of Various Types of R&D Activity in the R&D Centers by Degrees of Foreign Ownership

	Foreign Ownership			
	0-69	**70-99**	**100%**	**ALL**
Basic Research	6.09	6.15	5.77	5.90
Advanced Research	5.94	5.85	5.87	5.83
New Product Development	5.91	5.70	6.15	6.03
Product Design	5.88	5.63	5.87	5.77
New Process Development	5.74	5.41	5.60	5.65
Engineering Research, Engineering Implementation	5.32	5.33	5.28	5.29
Product Improvement	5.53	5.26	5.36	5.37
Process Improvement	5.71	5.44	5.62	5.57
Software Architecture, Software Tools Design	5.38	5.37	5.23	5.37
Middleware, Applied Software, Software Module Development	5.21	5.33	5.02	5.15
Software Programming and Testing	5.59	5.41	5.28	5.41
Technology Data Collection, Analysis, and Testing	5.65	5.48	5.11	5.39
Technological Support	5.82	5.59	5.28	5.53
Others (please specify):____________				

Appendix Table 10: Time Horizon of Research by Size of the Center

Time Horizon of research	**Number of Employees**					
	< 50	**50-99**	**100-249**	**> 250**	**Not Known**	**ALL**
A. Research output to be used immediately	5.96	5.86	6.25	5.67	5.00	5.79
B. Research output to be used in 1-2 years	5.52	5.76	5.35	5.52	5.17	5.43
C. Research output to be used in 3-5 years	4.38	4.24	4.55	4.43	4.67	4.33
D. Research output to be used in more than 5 years	3.68	3.52	4.40	3.95	5.00	3.83
E. Not known – Choice left to contracting organization						

Appendix Table 11: Time Horizon of Research by Year of Establishment

Time Horizon of research	Year of Establishment				
	Before 1990	**1990-2000**	**After 2000**	**Not Known**	**ALL**
A. Research output to be used immediately	5.66	6.31	5.62	5.40	5.79
B. Research output to be used in 1-2 years	5.28	5.44	5.62	5.00	5.43
C. Research output to be used in 3-5 years	4.66	4.56	4.00	4.50	4.33
D. Research output to be used in more than 5 years	4.17	3.88	3.35	4.50	3.83
E. Not known – Choice left to contracting organization					

Appendix Table 12: Time Horizon of Research by Degree of Foreign Ownership

Time Horizon of research	Foreign Ownership			
	0-69	**70-99**	**100%**	**ALL**
A. Research output to be used immediately	5.97	5.52	5.94	5.79
B. Research output to be used in 1-2 years	5.50	5.20	5.74	5.43
C. Research output to be used in 3-5 years	4.53	3.96	4.68	4.33
D. Research output to be used in more than 5 years	4.44	3.68	3.66	3.83
E. Not known – Choice left to contracting organization				

Appendix Table 13: Importance of Various Linkages and Channels for Foreign R&D Centers by Size of the Center

Linkages	Number of Employees					
	< 50	50-99	100-249	> 250	Not Known	ALL
Other R&D Centers of the Parent Company (excluding those in India)	5.96	6.18	5.43	5.81	5.17	5.79
Other R&D Centers of the Parent Company in India	5.54	5.68	5.52	5.67	5.50	5.58
Global Business Units of the Parent Company	5.44	5.86	5.67	6.05	4.67	5.63
Subsidiaries of the Parent Company in India	5.22	5.32	5.43	5.19	4.33	5.23
Local (Indian) Universities & Institutions	4.90	5.05	4.95	5.05	5.00	4.97
Local (Indian) Suppliers of machinery and inputs	5.00	5.00	5.10	5.00	5.00	5.02
Local (Indian) Buyers	4.92	5.36	5.43	5.14	5.00	5.13
Other Indian Companies in the Same Industry	5.04	5.14	5.43	4.95	4.67	5.09
Foreign-based contracting organizations for whom other services provided earlier	4.74	4.77	5.33	4.57	4.83	4.83
India-based contracting organizations for whom other services provided earlier	5.04	4.77	5.24	4.71	4.00	4.92

Appendix Table 14: Importance of Various Linkages and Channels for Foreign R&D Centers by Year of Establishment

Linkages	Year of Establishment				
	Before 1990	1990-2000	After 2000	Not Known	ALL
Other R&D Centers of the Parent Company (excluding those in India)	5.68	5.86	6.03	5.50	5.79
Other R&D Centers of the Parent Company in India	5.66	5.67	5.49	5.40	5.58
Global Business Units of the Parent Company	5.79	5.83	5.49	4.80	5.63
Subsidiaries of the Parent Company in India	5.24	5.52	5.13	4.30	5.23
Local (Indian) Universities & Institutions	5.07	5.05	4.79	5.00	4.97
Local (Indian) Suppliers of machinery and inputs	4.97	5.19	4.95	4.70	5.02
Local (Indian) Buyers	5.34	5.14	5.13	4.50	5.13
Other Indian Companies in the Same Industry	5.03	5.21	5.05	4.90	5.09
Foreign-based contracting organizations for whom other services provided earlier	5.03	4.90	4.62	4.70	4.83
India-based contracting organizations for whom other services provided earlier	5.31	4.81	4.72	5.00	4.92

Appendix Table 15: Importance of Various Linkages and Channels for Foreign R&D Centers by Degree of Foreign Ownership

Linkages	Foreign Ownership			
	0-69	**70-99**	**100%**	**ALL**
Other R&D Centers of the Parent Company (excluding those in India)	5.65	5.89	6.00	5.79
Other R&D Centers of the Parent Company in India	5.76	5.70	5.51	5.58
Global Business Units of the Parent Company	5.56	5.07	5.94	5.63
Subsidiaries of the Parent Company in India	5.21	5.22	5.32	5.23
Local (Indian) Universities & Institutions	5.41	4.78	4.74	4.97
Local (Indian) Suppliers of machinery and inputs	5.59	4.96	4.68	5.02
Local (Indian) Buyers	5.32	4.85	5.00	5.13
Other Indian Companies in the Same Industry	5.26	5.11	5.06	5.09
Foreign-based contracting organizations for whom other services provided earlier	5.29	5.00	4.55	4.83
India-based contracting organizations for whom other services provided earlier	5.44	5.07	4.53	4.92

Appendix Table 16: Relative Importance of Various Sources for R&D Projects

Source of R&D Projects	Number of Employees					
	< 50	50-99	100-249	> 250	Not Known	ALL
Proposed by researchers at the Center	5.76	6.05	5.95	5.76	4.50	5.78
Global Business Units of the Parent Company (Contracted projects)	5.66	5.91	5.57	5.71	4.33	5.63
Local Business Units of the Parent Company (Contracted projects)	5.48	5.82	5.10	5.00	4.00	5.32
Other companies with no base in India (Contracted projects)	4.24	5.09	4.71	4.81	3.50	4.54
Other companies with a base in India (Contracted projects)	4.36	5.05	4.67	5.10	3.83	4.64

Source of R&D Projects	Year of Establishment				
	Before 1990	1990-2000	After 2000	Not Known	ALL
Proposed by researchers at the Center	6.07	5.98	5.51	5.20	5.78
Global Business Units of the Parent Company (Contracted projects)	5.55	5.67	5.77	5.20	5.63
Local Business Units of the Parent Company (Contracted projects)	5.17	5.52	5.23	5.20	5.32
Other companies with no base in India (Contracted projects)	4.93	4.95	3.92	4.10	4.54
Other companies with a base in India (Contracted projects)	5.07	5.02	4.03	4.20	4.64

Source of R&D Projects	Foreign Ownership			
	0-69	70-99	100%	ALL
Proposed by researchers at the Center	6.18	5.63	5.72	5.78
Global Business Units of the Parent Company (Contracted projects)	5.76	5.44	5.70	5.63
Local Business Units of the Parent Company (Contracted projects)	5.68	4.96	5.32	5.32
Other companies with no base in India (Contracted projects)	4.94	4.37	4.43	4.54
Other companies with a base in India (Contracted projects)	5.18	4.67	4.30	4.64

Appendix Table 17: Frequency of Communication of Center with Various Entities by Size, Age and Degree of Foreign Ownership

Organizations	**Number of Employees**					
	< 50	**50-99**	**100-249**	**> 250**	**Not Known**	**ALL**
R&D headquarter of the parent company	4.10	4.55	4.00	4.38	4.67	4.24
Other R&D organizations of the parent company	3.60	4.32	3.62	4.10	4.00	3.84
Manufacturing companies of the parent company in India	3.02	3.86	3.76	3.33	3.33	3.38
Enterprises in India (suppliers or customers)	3.36	3.73	3.76	3.95	3.50	3.61
Universities or academies in India	2.92	3.14	3.24	3.33	3.00	3.09
Organizations	**Year of Establishment**					
	Before 1990	**1990-2000**	**After 2000**	**Not Known**	**ALL**	
R&D headquarter of the parent company	4.34	4.05	4.46	3.90	4.24	
Other R&D organizations of the parent company	4.03	3.57	3.92	4.10	3.84	
Manufacturing companies of the parent company in India	3.55	3.33	3.33	3.20	3.38	
Enterprises in India (suppliers or customers)	3.72	3.50	3.59	3.80	3.61	
Universities or academies in India	3.45	3.17	2.67	3.40	3.09	
Other organizations (Please specify):						
Organizations	**Foreign Ownership**					
	0-69	**70-99**	**100%**	**ALL**		
R&D headquarter of the parent company	3.82	4.48	4.28	4.24		
Other R&D organizations of the parent company	3.74	4.11	3.53	3.84		
Manufacturing companies of the parent company in India	3.79	3.37	3.02	3.38		
Enterprises in India (suppliers or customers)	4.09	3.59	3.21	3.61		
Universities or academies in India	3.76	3.22	2.45	3.09		

Appendix Table 18: Relative Importance of Different Entities in Resolving the R&D problem

Resolving the R&D problem	Number of Employees					
	< 50	50-99	100-249	> 250	Not Known	ALL
R&D headquarters of the parent company	5.88	6.23	6.62	6.00	5.17	6.06
Oversea R&D organizations of the parent company	5.14	5.91	6.00	5.62	4.67	5.49
Universities or academies in India	4.38	4.86	5.10	4.62	3.83	4.61
R&D organizations of other MNCs	4.46	4.68	4.90	4.24	4.00	4.52
R&D organizations of Indian companies	4.46	4.14	5.19	4.62	4.17	4.54
Professional research or technology references	4.74	4.68	5.24	5.05	4.00	4.83
Contracting organization	4.26	4.36	5.19	4.48	4.17	4.48

Resolving the R&D problem	Year of Establishment				
	Before 1990	1990-2000	After 2000	Not Known	ALL
R&D headquarters of the parent company	6.14	6.31	5.97	5.10	6.06
Oversea R&D organizations of the parent company	5.69	5.88	5.00	5.20	5.49
Universities or academies in India	4.90	5.14	3.79	4.70	4.61
R&D organizations of other MNCs	4.79	4.83	4.03	4.30	4.52
R&D organizations of Indian companies	4.76	4.79	4.15	4.40	4.54
Professional research or technology references	5.07	5.02	4.62	4.20	4.83
Contracting organization	4.72	4.79	4.08	4.00	4.48

Resolving the R&D problem	Foreign Ownership			
	0-69	70-99	100%	ALL
R&D headquarters of the parent company	5.97	6.15	6.15	6.06
Oversea R&D organizations of the parent company	5.71	5.48	5.51	5.49
Universities or academies in India	5.21	4.67	4.17	4.61
R&D organizations of other MNCs	4.94	4.81	4.00	4.52
R&D organizations of Indian companies	4.85	5.04	4.00	4.54
Professional research or technology references	5.21	4.85	4.51	4.83
Contracting organization	5.21	4.37	4.09	4.48