Is India Becoming More Innovative since 1991? Some Disquieting Features

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India is variously described as a knowledge-based economy in the making, thanks essentially due to her high economic growth and the role played by knowledge-intensive sectors such as information technology in spurring and maintaining this growth performance. This paper looks at the empirical evidence on whether this is indeed the case since the reform process began in 1991. A variety of conventional indicators are analysed and their movements over the last two decades or so are charted to draw some firm conclusions. The results show that instances of innovation are restricted to a few areas such as the pharmaceutical industry. Further, increasingly most of the innovations in industry are contributed by foreign firms operating in the country.

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Notwithstanding the global financial crisis, growth performance of India has attracted considerable attention among analysts of all hues and shapes. One of the issues that is highlighted in discussions is the emergence and rise of a number of knowledge-intensive manufacturing and service industries and these industries together now account for a growing share of the country's gross domestic product (GDP). India has now become a growing destination for innovative activities by multinational companies (MNCs) and this manifest itself in the form of a growing presence of foreign research and development (R&D) centres in the country. Foreign direct investment (FDI) from India has been steadily increasing and over 2007 and 2008 there were a number of high profile takeovers of western technology-based companies by Indian corporates. All these indicators have prompted analysts to think that India has become more innovative since 1991 and recent attempts at measuring the contribution of technology to economic growth essentially through measures such as total factor productivity (TFP) appear to indicate that Indian industries, both in manufacturing and services sectors, have become active from the innovation point of view. In the context, the purpose of the present study is to inquire into the direct evidence on whether innovative activities are on the rise in India. For this, we employ a variety of conventional indicators of innovation as data on new indicators are practically non-existent in the Indian context.

The paper is structured into three sections. Section 1, employing conventional indicators of innovative performance presents the trends in innovation in Indian industries. Recourse to conventional indicators is resorted to in the absence of new innovation indicators for India. Section 2 identifies two major disquieting features that can act as limiting factors to sustaining and improving innovative activity in the country. And finally Section 3 sums up the main findings of the paper.

1 India's Innovative Performance

Over the last several years there has been much discussion in the popular press about the rise of innovations in India. In my view, this discussion has been precipitated by a number of indicators of innovations in India's economy. These are: (a) Improvement in India's rank in the Global Innovation Index; (b) many instances of innovation in the services sector, especially in the healthcare segment; (c) increase in knowledge-intensity of India's overall output; (d) growing FDI from India including some high profile technology-based acquisitions abroad by Indian companies; and (e) competitiveness in high technology areas.

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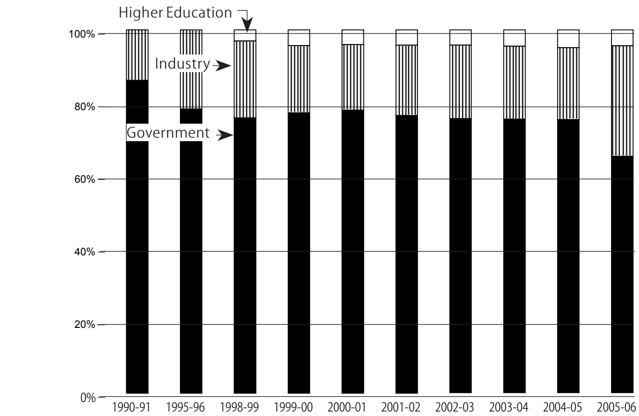
Figure 1: Sector-wide Investment in R&D in India (1990-91 to 2005-06, % shares)



	1990-91	1995-96	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Higher Education			3.04	4.33	4.02	4.20	4.17	4.51	4.88	4.40
Industry	13.84	21.74	21.17	18.46	18.05	19.33	20.27	20.05	19.81	30.40
Government	86.16	78.26	75.79	77.21	77.94	76.48	75.56	75.44	75.30	65.20

Source: Department of Science and Technology (2006 and 2008).

According to the Economist Intelligence Unit (2009), India's rank in its Global Innovation Index[1] increased from 58 in 2002-06 to 56 in 2004-08 and is predicted to further increase to 54 by 2009-13. According to the World Bank, India has emerged as the fifth largest economy in terms of its level of GDP in purchasing power parity (PPP) terms. However, relatively speaking her economy is only one-half of that of China's. India's real GDP has grown at a rate of 5.7% during the period 1990-91 to 1999-2000, and it increased to 7.3% during 2000-01 to 2007-08 and over the last three years (2005-06 to 2007-08) it has been growing at the rate of about 9%. Currently, the service sector accounts for over two-thirds of the economy and both service and manufacturing sectors have been performing very well. For a very long time the policymakers in the country never specifically used the term innovation in an explicit manner in Indian policy documents dealing with technological activities. For instance, the most recent policy document to promote innovations is titled the *Science and Technology Policy 2003.* But given the international trend and in realising the increasing number of innovations emanating from the country, a draft National Innovation Act is in the anvil and the usage of the expression "innovation" in this document is more than symbolic. In fact, there is a fair amount of belief in both policy and business circles that the country is becoming more innovative, at least certain specific industries in both manufacturing and service sectors have become important generators of innovations.[2] Within the manufacturing sector itself a number of innovations have been reported from the automobile and medical devices industries.[3] However, this proposition has not been subject to any rigorous empirical scrutiny.

Formal attempts at measuring innovation are supposed to have been on for very nearly 50 years or so. The first step involved in measuring innovation is to have a precise definition of the term "innovation" itself and then transliterating that definition into quantitative indicators. Indicators are essentially proxies, which come as close to the concept that is being measured. Although, there are a large number of definitions of the term "innovation", most of these are at best descriptions of it. This is because innovation is complex, non-linear, multidimensional, and unpredictable. No single measure is likely to characterise innovation adequately in its totality. Further, important aspects of innovation such as knowledge cannot be measured directly. Despite these difficulties the one definition that is very often invoked is that attributable to Schumpeter and found in his *Theory of Economic Development*. According to this definition, innovation is "the commercial or industrial application of something new – a new product, process or method of production; a new market or sources of supply; a new form of commercial business or financial organisation". Thus it can be seen that this definition is sufficiently broad enough to encompass both tangible and intangible innovations. However, a survey of the evolution of innovation indicators (Smith 2004) shows that most of these indicators, if not all, have attempted to measure tangible inputs and outputs of only product and process innovations. This is because, in those days (namely, during the 1950s, 1960s and 1970s), most of the economies were dominated by the industrial sector where there was a reasonable frequency of the occurrence of product and process innovations and service sector innovations were very rare. Although new indicators for measuring innovation through innovation surveys have appeared, their widespread diffusion has been limited due to the low response rates to these surveys and due to the poor quality of the data. Therefore, we have been constrained to measure innovative performance at the macro level (namely, at the level of a nation state) by employing the conventional measures of input to innovation in the form of intra-mural R&D investments and output indicators such as various types of patents and the technology balance of trade. Employing these indicators, I measure India's innovative performance during the period since the onset of economic reforms in 1991.

1.1 Trends in R&D Investments

I start by analysing the overall investments in R&D in the country as a whole (Table 1, p 44). Trends in R&D investments both at constant and current prices are tracked so also the overall Gross Expenditure on Research and Development (GERD) to GDP ratio as well. Both the nominal and real growth rates have declined since 1991 and the overall research intensity of the country has virtually remained constant pre- and post-liberalisation periods at about 0.78.[4]

Care has to be exercised while interpreting these figures that the overall investments in R&D have actually declined. This is because of certain peculiarities with respect to India's R&D performance. Even now the government accounts for over 63% of the total R&D performed within the country although the share of government has tended to come down over time (Figure 1). This has been accompanied by an increase in R&D investments by business enterprises, which now account for about 30% of the total – a significant increase from just 14% in 1991 (for China the similar percentage is about 71% by business enterprises and research institutes (read government) account for only 19%). The increase in the share of R&D performed by business enterprises is generally considered to be a desirable trend as business enterprises tends to implement or productionise the results of their research rather more quickly than the government sector where much of the research does not fructify into products and process for the country as a whole.[5]

Table 1: Trends in India's Overall Investments in R&D (1980-81 to 2007-08; Current and constant values are in Rs Crore; constant values are in 1999-2000 prices)

	GERD Current	Nominal Growth Rates (%)	GERD Constant	Real Growth Rates (%)	GERD to GDP Ratio
1980-81	761		3,686		0.57
1981-82	941	24	4,112	12	0.61
1982-83	1,206	28	4,855	18	0.70
1983-84	1,381	15	5,127	6	0.68
1984-85	1,782	29	6,124	19	0.78
1985-86	2,069	16	6,628	8	0.81
1986-87	2,435	18	7,298	10	0.86
1987-88	2,853	17	7,809	7	0.89
1988-89	3,347	17	8,457	8	0.87
1989-90	3,726	11	8,673	3	0.84
1990-91	3,974	7	8,361	-4	0.77
Average		18		9	0.76
1991-92	4,513	14	8,348	0	0.76
1992-93	5,005	11	8,504	2	0.73
1993-94	6,073	21	9,382	10	0.77
1994-95	6,622	9	9,320	-1	0.72
1995-96	7,484	13	9,651	4	0.69
1996-97	8,914	19	10,665	11	0.71
1997-98	10,611	19	11,908	12	0.76
1998-99	12,473	18	12,954	9	0.77
1999-2000	14,398	15	14,398	11	0.81
2000-01	16,199	13	15,688	9	0.84
2001-02	17,038	5	16,022	2	0.81
2002-03	18,000	6	16,304	2	0.80
2003-04	19,727	10	17,276	6	0.78
2004-05	21,640	10	17,960	4	0.75
2005-06	28,777	33	22,954	28	0.88
2006-07	32,942	14	24,895	8	0.87
2007-08	37,778	15	27,413	10	0.88
Average		16		7	0.78

Source: Department of Science and Technology (2006 and 2008).

An interesting result thrown up by the above analysis is that the higher education sector, which includes the prestigious Indian Institute of Science, the Indian Institutes of Technology and a host of over 300 universities, constitutes only a very small share of the total R&D performed within the country. In other words, the higher education sector in India is not a source of technology for the industry. However, the sector is an important source of human resource for the other actors in India's national system of innovation.

It is thus seen that the only actor of the country's innovation system that has increased its share in total R&D performance has been the industrial sector. Within the industrial sector much of the R&D is performed by private sector enterprises (Table 6, p 47). Currently, Indian private sector enterprises spend approximately four times their public sector counterparts and nearly three times when compared to GRIS. In other words in terms of R&D performance, the private sector enterprises in India are moving towards the core of India's innovation system.

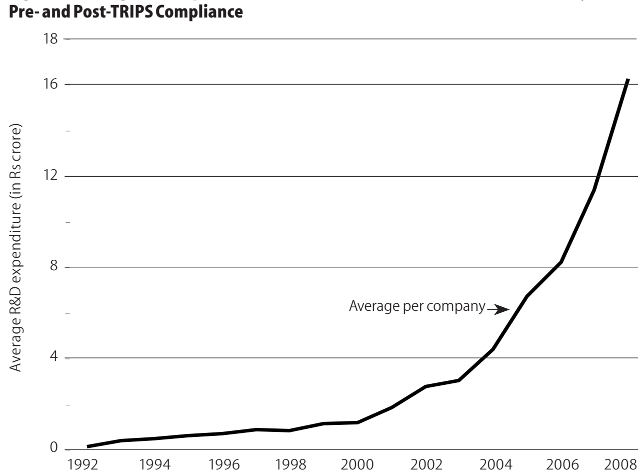
This increase in the share of private sector in the performance of R&D is sometimes questioned on the grounds that the private sector enterprises reporting expenditures in this area to the DST would have exaggerated their spending to gain tax incentives that are available in India to any business enterprise investing in R&D. These tax incentives are linked to the volume of R&D performed. Hence the desire to overstate it. However, this does not appear to be the case and in order to verify this proposition we have compared the R&D investments as reported by the DST with those available from the Centre for Monitoring Indian Economy's (CMIE) Prowess dataset (Appendix Figure 1, p 51). The comparison shows that although the level of R&D as reported by DST is higher over most of the years under consideration, the differences in the levels have tended to decrease over time. Moreover, the direction of movement of both the series is more or less exactly the same. So the argument that the increase in R&D expenditure by private sector enterprises is a mere statistical artefact does not appear to be true.

Within the industrial sector about four industries account for a significant share of R&D investments (Table 3, p 45). The pharmaceutical and the automotive industries are the two most important spenders on R&D. In fact, it is sometimes said that India's national system of innovation is led by the sectoral system of innovation of her pharmaceutical industry.

An interesting point to be noted is that the R&D expenditure of the pharmaceutical industry was expected to decrease after the Indian Patent Act in 2005 was amended in compliance with the Trade-related Aspects of Intellectual Property Rights (TRIPS). This reasoning was based on the belief that much of the Indian R&D in pharmaceuticals was of the "reverse engineering" type and this may not be possible since the amended patents act requires recognition of both product and process patents, thus effectively reducing the space that is available for executing R&D projects of this type. However, in actuality, the R&D investments of private sector pharmaceuticals in India have been registering an increase of almost 35% per annum (Figure 2).

It can, therefore, be safely concluded that although overall R&D investments may not have increased, there have been tremendous increases in R&D by the private industrial sector enterprises led by the pharmaceutical industry. So based on this one

Figure 2: Average R&D Expenditure Per Firm in India's Pharmaceutical Industry: Pre- and Post-TRIPS Compliance



Source: Own compilation based on the Prowess dataset.

indicator, the more correct statement to be made is that there is not enough evidence to show that the entire industrial sector in India is becoming more innovative since 1991, but there is some evidence to show that the India's pharmaceutical industry

Table 2: Nominal R&D Expenditure by Private Sector Enterprises (in Rs crore)

	Public Sector Enterprises	Government Research Institutes	Private Sector Enterprises	Ratio of Private Sector to Public Sector Enterprise	Ratio of Private Sector to Government Research Institutes
1985-86	1,986.18	1,622.7	2,519.44	1.27	1.553
1986-87	2,356.99	1,723.36	2,916.33	1.24	1.692
1987-88	2,884.66	1,851.29	3,102.67	1.08	1.676
1988-89	3,421.24	2,093.28	4,176.25	1.22	1.995
1989-90	4,129.01	2,395.21	4,905.94	1.19	2.048
1990-91	4,145.33	2,491.88	5,499.81	1.33	2.207
1991-92	4,843.88	2,745.50	6,369.44	1.31	2.320
1992-93	5,139.50	2,993.65	8,362.47	1.63	2.793
1993-94	5,428.11	NA	9,825.37	1.81	
1994-95	4,146.09	3,564	13,188.70	3.18	3.701
1995-96	4,275.76	4,116.99	16,270.69	3.81	3.952
1996-97	5,360.52	4,440	23,307.50	4.35	5.249
1997-98	5,392.40	5,641.30	24,382.50	4.52	4.322
1998-99	6,738.70	7,133.20	21,766.10	3.23	3.051
1999-2000	7,576.30	7,808.82	21,781.10	2.87	2.789
2000-01	8,428.80	8,641.20	24,114	2.86	2.791
2001-02	7,673.70	8,922.60	27,874.80	3.63	3.124
2002-03	8,089.50	9,512.50	30,649.30	3.79	3.222

Source: Department of Science and Technology (2006 and 2008).

certainly is becoming more innovative. I propose to confront this proposition a bit more, but this time employing an input-based indicator such as the number of patents applied for and awarded.

1.2 Trends in Patenting

I consider the performance of Indian inventors with reference to four (three foreign and one Indian) different types of patenting. First and foremost is the US patenting performance, followed by India's share in the Patent Cooperation Treaty (PCT) applications[6] and in Triadic[7] patents. This is followed by a discussion of the recent surge in Indian patenting within India itself.

1.2.1 US Patenting Behaviour of Indian Inventors

The US is considered to be the main market for disembodied technology and securing a patent for a new innovation in either a product may signal the technological strength of a firm or an institution that is actually patenting in that country. Further, the US Patent and Trademark Office (USPTO) is supposed to have one of the lowest home biases as more than 50% of the patents that are issued in the US goes towards non-US entities. For these two reasons the number of US patents is a good indicator. Given the average time lag of two years between patent applications and patent awards, I consider both patent applications and those awarded in the US. Three dimensions of US patenting are considered: first the volume of patent applications and awards, second the distribution of patents according to the ownership of the assignee and third the field of specialisation of patenting from India.

Table 3: Industry-wide Distribution of Industrial R&D (cumulative shares in%, 1998-99 to 2002-03)

Industry	Share
Metallurgical industries	4.21
Fuels	6.12
Electricals and electronic equipment	8.94
Telecommunications	3.75
Transportation	15.16
Chemicals (other than fertilisers)	8.35
Drugs and pharmaceuticals	19.30
Defence industries	8.32
Information technology	4.69
Biotechnology	1.59
Others	18.97
Total	100.00

Source: Department of Science and Technology (2006 and 2008).

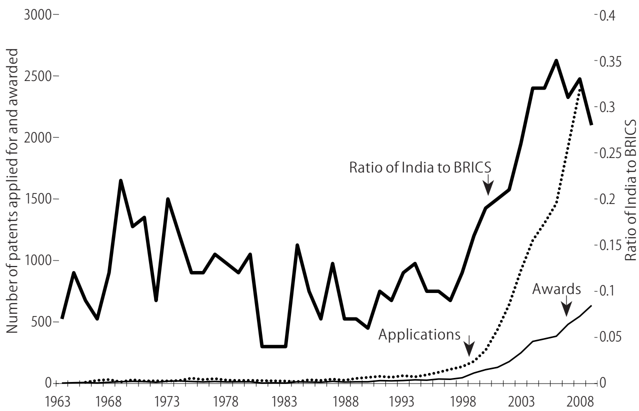
Volume of Patents: The number of patents applied for and awarded is presented in Figure 3. In order to see the significance of Indian patenting I compare it not only across time but across the Brazil, Russia, India, China, and South Africa (BRIC) group of countries as well.

The tables indicate that there has been a tremendous increase in the number of patents applied for and awarded since 1991. India accounts for approximately a third of the patents applied for and awarded by BRICS country innovators in the US.

In order to find out the specific year or years in which the structural break dates have occurred in patenting so that one can identify phases of growth (both in the applications and in awards), we perform some econometric tests[8] (Table 4, p 46).

In the time series in patent applications and awards over the long period, 1965-2007, three break dates have been observed: for applications it is 1973, 1983 and 1992 and in the case of awards the three break dates are 1970, 1979 and 1997. It is seen that in

Figure 3: Number of Patents Applied For and Awarded to Indian Inventors in the USPTO (1963-2008)



Source: Compiled from the USPTO.

both cases there are two break dates of 1992 and 1997 and these are during the phase of economic liberalisation in the country. The time lag in the break dates in applications and awards is found to be five years as against the actual time lag of two years between patent applications and awards.

The lagged relationship[9] between patent applications and awards (Figure 4, p 46) indicates that over the years the success rate of Indian applications (defined as the ratio of patent awards in year 't+2' to applications in year 't') for patents has actually decreased. This finding is interesting as during this period the USPTO had become a bit more liberal in awarding patents (Jeffe and Lerner 2004).

An analysis of the distribution of ownership of these patents (Table 5 and Figure 5, p 46) shows that in 1991, domestic inventors (consisting of government research institutes (read as CSIR), private sector enterprises and individuals) accounted for about 71% of the innovations taking place within the country. This has since got reduced to just 39%. The share vacated by domestic inventors have been taken up by foreign companies implying the

Table 4: Estimated Break Dates and Growth Rates in Indian Patent Applications and Awards in the US (1965-2007)

Break Dates	First Break	Second Break	Third Break	
1 Patent applications	1973	1983	1992	
2 Patent awards	1970	1979	1997	
Growth Rates (%)	Period 1: 1965-73	Period 2: 1974-83	Period 3: 1984-92	Period 4: 1993-2007
1 Patent applications	16.7	-4.09	8.44	32.90
2 Patent awards	26.52	-10.35	8.45	28.12

Source: See text.

Table 5: Distribution of US Patents according to Ownership (1991 and 2007)

	Distribution of Indian Patents in the US according to Ownership (%)		Distribution of Domestic Patents according to Ownership (%)		
	MNCs	Domestic	GRI	Private Sector Enterprises	IOP
1991	29	71	27	27	45
2007	61	39	55	30	15

GRI: Government Research Institute; IOP: Individually Owned Patents .
Source: Compiled from USPTO.

fact that many affiliates of MNCs have started doing R&D – often enough through the outsourcing mode[10] – and have started taking patents based on this research. This implies that increasingly most of the US patents that are assigned to India are actually owned by MNCs. So an increase in the number of Indian patents in the US need not necessarily correspond to an increase in India becoming more innovative or at best this proposition is difficult to be substantiated in an unambiguous fashion.

The CSIR has an extremely good patenting record until 2003 (Figure 5) and thereafter it seems to be tapering off. The precise reasons for this declining rate of patenting in CSIR require some in-depth examination. Currently, CSIR is in the process of consolidating its patent inventory. It is supposed to be having a total of 3,016 patents in force (1,770 foreign, and 1,246 Indian patents) and it is planning to transfer these to an independent professionally-managed holding company of the type like Intellectual Ventures Llc (Koshy and Kumar 2008) so that these patents can be more gainfully licensed and royalties earned.

The next important category among domestic inventors is private sector enterprises (Figure 5). A run through this list of domestic enterprises (Appendix Table 1, p 50) shows us an interesting result, namely, that almost all the 23 firms[11] excepting for one active in obtaining patents abroad are pharmaceutical firms and the only non-pharmaceutical firm is the largest IT services firm in the country.

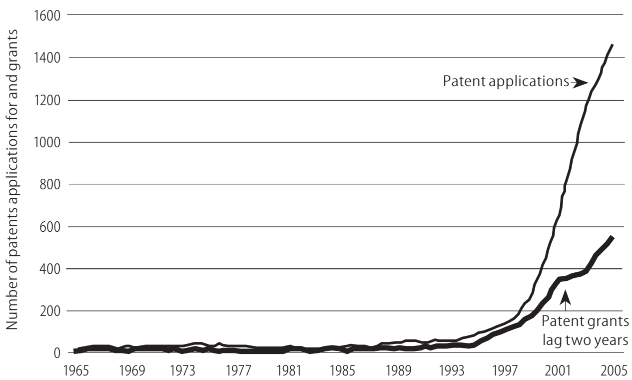
This data further confirms that most of the innovations in India are actually done by pharmaceutical firms. Although IT services are an important industry with significant exports, the firms within the IT services industry in India do not appear to be active in patenting. A number of hypotheses have been put forward for this. First of all, Indian IT companies are much more services companies where they do not have that much scope for patenting as compared to the global IT companies which are more product-oriented. Second, Indian IT companies depend on other forms of intellectual property right (IPR) mechanisms such as trade secrets and reducing the time spent to complete any typical project than filing patents as forms of IPRs.[12]

However, currently most of the Indian patents in the US are held by MNC affiliates operating from India. In fact, one can see a (Figure 5) sharp rise in the US patenting of these enterprises since 1999. A run through the list (Appendix Table 2) of these enterprises shows that almost all of them are from the IT and IT-related industries.

Thus, combining the data (Appendix Tables 1 and 2) it is clear that Indian private sector enterprises are specialising in pharmaceutical innovations while the foreign enterprises are specialising in IT-related patents. As a result, specialisation of Indian patenting in the US (Table 6) has actually increased. For instance in 1991, almost 65% of the Indian patents were in a wide range of technologies although the single largest patenting was in the area of pharmaceuticals and chemicals. But by 2007 almost 72% of the patenting was in just two broad areas of pharmaceuticals and IT-related technologies.

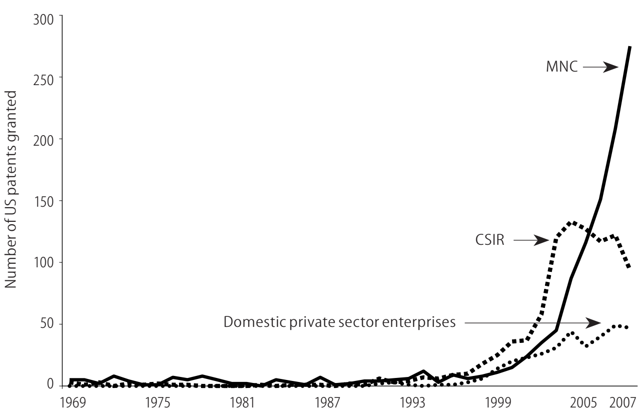
In order to find out if Indian patents are competitive or not, I have computed the Revealed Technological Advantage (RTA) indices of two of the leading technologies in which Indian companies and CSIR are prolific (Figure 6). These are Class 424 Drug, Bio-Affecting and Body Treating Compositions (DBABTC) and 532 (Organic Compounds (includes Classes 532-570)).

Figure 4: Lagged Relationship between Patent Applications and Awards



Source: USPTO.

Figure 5: Trends in US Patenting by MNCs Operating from India, CSIR and Domestic Private Sector Enterprises



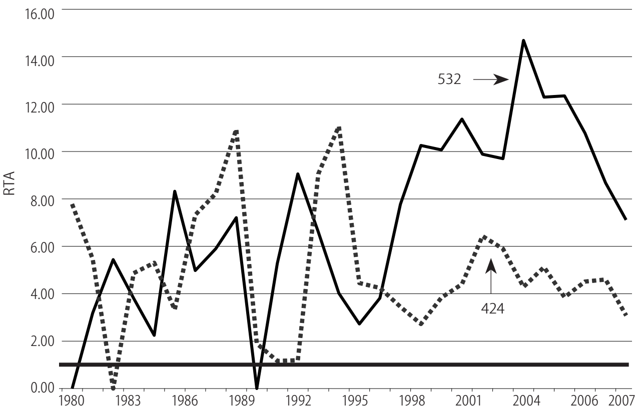
Both the indices are above unity implying competitiveness although for both the leading technology classes India's competitiveness has been fluctuating for most of the years and since 2000 or so has been decreasing. Given the fluctuations in the data series, it is of course not so easy to conclude that competitiveness is actually decelerating.

Table 6: Specialisation of Indian Patenting in the US, 1980-2007 (Percentage shares)

	Chemicals and Pharmaceuticals	IT-Related	Telecommunications	Total
1980	50.00	0	0.00	50.00
1991	45.45	0	4.55	50.00
2003	57.89	16.37	1.46	75.73
2007	30.04	33.52	8.42	71.98

Source: Compiled from USPTO.

Figure 6: Revealed Technological Advantage Indices for Two Leading Technologies



Source: Compiled from USPTO.

Apart from US patenting, it is also possible for Indian inventors to secure patents abroad. Two of the important avenues for patenting are PCT applications at the World Intellectual Property Organisation (WIPO) and Triadic patents.

1.2.2 PCT Applications

India joined the PCT in 1999. Thereafter, the number of applications from India has been increasing and most of these are by firms and institutions (legal entities). See Appendix Table 3 (p 51). According to a news item in the journal *Current Science* (Anonymous 2003), India's CSIR is one of the most notable performers from among the developing world in terms of PCT applications.

In fact, CSIR is supposed to be sharing the first rank along with Samsung of Korea although within the CSIR this good performance in patenting is restricted to just five laboratories[13] out of a possible 38. An analysis of the technology-wide distribution of these patents (Appendix Table 4, p 51) confirms the result that we have obtained earlier from the analysis of US patenting. Most of these patents are in organic chemistry and in pharmaceuticals – showing that India's innovation capability is largely in these specific areas.

1.2.3 Triadic Patents

The methodology used for counting patents can influence the results. Simple counts of patents filed at a national patent office are affected by various kinds of limitations, such as weak international comparability (home advantage for patent applications) and highly heterogeneous patent values. The OECD has developed triadic patent families, which are designed to capture all important inventions only and to be internationally comparable. The performance of a country in securing Triadic patents is a good indicator of not just the quantity of innovations but also of its quality for the simple reason that since patents have to be taken from three different patenting offices and given the high cost of not just securing these patents but maintaining these as well, firms and institutions are likely to self-select only their best inventions to be patented. So one may use the number of Triadic patents secured by a country as a good indicator of its innovative performance. Employing this indicator (Table 7) it is seen that India (along with China) has registered one of the highest growth rates in these kinds of patents and both the countries have a larger share of the BRICS as well.

Data on the ownership of these patents is not readily available. It may well be that (as noted in the case of US patents, these patents are actually owned by MNCS operating from India and in which case interpretation of an increase in the growth of Triadic patents secured by India may not mean India becoming more innovative.

1.2.4 Patenting in India

Hitherto, our discussion has been solely in terms of foreign patenting of Indian inventors. I now turn to the performance with respect to Indian patenting (Figure 7, p 48). Traditionally speaking, foreigners have taken more patents in India than Indians at the India Patent Office. This trend has continued during the post-liberalisation period although the ratio of Indian patents to foreign patents has increased from 0.37 to 0.46 between pre- and post-liberalisation implying a surge in Indian patenting. This is also reflected in the significantly higher growth rate of almost 24% per annum during the post-liberalisation period compared to just 5% per annum during the pre-liberalisation period. An interesting point brought out by the above table is that the TRIPS compliance of the Indian patent regime appears to have signalled a surge not just in foreign patents awarded in India but also Indian ones. Analysis of technology-wide patenting (Table 8, p 48) shows that chemicals,

Table 7: Performance of India in Triadic Patents as Compared to Select Other Countries and Total World (1990-2006)

	Brazil	Russian Federation	China	India	South Africa	World
1990	10	21	12	12	13	32,417
1991	6	36	12	8	18	29,786
1992	13	45	17	7	33	29,922
1993	22	34	16	8	32	30,794
1994	12	51	17	6	21	32,414
1995	17	60	21	11	25	35,731
1996	18	58	23	14	29	39,098
1997	29	69	43	22	34	41,515
1998	29	94	47	34	35	42,878
1999	31	60	62	40	31	45,507
2000	33	69	84	45	35	47,162
2001	47	56	114	85	24	45,565
2002	44	48	178	106	28	46,120
2003	51	51	252	120	30	48,093
2004	51	55	290	122	33	50,727
2005	56	64	384	133	31	50,569
2006	65	63	484	136	30	51,579
Growth rate (%)	18.77	10.38	27.86	20.98	8.39	3.04

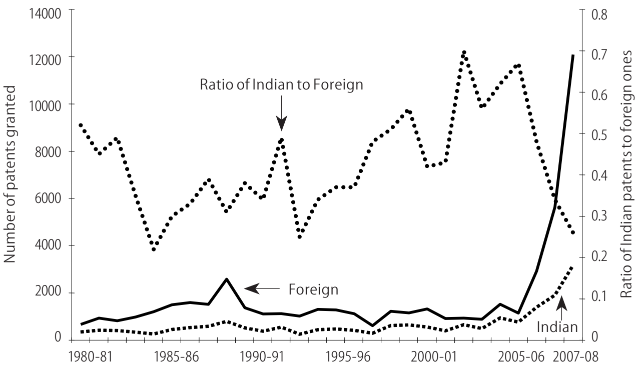
Source: OECD (2009).

Table 8: Technology-wide Distribution of Patents Awarded in India (1999-2000 to 2007-08)

	Chemical	Drug	Food	Electrical	Mechancial	Computer/ Electronics	Bio- technology	General	Total	Chemicals+ Drug+ Bio- technology
1999-2000	516	307	250	147	569			92	1,881	823
2000-01	353	276	72	142	254			221	1,318	629
2001-02	483	320	36	139	311			302	1,591	803
2002-03	399	312	67	118	228			255	1,379	711
2003-04	609	419	110	396	539			401	2,474	1,028
2004-05	573	192	67	245	414	71	71	278	1,911	836
2005-06	1,140	457	110	451	1,448	136	51	497	4,320	1,648
2006-07	1,989	798	244	787	2,526	237	89	869	7,539	2,876
2007-08	4,071	1,469	88	1,078	3,230	2,052	314	2,959	15,261	5,854

Source: Controller General of Patents, Designs and Trade Marks (various issues).

Figure 7: Number of Patents Granted to Domestic and Foreign Inventors by the Indian PTO



Source: Controller General of Patents, Designs and Trade Marks (various issues).

pharmaceuticals and biotechnology are the preferred areas while mechanical engineering and computer technologies too have registered important increases in patenting during the post-liberalisation period.

In conclusion, our detailed analysis of both foreign and Indian patenting presents us with the following:

(i) There has been a significant surge in patenting by Indian inventors abroad and in India; (ii) the share of domestic inventors is still much lower than those of foreign inventors using India as a R&D location; (iii) most of the domestic patents are in chemicals and pharmaceuticals; while the foreign patents are in IT and computer software-related areas; and (iv) among the domestic inventors, CSIR is an important entity although private sector pharmaceutical enterprises too are very important.

1.3 Technology Balance of Payments

The Technology Balance of Payments is the third indicator of innovative performance that is usually employed in the literature although due to data constraints and to difficulties involved in interpreting the results it is not a popular indicator of innovativeness like R&D expenditure and patents.[14] TBOP measures international transfers of technology licences, patents, know-how and research, and technical assistance. Although the TBOP reflects a country's ability to sell its technology abroad and its use of foreign technologies, a deficit position does not necessarily indicate low competitiveness. Only a handful of countries in the world are net exporters of technology (the prominent among them are the US, Japan and Switzerland). I have constructed India's TBOP over the years since 1999-2000 (Figure 8). It is seen that India has been a net importer of technology until 2004-05. Over the last three years, the country has become a net exporter of technology thanks to increasing R&D and other technology-based outsourcing activities. Data constraints do not allow us to measure the TBOP industry-wide. But given the fact that much of R&D sourcing is confined to pharmaceutical and IT-related (including telecommunications) industries, this result, once again, substantiates the conclusions that we reached with the aid of the previous two indicators.

In conclusion, my analysis on India's innovative performance over the period since 1991, the following points emerge:

– Overall research intensity of the country as judged by rates of growth of GERD and GERD to GDP ratio has actually gone down since 1991.

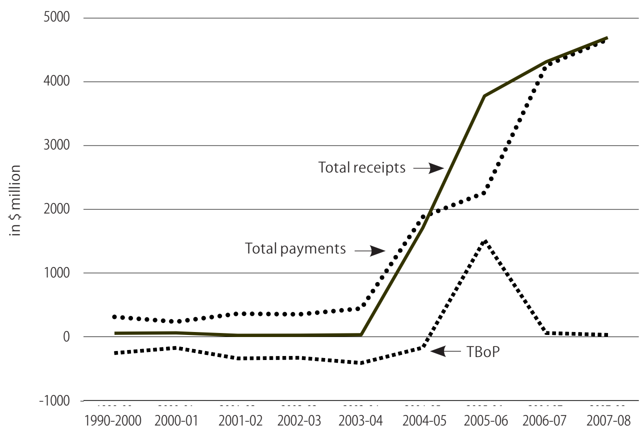
– But the share of the industrial sector within the overall GERD has actually increased by a factor of two since 1991 and the industrial sector now performs close to a third of overall GERD.

– Within the industrial sector over two-thirds of the industry is performed by private enterprises and most of these are concentrated in the pharmaceutical industry.

– Analysis of various types of patent data and notably the USPTO data shows that much of it is actually done by MNCs operating from India, although the domestic private sector and enterprises and government research institutes (read CSIR) have also increased their share of innovative activity during the period since 1991.

– Once again, the patent data too shows that there is a specialisation in pharmaceutical technologies although MNCs operating from India tend to specialise in IT-related activities.

Figure 8: India's Technology Balance of Payments (1999-2000 to 2007-2008)



Source: RBI (various issues).

– This prompts us to conclude that India's national system of innovation is largely dominated by the sectoral system of innovation of her pharmaceutical and IT industries. The former is largely in the hands of domestic enterprises while the latter is in the hands of MNCs.

2 Disquieting Features

Our analysis thus far draw our attention to the fact that improvement in innovative activities are restricted to a few sectors. In the present section I identify two important barriers to furthering innovations across sectors in the country.

2.1 Financing of Innovation

India has two types of financial schemes for financing innovations: first, research grants and loans at concessional rates of interest and second, tax incentives for committing resources to R&D. A recent analysis by Mani (2008) showed that much if not all of the small number of research grants and loans available for financing innovations (such as those by the Technology Development Board, etc) are directed largely at the public sector although, as we have just demonstrated that, much of the innovations actually emanate from private sector enterprises. In short, there is a mismatch in the financing of innovations in the sense that research grants and concessional loans are not directed towards those sectors which are active in innovations. Second, the country has a tax incentive scheme for encouraging more investments in R&D. These incentives have been correctly fine-tuned to encourage innovations in 10 high and medium technology-based industries which are at the same time active in innovative activity. Mani (2008) endeavoured to estimate the coefficient of elasticity of R&D with respect to tax foregone as result of this incentive scheme. The elasticity of R&D expenditure with respect to tax foregone as a result of the operation of the R&D tax incentive is less than unity for all the relevant industries, although it is significant only in the case of the chemicals industry. In two of the industries, namely in automotive and electronic industries the elasticity is even negative, although not significant. From this the reasonable interpretation that is possible is that tax incentive does not have any influence on R&D, excepting possibly in the chemicals industry where it has some influence although even in this case the change in R&D as a result of tax incentive is less than the amount of tax foregone. This lack of a significant relationship between R&D and tax foregone can be explained by the fact that the tax subsidy covers only a very small percentage share (on an average 6%) of R&D undertaken by the enterprises in the four broad industry groups. So our conclusion is that for tax incentive to be effective in raising R&D expenditures it must form a significant portion of R&D investments by an enterprise. It is not thus a determinant of R&D investments by enterprises for the present.

2.2 Availability and Quality of Science and Engineering Personnel

The recent growth performance of knowledge-intensive industries in India is prompting many commentators to feel that India is transforming itself into a knowledge-based economy. The copious supply of technically trained human resource is considered to be one of the most important reasons for this growth performance. However, of late, the industry has been complaining of serious shortages in technically trained manpower. For instance, a recent study (2007) conducted by the Federation of Indian Chambers of Commerce and Industry (FICCI) has revealed that the rapid growth in the globally integrated Indian economy has led to a huge demand for skilled human resources. However, lack of quality in the higher education sector has become a hindrance in filling the gap. The survey, based on a study conducted in 25 sectors, also showed that currently there is a shortage of about 25% skilled manpower in the engineering sector. Budgetary allocation for technical education has increased, although with some fluctuations. Its share as a proportion of expenditure on higher education has increased. In order to increase the quality of new supply of science and engineering personnel, the central government has established or is in the process of establishing five new Indian Institutes of Science Education and Research, eight new Indian Institutes of Technology, and 20 new Indian Institutes of Information Technology. Further, 30 new central universities of various sorts are going to be established.

3 Summing Up

There is evidence to show that innovative activities in the industrial sector have shown some significant increases during the post-reform process. Hi-tech industries now contribute over 5% of India's GDP. The innovative activity is, of course, restricted to a few hi-tech industries. There is even some macro evidence to show that the productivity of R&D investments in India is higher than in China, although this proposition requires careful empirical scrutiny before firm conclusions can be reached. This rise in innovative activity is largely contributed by the domestic private sector if one takes into account all the indicators. Within the domestic private sector innovative performance is largely confined to the pharmaceutical industry. In short, India's national system of innovation is to a large extent dominated by the sectoral system of innovation of its pharmaceutical industry and as such this trait is not widespread. Increasingly MNCs operating from India are also contributing to enhancing the country's innovative performance. This is very likely the consequence of ever increasing FDI in R&D. Most of the MNCs patents are in the IT industry. In short, it may not be incorrect to draw the conclusion that India's pharmaceutical and IT industries are becoming innovative, although domestic enterprises are more active innovators only in the former while it is the MNCs that are active in the latter. Integration of India's economy with rest of the world has opened up a number of opportunities which seem to have been capitalised by the private sector industry. However, continued rise in innovative activity is limited by the availability of finance and of good quality scientists and engineers. Although the available supply appears to be very productive, it is important that to sustain this on a long-term basis and also to spread the innovation culture to other areas of the industrial establishment concerted efforts will have to be made to increase both the quantity and quality of scientific manpower. Fortunately, the government is aware of this problem and has started initiating a number of steps towards easing the supply of technically trained personnel. The government still has to rethink its financial support schemes by reducing as much as possible the distortions that are currently in this area.

NOTES

1 The index, which measures innovation performance in 82 countries, is based on the number of patents awarded to people from different countries by patent offices in the United States (US), European Union (EU) and Japan. It also takes in factors that help and hinder the ability to innovate, such as the amount of research and development undertaken and the technical skills of the country's workforce. See for details, Economist Intelligence Unit (2009).

2 According to international press, the health delivery sector in India is one such sector that is replete with many innovations. See for the details, *Economist* (2009).

3 The recent release of Tata's Nano and the innovations in bio design (MAC 400 an ECG machine that can be used in rural areas) from General Electric's (GE) John F Welch Technology Centre in Bangalore are some of the innovations from the formal corporate sector targeted essentially at the rural sector that has made it into the news. For a systematic and journalistic account of the growth of innovations in India in recent times, see Bagla and Goel (2009).

4 For China the GERD to GDP ratio has actually increased to reach 1.42% by 2006. See Ministry of Science and Technology (2007).

5 Governmental R&D in India is expended by atomic energy, defence, 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, the conscious efforts made by the government are slowly beginning to produce results. This is especially so in the area of space research.

6 Any resident or national of a contracting state of the PCT may file an international application under the PCT. A single international patent application has the same effect as national applications filed in each designated contracting state of the PCT. However, under the PCT system, in order to obtain patent protection in the designated states, a patent shall be awarded by each designated state to the claimed invention contained in the international application.

7 A patent family is defined as a set of patents taken in various countries (i e, patent offices) to protect the same invention. Triadic patent families are a set of patents taken at all three of these major patent offices –the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO).

8 This is based on the methodology contained in Balakrishnan and Parameswaran (2007). I am grateful to M Parameswaran for the actual performance of these tests.

9 Patents applied for in year 't' is related to patents awarded in year 't+2'.

10 Over the four-year period 2004-05 to 2007-08, R&D outsourcing has been growing at a rate of about 82% per annum.

11 The firm with the largest number of patents, Ranbaxy has been taken over by the Japanese MNC, Daichi Sankyo in June 2008. Ranbaxy will now have to be classified as an affiliate of its Japanese parent and therefore will have to be declassified as a domestic company, although this does not affect our present analysis.

12 According to press reports some of the leading IT services companies such as TCS, WIPRO and Infosys have filed for a number of patents, perhaps at the Indian Patent Office. See Mahalingam (2003) and Gowda (2009).

13 These five are IICT, CFTRI, CIMAP, RRL (JM) and NCL.

14 Technology receipts and payments constitute the main form of disembodied technology diffusion. Trade in technology comprises four main categories:
- Transfer of techniques (through patents and licences, disclosure of know-how).
- Transfer (sale, licensing, franchising) of designs, trademarks and patterns.
- Services with a technical content, including technical and engineering studies, as well as technical assistance.
- Industrial R&D.

The main limitations of these data are the heterogeneity of their content at country level and the difficulty of dissociating the technological from the non-technological aspect of trade in services, which falls under the heading of pure industrial property. Trade in services may be underestimated when a significant proportion does not give rise to any financial payments or when payments are not made in the form of technology payments.

REFERENCES

Anonymous (2003): "Innovation Chain and CSIR", *Current Science*, Vol 85, No 5, pp 570-74.

Bagla, Gunjan and Atul Goel (2009): "Innovation from India: The Next Big Wave", *The Business Week*, 11 February.

Balakrishnan, P and M Parameswaran (2007): "Understanding Economic Growth in India, A Prerequisite", *Economic & Political Weekly*, 14 July, pp 2915-22.

Controller General of Patents, Designs and Trade Marks (various issues): *Annual Report*.

Department of Science and Technology (2006 and 2008): R&D *Statistics*.

Economist (2009): "Healthcare in India: Lessons from Frugal Innovator", 16 April, http://www.economist.com/businessfinance/displayStory.cfm?story_id=13496367 (accessed on 25 June 2009).

Economist Intelligence Unit (2009): "A New Ranking of the World's Most Innovative Countries", http://graphics.eiu.com/PDF/Cisco_Innovation_Complete.pdf (accessed on 4 August 2009).

Gowda, Aravind (2009): "Infosys to Increase Patent Filings", *Business Standard,* 29 January, http://www.business-standard.com/india/news/infosys-to-increase-patent-filings/311913/ (accessed on 20 July 2009).

Jeffe, Adam B and Josh Lerner (2004): *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It* (Princeton: Princeton University Press).

Koshy, Jacob P and K P Narayana Kumar (2008): "CSIR Looks to Profit from Patents Stock", *Mint*, http://www.livemint.com/2008/10/05235209/CSIR-looks-to-profit-from-pate.html (accessed on 18 July 2009).

Mani, Sunil (2008): "Financing of Industrial Innovations in India, How Effective Are Tax Incentives for R&D", CD: Working Paper Series 405 (Thiruvananthapuram: Centre for Development Studies).

Mahalingam, T V (2003), "Intellectual Property: Indian IT Wakes Up To Patents", *Dataquest,* http://dqindia.ciol.com/content/dqtop202K3/analysis/103080411.asp (accessed on 20 July 2009).

Ministry of Science and Technology (2007): *China Science & Technology Statistics Data Book*, http://www.most.gov.cn/eng/statistics/2007/200801/P020080109573 867344872.pdf (accessed 15 July 2009).

Nayyar, Deepak (2008): "The Internationalisation of Firms from India: Investment, Mergers and Acquisitions", *Oxford Development Studies*, March.

OECD (2009): *OECD Factbook 2009: Economic, Environmental and Social Statistics,* http://titania.sourceoecd.org/vl=4169706/cl=23/nw=1/rpsv/factbook2009/07/01/04/index.htm (accessed on 21 July 2009).

Reserve Bank of India (various issues): *Reserve Bank of India Bulletin*.

Smith, Keith (2004): "Measuring Innovation" in Jan Fagerberg, David C Mowery and Richard R Nelson (ed.), *The Oxford Handbook of Innovation* (New York: Oxford University Press), pp 148-78.

WIPO (2008): *WIPO Statistics Database*, July.

Appendix Table 1: Domestic Private Sector Enterprises Active in Patenting at the USPTO

Domestic Private Sector Enterprises	Cumulative Total 1969-2007
Ranbaxy Laboratories Ltd	78
Dr Reddy's Laboratories Ltd	33
Dr Reddy's Research Foundation	31
Dabur Research Foundation	28
Orchid Chemicals and Pharamaceuticals	22
Panacea Biotec Ltd	16
Wockhardt Ltd	14
Lupin Laboratories Ltd	13
Sun Pharamaceutical Industries Ltd	11
Aurobindo Pharma Ltd	10
Torrent Pharamaceuticals Ltd	10
Usv Ltd	9
Biocon Ltd	8
Biocon India Ltd	7
Sasken Communication Technologies Ltd	7
Dabur India Ltd	6
Gem Energy Industry Ltd	6
Vittal Mallya Scientific Research Foundation	6
Alembic Ltd	5
Glenmark Pharamaceuticals Ltd	5
Tata Consultancy Services Ltd	5
U & I Pharamaceuticals Ltd	5
Cumulative total 1969-2007	335

Source: Compiled from USPTO.

Appendix Table 2: MNCs Operating from India and Active in Patenting at the USPTO

MNC (1969-2007)	Cumulative Total 1969-2007
Texas Instruments, Incorporated	180
International Business Machines Corporation	151
General Electric Company	141
Stmicroelectronics Pvt Ltd	70
Hoechst Aktiengesellschaft	46
Cisco Technology, Inc	30
Veritas Operating Corporation	30
Cypress Semiconductor Corp	28
Broadcom Corporation	27
Ge Medical Systems Global Technology Company, Llc	27
Honeywell International Inc	27
Hewlett-Packard Development Company, L P	24
Unilever Home and Personal Care Usa, Division of Conopco, Inc	22
Intel Corporation	20
Lever Brothers Company, Division of Conopco, Inc	18
Ciba-Geigy Corporation	17
Freescale Semiconductor, Inc	15
Novell, Inc	15
Sun Microsystems,Inc	15
Analog Devices,Inc	13
Ciba-Geigy Ltd	13
Cirrus Logic, Inc	12
Natreon Inc.	11
Stmicroelectronics,Ltd	11
Adobe Systems,Inc	11
Cadence Design Systems,Inc	9
Indian Explosives Ltd	8
Galaxy Surfactants Ltd	8
National Semiconductor Corporation	8
Monsanto Company, Inc	7
Aktiebolaget Astra	7
Hellosoft, Inc	6
Hetero Drugs Ltd	6
Lucent Technologies, Inc	6
Microsoft Corporation	6
Astrazeneca Ab	6
Aventis Pharama Deutschland Gmbh	5
Diebold Incorporated	5
Genesis Microchip, Inc	5
Hewlett-Packard Company	5
Iowa India Investments Company Ltd	5
Osram Sylvania, Inc	5
Redpine Signals, Inc	5
Sap Aktiengesellschaft	5
Silicon Automation Systems Ltd	5
Tektronix, Inc	5
Cumulative total 1969-2007	1,101

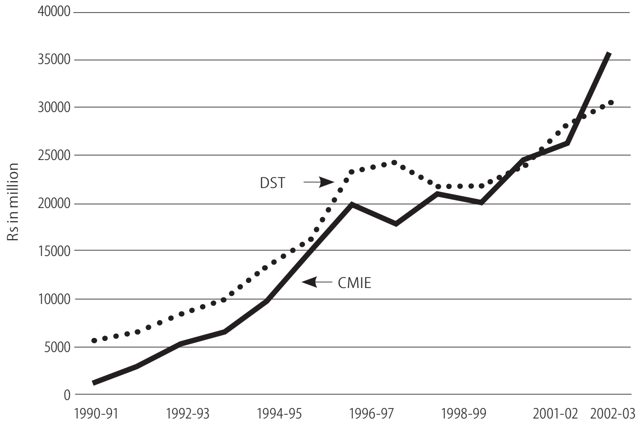
Source: Compiled from USPTO.

Appendix Table 3: PCT Applications by Indian Inventors (2000-01-2006-07)

	Individuals	Legal Entity	Total
2000-01	45	129	174
2001-02	49	189	238
2002-03	57	227	284
2003-04	102	328	430
2004-05	105	351	456
2005-06	130	352	482
2006-07	144	390	534
2007-08	169	538	707

Source: Controller general of patents, designs and trademarks (various issues).

Appendix Figure 1: Trends in Private Sector Enterprise R and D Expenditure: DST vs CMIE



Source: Own Compilation from DST (2006 and 2008) and CMIE, Prowess dataset.

Appendix Table 4: Distribution of PCT Applications from India-Technology-wide

	Average Number 2001-05	Share (%)
I-Electrical engineering		
Electrical machinery, apparatus, energy	131	1.08
Audio-visual technology	61	0.50
Telecommunication	183	1.51
Digital communication	107	0.88
Basic communication processes	142	1.17
Computer technology	438	3.60
IT methods for management	44	0.36
Semiconductors	32	0.26
II-Instruments		
Optics	45	0.37
Measurement	201	1.65
Analysis of biological materials	102	0.84
Control	52	0.43
Medical technology	1,795	14.77
III-Chemistry		
Organic fine chemistry	3,127	25.73
Biotechnology	714	5.87
Pharmaceuticals	2,872	23.63
Macromolecular chemistry, polymers	182	1.50
Food chemistry	393	3.23
Basic materials chemistry	547	4.50
Materials, metallurgy	323	2.66
Surface technology, coating	78	0.64
Micro-structural and nano-technology	3	0.02
Chemical engineering	351	2.89
Environmental technology	122	1.00
IV-Mechanical engineering		
Handling	81	0.67
Machine tools	50	0.41
Engines, pumps, turbines	62	0.51
Textile and paper machines	70	0.58
Other special machines	178	1.46
Thermal processes and apparatus	59	0.49
Mechanical elements	54	0.44
Transport	73	0.60
V-Other fields		
Furniture, games	31	0.26
Other consumer goods	53	0.44
Civil engineering	23	0.19
Total	12,155	100

Source: WIPO (2008).