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HAS INDIA BECOME MORE INNOVATIVE SINCE 1991? ANALYSIS OF THE EVIDENCE AND SOME DISQUIETING FEATURES

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This is a revised version of a paper that I presented as public lectures at the Institute of Public Enterprise, the National Geophysical Research Laboratory, both at Hyderabad, the Lal Bahadur Shastri National Academy of Administration, Mussorrie and as seminars at CSTM, University of Twente, The Netherlands and at the Centre for Development Studies, Trivandrum. I am grateful to the comments that I received at these occasions and in particular to R K Mishra, V P Dimri, Manoj Panda, Chiranjib Sen, Sushil Khanna and Joy Clancy. Thanks are also due to V S Sreekanth for very efficient research assistance. The usual disclaimer holds good.

ABSTRACT

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 high growth performance. There is also a strong feeling among especially the West that India is becoming very innovative. The study will take the reader through the empirical evidence on whether this is indeed the case since the reform process of 1991. A variety of conventional (in the absence of new indicators such as the results of innovation surveys) are analysed and their movements over the last two decades or so chartered to draw some firm conclusions on this front. The conventional indicators considered are the growth in research intensity, patenting, scientific publications, and technology balance of payments. The study is organised into five parts. In the first part I will discuss certain macro features of the growth performance over the last two decades or so and thus sketch the context in which the study is conducted. In the second I engage myself with the literature on measuring innovation using a variety of indicators. In the third section I measure the actual innovative performance of India's economy since economic liberalization by employing a variety of these indicators. The ensuing analysis shows that the growth in innovations is not widespread but concentrated in certain specific sectoral systems of innovation such as in the case of the pharmaceutical industry. In the process of analyzing and piecing together this evidence, the fourth section identifies certain disquieting features which can act as limiting factor to the future innovative potential of the nation. Two such factors are identified and analysed: first, the financing of innovation and second, the availability and quality of science and engineering personnel. The fifth section concludes by examining the efforts made by the government to overcome these two constraints through public policy initiatives.

Key words: India, innovation, R&, patents, technology balance of payment, high-tech industry, financing of innovation, technical education

JEL Classification: O31; O32; O34

Introduction

Notwithstanding the global financial crisis affecting all nations of the world, the recent improvement in the growth performance of India as one of the fastest growing economies of the world have attracted considerable attention among analysts of all hues and shapes. One of the issues that is highlighted in these 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 GDP. India has now become a growing destination for innovative activities by MNCs and this manifest itself in the form of growing presence of foreign R&D centres in the country. FDI from India has steadily been increasing and over the last two years (namely in 2007 and 2008) there have been a number of high profile take-over 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 through essentially 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 and see 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 five sections. The first section maps out the context against which this study is conducted. In the second section I engage with the literature on indicators for measuring innovation. Employing standard indicators, in the third part, I measure the innovative performance of Indian industries. Finally in the fourth and last part I identify two major disquieting features that can act as a limiting factor to sustaining and improving innovative activity in the country. The fifth section sums up the main findings of the study.

I. The context

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 and especially in health care 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;

e. Competitiveness in high technology areas; and

f. Increase in the average propensity to adapt

I consider each of these dimensions in some detail:

According to EIU (2009), India's rank in its Global Innovation Index[1] increased from 58 in 2002-06 to 56 in 2004-08 and is predicted

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, European Union 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).

to further increase to 54 by 2009-13. India has emerged as the fifth largest economy in terms of its level of GDP in PPP terms (World Bank, 2008). 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 per cent during the period 1990-91 through 1999-2000, and it increased to 7.30 per cent during 2000-01 through 2007-08 and over the last three years (2005-06 through 2007-08) it has been growing at rate of about 9 per cent. Currently the service sector accounts for over two-thirds her economy and both service and manufacturing sectors have been performing very well. For a very long time the policy makers in the country never specifically used the term innovation in an explicit manner in Indian policy documents dealing with technological activities. For instance most recent policy document to promote innovations is titled *Science and Technology Policy* 2003. But given the international trend and in realizing the increasing number of innovations emanating from the country, a draft *National Innovation Act 2008* is in the anvil and the usage of the expression 'innovation' in the 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, medical devices industries[3]. However this proposition has not been subject to any rigorous empirical scrutiny.

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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 Center 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 but journalistic account of the growth of innovations in India in recent times, see Bagla and Goel (2009).

One of the distinguishing aspects of India's growth performance especially since 2000 is that its knowledge-intensity has increased (Table 1: see notes to this table for the empirical definitions). Currently about 14 per cent of overall NDP of the country can be termed as composed of knowledge-intensive production.

Table 1: Share of knowledge-intensive production in India's overall domestic production (Based on knowledge intensive products and services in Rs Crores at 1999-2000 prices)

Fiscal year 1	NDP at factor cost 2	Knowledge intensive manufacturing industry[1] 3	Knowledge intensive services industry[2] 4	Knowledge intensive production 5 = (3+4)	Share of knowledge intensive production 6 = (5/2) *100
1999-00	1605103	87049	50054	137103	9
2000-01	1670448	92256	66880	159136	10
2001-02	1764137	95257	79041	174298	10
2002-03	1824635	99760	96196	195956	11
2003-04	1981389	110650	120575	231225	12
2004-05	2126018	125795	149060	274855	13
2005-06	2326581	137703	185772	323475	14
2006-07	2549648	153787	100492[3]	254279[3]	

Note: 1. Knowledge-intensive manufacturing = Chemical and chemical products (24) +Metal products and machinery (28+29+30) +Electrical machinery (31+32) + Transport equipment (34+35); Figures in parentheses indicate the NIC-98 codes of these industries;

2. Knowledge-intensive services = Communication + Computer relating services + R& D services

3. Excludes communication services as CSO (2008) does not report this for 2006-07

Source: Central Statistics Organisation (2008)

Mirroring the general trend, much of the knowledge intensive production comes from the services sector. Further the growth performance of the knowledge-intensive production sector is larger than that of the overall economy.

The increasing knowledge-intensity of the country's GDP is caused by the growth and emergence of knowledge-intensive enterprises. For measuring this aspect we employ a direct measure and by using a proxy. The direct variable is the number of new company registrations in India according to the level of activity (National Knowledge Commission, 2008). According to the National Knowledge Commission, there are four levels of entrepreneurship in terms of the level of technology involved with low technology activities such as agriculture and allied activities at the bottom of the pyramid (Level 1) and knowledge-intensive sectors at the top of the pyramid (Level 4):

- Level 1: Agriculture and other activities: Crop production, Plantation; Forestry, Livestock, Fishing, Mining and Quarrying;
- Level 2: Trading services: Wholesale and retail trade; Hotels and Restaurants;
- Level 3: Old economy or traditional sectors: Manufacturing, Electricity, Gas and Water supply
- Level 4: Emerging sectors (including knowledge intensive sectors): IT, Finance, Insurance and Business services, Construction, Community, Social & Personal Services, Supply Chain, Transport- Storage-Communications etc.

The data on new company formations (Ministry of Company Affairs, 2007) could be cross classified according to these four levels (Figure 1) and it shows that new companies belonging to knowledge intensive sectors account for the largest share and the number of new companies formed has significantly increased since 2003 or so.

This dominance of technology-intensive sectors in total company formation is further corroborated by our proxy- namely the technology content of all industrial proposals actually implemented since 1991 (Secretariat of Industrial Assistance, 2008). Once again, with the exception of a few industries such as textiles, majority of the new proposals are in technology-oriented industries such as chemicals, fuel, electrical equipments etc. This once again prompts us to conjecture that technology oriented ventures are on the rise in India since the initiation of economic reforms in 1991.

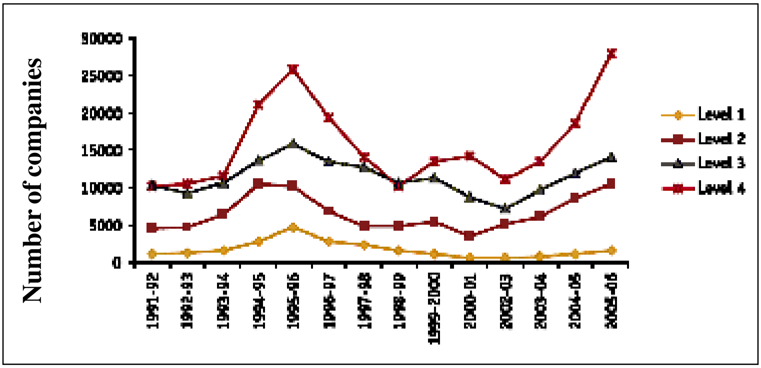

Figure 1: Distribution of new company formations in India according to intensity of knowledge

Source: National Knowledge Commission (2008), p. 6

The rate of survival of these ventures are, however, not available. There has always been insignificant amounts of FDI from India (Morris,), but there has been a torrent of FDI from India since 2005-06. See Table 2.

Most of these investments have flown to technology-based ventures in manufacturing sector of developed economies (Nayyar, 2008). According to Nayyar, “it must be recognized that Indian firms could not have become international without the capacity and the ability to compete in the world market. The attributes of Indian firms, which created such capacities and abilities, are embedded in the past and have emerged over a much longer period of time”.

Table 2: FDI from and to India, 2000-01 to 2007-08 (in Millions of US $)

	FDI to India			FDI from India			Ratio of FDI from India to India
	Credit	Debit	Net	Credit	Debit	Net	
1990-91	107	10	97				
1991-92	147	18	129				
1992-93	345	30	315				
1993-94	651	65	586				
1994-95	1351	8	1343				
1995-96	2173	29	2144				
1996-97	2863	22	2841				
1997-98	3596	34	3562				
1998-99	2518	38	2480				
1999-00	2170	3	2167				
2000-01	4031	0	4031	70	829	-759	0.21
2001-02	6130	5	6125	99	1490	-1391	0.24
2002-03	5095	59	5036	73	1892	-1819	0.37
2003-04	4322		4322	142	2076	-1934	0.48
2004-05	6052	65	5987	35	2309	-2274	0.38
2005-06	8962	61	8901	216	6083	-5867	0.68
2006-07	22078	87	21991	881	14393	-13512	0.65
2007-08	32453	125	32327	2471	19253	-16782	0.59

Source: Reserve Bank of India, Date base of Indian Economy

According to the Economist (2009) the pursuit of technology is a powerful motive for foreign acquisitions. Before Tata Steel's purchase of Corus, the Indian steelmaker did not hold a single American patent. The takeover bought it over 80, as well as almost 1,000 research staff. Thus increasing foreign acquisitions of technologically speaking active targets have given Indian companies considerable access to technological inputs of the acquired firm without having the need to build it up assiduously from the scratch. Also mergers between two different companies with differential innovative cultures.

Growing competitiveness in high technology areas: I had already shown that the knowledge intensity of India's GDP has shown some increases (Table 2) over the period since the beginning of this millennium. The fact that India has become the largest exporter of IT services[4] in the world has been known now for some time. Technology content of India's manufactured exports has shown some impressive increases since 1991. See Table 3:

Table 3: Technology content of India's manufactured exports, 1988-2007 (Percentage shares of manufactured exports)

	Low Tech	Medium Tech	High Tech	Total
1988	82.08	12.96	4.96	100
1989	79.84	13.74	6.42	100
1990	79.74	14.69	5.57	100
1991	79.15	15.40	5.45	100
1992	82.36	13.39	4.25	100
1993	81.35	14.11	4.54	100
1994	80.44	14.91	4.66	100
1995	79.04	15.42	5.54	100
1996	77.94	15.83	6.23	100
1997	78.11	15.64	6.25	100
1998	80.80	13.88	5.32	100
1999	81.38	13.01	5.60	100
2000	78.37	15.44	6.19	100
2001	76.15	16.43	7.42	100
2002	75.83	16.80	7.37	100
2003	74.41	18.28	7.31	100
2004	73.38	19.87	6.75	100
2005	71.75	21.37	6.88	100
2006	68.90	23.00	8.10	100
2007	67.80	23.48	8.72	100

Source: UN Comtrade database by applying the UNIDO (2009) definitions of high, medium and low tech

4 This is according to the recent IMF Balance of Payments Statistics (2008).

Employing the UNIDO (2009) definition of high, medium and low technology products to the UN Comtrade data on India's manufactured exports, the relative composition of manufactured exports to these three technology categories have been arrived at in Table 3. Although India's manufactured exports are still dominated by low technology products, the share of high tech products has doubled itself over the period under consideration. It is also interesting to note that India's exports of aerospace products have been increasing at a rate of 74 per cent per annum as against the world exports of these products at 15 per cent per annum. India is acknowledged to have considerable technological capability in the design and manufacture of spacecrafts and is now an acknowledged global leader in remote sensing. The Space Competitiveness Index (SCI) devised by Futron Corporation[5] assesses more than 50 individual metrics across three underlying dimensions of

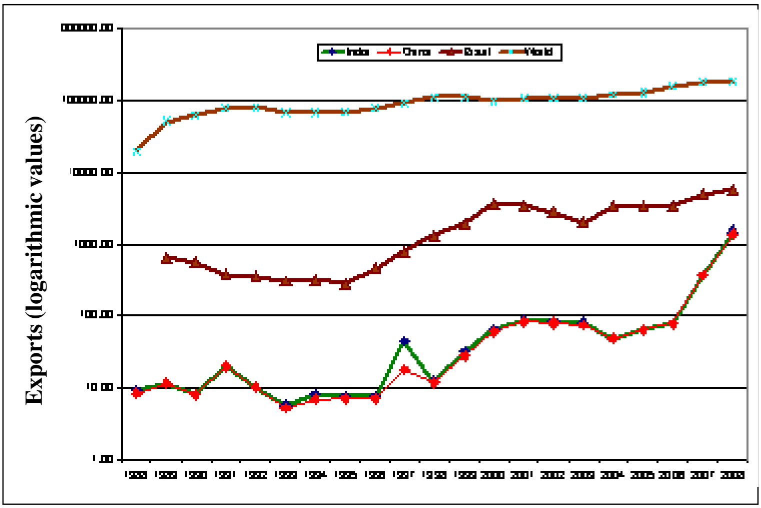

Figure 2: Exports of Aerospace products from India, 1988-2008

Source: Computed from UNU Comtrade data

5 See Futron (2009), http://www.futron.com/pdf/resource_center/reports/Futron_2009_SCI_Executive_Summary.pdf (accessed on July 2 2009)

competitiveness: government, human capital, and industry. Using this framework, Futron offers a comparative assessment of ten leading space participant nations: Brazil, Canada, China, Europe (counted as a single entity), India, Israel, Japan, Russia, South Korea, and the United States. According to Futron's 2009 ranking of the ten countries on the SCI, India with a total score of 15.34 is ranked 7 and has a better ranking than South Korea, Israel and Brazil. However most of the innovations in this area in India are contributed entirely by the government sector and not by the industry. In fact my argument is that the government in India has thwarted all attempts to create a sectoral system of innovation in the aerospace industry by invoking a security angle. Therefore even though it possessed all the necessary ingredients, the country could never emerge as a serious player in the civilian aerospace sector. But this is all set to change now and as Figure 2 has shown aerospace exports from India has increased manifold during recent times although almost all the exports of this item are parts or components of aircrafts. With approximately 300 small and medium enterprises active in this area[6], India is slowly emerging as one of the few developing countries to have a high technology industry such as the aerospace industry.

Increasing average propensity to adapt by enterprises: Enterprises in developing countries have, essentially, two sources for their technological requirements. The first source is from its own in-house R&D centers and the second one is from external sources which are either from within the country or from abroad. There is of course a relationship between the two sources. Very often enterprises first purchased technology from external sources and then adapted it to local conditions by performing in-house R&D efforts. The literature that has reviewed in house R&D and technology acquisition efforts often enough

6 The SIATI, the Society of Indian Aerospace Technologies and Industries, formed in 199, based at Bangalore, India, with a current (c2009) membership of over 300, brings together R & D, manufacturing and support organization in the field of aerospace.

found this relationship to be complementary in nature (Katrak, 2002). With this idea in mind, it is possible for us to find out the average propensity to adapt by taking the ratio of in house R&D to technology acquisition from abroad. If the ratio is greater than unity, the interpretation is that firms are becoming more and more self sufficient. Given the fact in India, in house R&D expenditures have increased tremendously since 1991and since enterprises have a freer access to external sources of technology resulting from liberalization of the conditions governing the importation of technologies from abroad. See Figure 3:

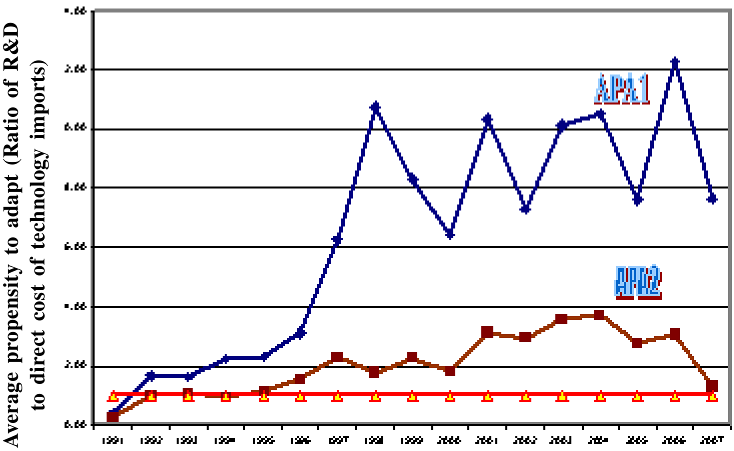

Figure 3: Average propensity to adapt of Indian private sector enterprises, 1991-2007

Source: Department of Science and Technology (2008) and Reserve Bank of India

Two measures of average propensity to adapt is employed, APA_1 and APA_2. Both the ratios have a common numerator, namely the in-house R&D expenditure. The denominators are slightly different, for APA_1 it is the direct cost of technology imports through the formal licensing channel, where as in APA_2 the denominator include the direct cost of technology imports through both formal and informal channels.

Both the ratios, although fluctuating, are above unity showing that enterprises invested more in creating technologies through in-house R&D expenditure efforts than purchasing it from external sources. This statement is more valid with respect to APA_1, but when indirect channels of technology imports are included as is the case with APA_2, the average propensity to adapt is considerably less and is showing a downward trend over the last three years. This shows that the informal channels of technology imports have become very pronounced during the period of liberalization. Nevertheless, the APA values are greater than unity implying that the average propensity to adapt for a typical Indian firm has actually increased since 1991, although it has tended to come down over the last three years or so with firms taking recourse, increasingly to informal channels of technology importation. According to Mohan (2008) based on data from RBI most, Indian enterprises import technology from abroad through the employment of consultants.

II. Engagement with the literature on measuring innovation: 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, nonlinear, multidimensional, and unpredictable. No single measure is likely to characterize 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 the one 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 organization'. 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) show that most of these indicators, if not all, has only attempted to measure tangible inputs and outputs of only product and process innovations. This is because, in those days (namely during the 1950s, 60s and the 70s), 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.

For a very long time until the early 1990s, measurement of innovation even in developed countries was in the form of conventional indicators. The growth of innovation indicators has progressed exponentially (Table 4). These conventional indicators include the following: R&D expenditure and intensity; Patent applications, awards and citations; bibliometric data (scientific publication and citation). With the jettisoning of the linear view of innovation and the embracing of the "chain linked" conceptualization of innovation, new indicators were developed to measure innovative activity. The most prominent of these are innovation surveys. Innovation surveys are of two types:

(i) Those that focus on firm-level innovation activity, asking about general innovation inputs (both R&D and non R&D) and outputs (usually of product innovations). This is sometimes referred to as the subject approach since it focuses on the innovating agent; and,

(ii) Those that focus on significant technological innovations (usually identified through expert appraisal, or through new product announcements in trade journals or other literature). This is referred to as the object approach since it focuses on the objective output of the innovation process.

The subject approach includes small scale, incremental changes while the object approach tends to focus on significantly new products. By new indicators we mean only the subject approach.

Innovation surveys have joined the list in 1980s and have diffused somewhat cautiously across the developing world through the 1990s. The idea of an innovation survey is inherently appealing to developing countries as it is based on the premise that firms do not always innovate

Table 4: Exponential growth of innovation indicators: 1950s through the 1990s

Decades	50s and 60s	70s	80s	90s
Main Indicators used	R&D	R&D	R&D	R&D
		Patents	Patents	Patents
		Technological balance of payments	Technological balance of payments	Technological balance of payments
			High-tech products and sectors	High-tech products and sectors
			Bibliometrics	Bibliometrics
			Human Resources	Human Resources
			Innovation Surveys	Innovation Surveys
				Innovations mentioned in technical literature
				Surveys of production technologies
				Intangible investment
				Productivity

Source: Own compilation

through the performance of R&D. In fact a whole host of innovation generating non R&D routes is used, for instance by acquiring machinery, purchasing innovative outputs from outside, training of personnel etc. In fact firms in developing countries are more prone to using these non-R&D routes. An analysis of the data on GERD to GDP ratio and patents presented above shows that even with low levels of R&D investments some of these developing countries are able to continuously improve their respective patenting records.

Even in the European Union, which has been the home of innovation survey and where at least six rounds of innovation surveys have been completed, innovation targets under the *Lisbon Strategy* requires that all countries within the union are expected to have a GERD to GDP ratio of 3 per cent by 2013. So despite all the perceived limitations (Smith, 2004) of these available indicators the measurement of innovations and its analysis is still conducted, in the literature, by employing the conventional input and output indicators such as investments in R&D and the number of patents awarded respectively.

In this context, it will be useful to discuss the actual indicators employed in real life by business enterprises to measure innovation. For this I consider two different sets of evidences. The first one is based on a series of annual surveys of innovation measurement[7] in business enterprises conducted by the global management consultancy firm, *The Boston Consulting Group* (BCG). The second one is on the basis of a recent competition conducted to identify the most innovative small

7 The BCG surveys covered 170 senior executives and managers in North America (71), Europe (60), Asia-Pacific (36), and Latin America (3) across a range of manufacturing and service sector industries. Technology-based industries such as telecommunications, pharmaceuticals, biotechnology and health care accounted for the largest share. The survey was conducted in 2007, 2008 and in 2009.

and medium enterprise in India. The first one deals with innovation measurement within a firm while the second one deals with measuring innovation across firms. I discuss these two exercises in some detail below as it can better inform us about innovation measurement.

(i) Measurement of innovation within a firm: The successive surveys conducted by the BCG have thrown up some interesting facts about innovation measurement within a firm. These are summarized in Box 1.

Box 1: Measuring innovation at the firm level: Findings from a senior management survey

- Only 32 percent of executives are satisfied with their company's innovation-measurement practices. And that percentage has been falling.
- While most executives-73 percent of respondents-believe that innovation should be tracked as rigorously as other business operations, only 46 percent said that their company actually does so.
- The majority of companies continue to rely on a handful of metrics to measure the full scope of their innovation activities. Fifty-two percent of respondents said their company uses five or fewer metrics. But that number is starting to rise.
- A surprisingly small no of companies-27 percent of respondents-attempt to drive innovation by linking employee incentives metrics. But that number, too, is edging up.
- The most widely tracked components of innovation are overall company profitability (79 percent of respondents said their company measures it), overall customer satisfaction (75 percent), and incremental revenue from innovation (73 percent)

cont'd...

- The metrics that employees pay the most attention to-the ones that have the greatest impact on their behavior and attitudes towards the company's innovation efforts-are incremental revenue from innovation and overall customer satisfaction.
- Companies consider themselves most effective at measuring innovation outputs (such as revenue growth, shareholder returns, and brand impact). They consider themselves far less successful at tracking innovation inputs (for example, dedicated resources, such as people and funds invested) and the quality of their innovation processes.

Source: Andrew et al (2009)

(ii) Innovation measurement across firms: In 2009 at the InfoVision 2009[8] at Bangalore, two Indian firms Sterlite Technologies[9] and Glenmark Pharma[10] were declared as the most innovative small and medium enterprises in India. Criteria[11] for the award included the number and impact of patents, the efficiency and effectiveness of research, and the impact of innovation as measured by patent citations. In order to provide a true comparison of innovation, it is necessary to count the number of inventions per entity, rather than the number of individual patents. *The Derwent World Patents Index* (DWPI)[12] is the world's most comprehensive database of enhanced patent information. The basic measure of innovation of entities is to measure the volume of patents to

8 http://www.infovision.org.in/2009/programme.html (accessed on July 15 2009).

9 Sterlite Technologies Limited (formerly, Sterlite Optical Technologies Ltd) is a leading global provider of transmission solutions for the telecom and power industries. It is India's only fully integrated optical fiber producer and among the Top 5 global manufacturers of power conductors.

10 Glenmark is considered to be the leader in India in drug discovery with 13 NCE and NBE molecules in the pipeline.

11 This write up is based on Thomson Reuters (2009).

12 DWPI provides one descriptive record for each invention from inventors around the world and can therefore be used to measure the number of inventions as required.

each entity and rank them according to these volumes. It is a provision of patenting that an individual invention can be registered in many countries for patent protection so that one invention can give rise to many patents. Counting patent documents would give rise to much double counting and is not useful for measuring the true volume of innovation. In order to provide a true comparison of innovation, it is necessary to count the number of inventions per entity, rather than the number of individual patents. The DWPI database was searched (previous winners were omitted) for recent inventions originating from India (PR=IN) and published from 2006 to date (PY=2006:2008) which gave a total of 17290 results as of November 2008. These records were ranked according to assignee and used to identify the top SME companies in two technology areas – Life Sciences and Corporate Services. An assessment of the impact of an organization's innovation can be made by considering later published inventions which cite the earlier work of the organization being assessed. Since those organizations with a greater number of published inventions have a greater likelihood of being cited, the number of citations is divided by the total number of inventions to produce a normalized.

It is thus clear that even at the firm level there is plenty of scope for measuring and interpreting innovations and output indicators are more easily measured and interpreted than input-based indicators. It is also interesting to note that firms are employing output indicators such as revenue growth, shareholder returns and brand impact as output indicators of innovation which are not that easily considered as innovation indicators in the relevant literature. In other words, there is a clear discordance between the innovation indicators that are used at the micro and macro levels. For the economy as a whole much of the discussion is in terms of input indicators such as R&D investments (and various variants of it) and output indicators such as patents applied for and awarded. In the following, I apply these indicators to see if India is becoming more innovative since the onset of reforms in 1991.

(III) India's innovative performance

(i) Trends in R&D investments

I start by analyzing the overall investments in R&D in the country as a whole. See Table 5. Trends in R&D investments both at constant and current prices are tracked so also the overall 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 libralisation periods at about 0.78[13].

Care has to be exercised while interpreting these figures to mean 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 per cent of the total R&D performed within the country although the share of government has tended to come down over time (Figure 4). 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). 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 quickly than the government sector where much of the research does not fructify into products and process for the country as a whole[14].

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

14 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 space research.

Table 5: Trends in India's overall investments in R&D, 1980-81 through 2007-08 (Current and Constant values are in Rs Crores; Constant values are in 1999-2000 prices);

	GERD current	Nominal growth rates (%)	GERD constant	Real growth rates (%)	GERD to GDP ratio
1980-81	761		3686		0.57
1981-82	941	24	4112	12	0.61
1982-83	1206	28	4855	18	0.70
1983-84	1381	15	5127	6	0.68
1984-85	1782	29	6124	19	0.78
1985-86	2069	16	6628	8	0.81
1986-87	2435	18	7298	10	0.86
1987-88	2853	17	7809	7	0.89
1988-89	3347	17	8457	8	0.87
1989-90	3726	11	8673	3	0.84
1990-91	3974	7	8361	-4	0.77
Average		18		9	0.76
1991-92	4513	14	8348	0	0.76
1992-93	5005	11	8504	2	0.73
1993-94	6073	21	9382	10	0.77
1994-95	6622	9	9320	-1	0.72
1995-96	7484	13	9651	4	0.69
1996-97	8914	19	10665	11	0.71
1997-98	10611	19	11908	12	0.76
1998-99	12473	18	12954	9	0.77
1999-00	14398	15	14398	11	0.81
2000-01	16199	13	15688	9	0.84
2001-02	17038	5	16022	2	0.81
2002-03	18000	6	16304	2	0.80
2003-04	19727	10	17276	6	0.78
2004-05	21640	10	17960	4	0.75
2005-06	28777	33	22954	28	0.88
2006-07	32942	14	24895	8	0.87
2007-08	37778	15	27413	10	0.88
Average		16		7	0.78

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

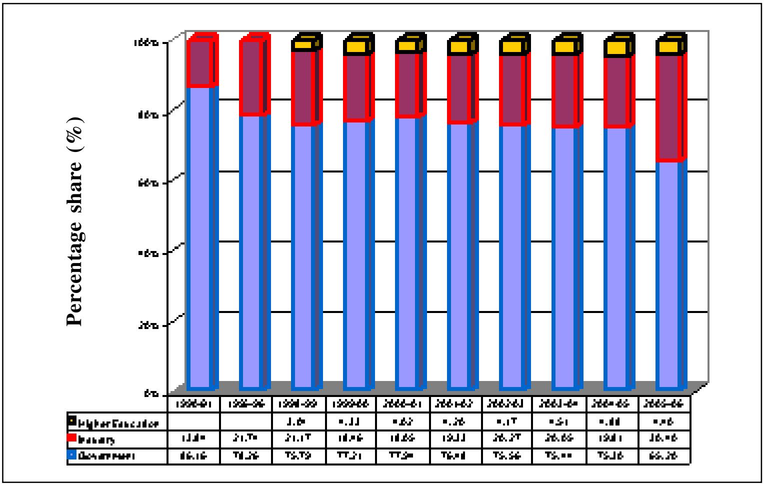

Figure 4: Sector-wide performance of R&D in India, 1990-91 through 2005-06

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). 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.

Table 6: Nominal R&D expenditure by private sector enterprises (Rs in Millions)

	Public sector enterprises	Government research institutes	Private sector enterprises	Ratio of Private sector to Public sector enterprises	Ratio of Private sector to Government research institutes
1985-86	1986.18	1622.7	2519.44	1.27	1.553
1986-87	2356.99	1723.36	2916.33	1.24	1.692
1987-88	2884.66	1851.29	3102.67	1.08	1.676
1988-89	3421.24	2093.28	4176.25	1.22	1.995
1989-90	4129.01	2395.21	4905.94	1.19	2.048
1990-91	4145.33	2491.88	5499.81	1.33	2.207
1991-92	4843.88	2745.50	6369.44	1.31	2.320
1992-93	5139.50	2993.65	8362.47	1.63	2.793
1993-94	5428.11	NA	9825.37	1.81	
1994-95	4146.09	3564	13188.70	3.18	3.701
1995-96	4275.76	4116.99	16270.69	3.81	3.952
1996-97	5360.52	4440	23307.50	4.35	5.249
1997-98	5392.40	5641.30	24382.50	4.52	4.322
1998-99	6738.70	7133.20	21766.10	3.23	3.051
1999-00	7576.30	7808.82	21781.10	2.87	2.789
2000-01	8428.80	8641.20	24114	2.86	2.791
2001-02	7673.70	8922.60	27874.80	3.63	3.124
2002-03	8089.50	9512.50	30649.30	3.79	3.222

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

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 R&D expenditures to the DST would have exaggerated their R&D expenditures 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 I compared the R&D investments as reported by the DST with that of those available from *Centre for Monitoring Indian Economy's (CMIE)* Prowess dataset (Annexure 1). 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. More over 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 artifact does not appear to be true.

Within the industrial sector about four industries account for a significant share of R&D investments (Table 7). The pharmaceutical and the automotive industries are the two most important spenders on

Table 7: Industry-wide distribution of Industrial R&D
(Cumulative shares in per cent 1998-99 through 2002-03)

Industry	Share
Metallurgical Industries	4.21
Fuels	6.12
Boilers & steam Generating Plants	0.01
Prime Movers	0.09
Electricals & Electronic Equipment	8.94
Telecommunications	3.75
Transportation	15.16
Industrial Machinery	1.84
Machine Tools	0.75
Agricultural Machinery	1.33
Earth Moving Machinery	0.10
Misc. Mechanical Engineering Industries	1.22

cont'd.....

Commercial Offices, Household Equipment	0.15
Medical & Surgical Appliances	0.04
Industrial Instruments	0.74
Scientific Instruments	0.09
Math. Surveying & Drawing Instrument	0.00
Fertilisers	0.81
Chemicals (other than Fertilisers)	8.35
Photographic Raw Film & Paper	0.05
Dye-Stuffs	0.26
Drugs & Pharmaceuticals	19.30
Textiles(Dyed, Printed, Processed)	1.21
Paper & pulp	0.34
Sugar	0.92
Fermentation Industries	0.05
Food Processing Industries	1.39
Vegetable Oil & Vanaspathi	0.09
Soaps, Cosmetics & Toilet Preparations	2.37
Rubber Goods	0.95
Leather, Leather Goods and Pickers	0.21
Glue and Gelatin	0.05
Glass	0.21
Ceramics	0.25
Cement & Gypsum Products	0.60
Timber Products	0.01
Defence Industries	8.32
Information Technology	4.69
Biotechnology	1.59
Consultancy Services	1.05
Miscellaneous Industries	2.38

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

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 TRIPS compliance of Indian Patent in 2005 (Figure 5). This reasoning was based on the belief that much of the Indian R&D in pharmaceuticals were 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 cent per annum.

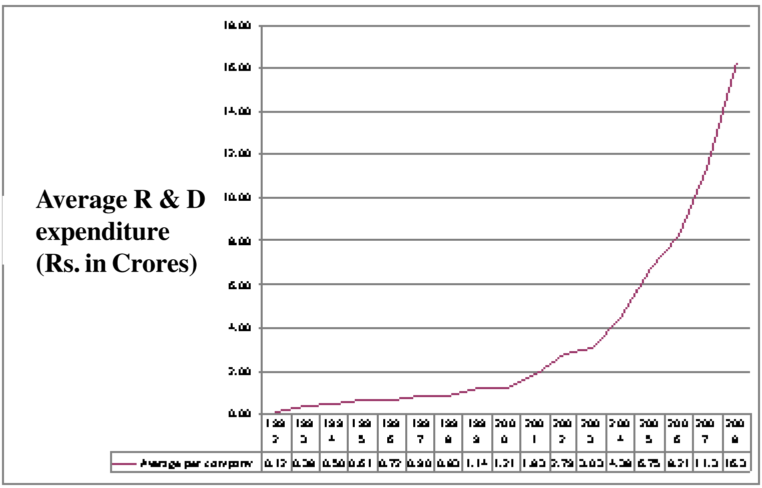

Figure 5: Average R&D expenditure per firm in India's pharmaceutical industry: pre and post TRIPS compliance

Source: Own compilation based on the Prowess Dataset

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

(ii) 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 Patent Co-operation Treaty (PCT) applications[15] and in Triadic[16] patents. This is followed by a discussion of the recent surge in Indian patenting within India itself.

(a) US patenting behaviour of Indian inventors: USA 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

15 Any resident or national of a Contracting State of the Patent Cooperation Treaty (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.

16 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).

patenting in the USA. Further USPTO is supposed to have one of the lowest home biases as more than 50 per cent 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 specialization of patenting from India.

Volume of patents: The number of patents applied for and awarded is presented in Tables 8 and 9. In order to see the significance of Indian patenting I compare it not only across time but across the BRICS (Brazil, Russia, India, China, and South Africa) 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[17]. See Table 10.

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

Table 8: Trends in patent applications by Indian inventors in the USPTO in comparison with BRICS (Number of patent applications)

	Brazil	Russia	India	China	South Africa	Total BRICS	Ratio of India to BRICS	Ratio of India to China
1965	33		10		99			
1966	35		25		83			
1967	30		32		101			
1968	29		13		102			
1969	22		30		115			
1970	30		21		98			
1971	51		22		149			
1972	46		21		145			
1973	43		24		165			
1974	44		43		152			
1975	64		32		179			
1976	51		39	9	149			4.33
1977	51		27	9	169			3.00
1978	72		24	6	175			4.00
1979	72		25	15	206			1.67
1980	53		23	7	203			3.29
1981	66		22	10	213			2.20
1982	70		20	5	199			4.00
1983	57		15	12	207			1.25
1984	62		30	18	216			1.67
1985	78		25	24	227			1.04
1986	68		36	112	204			0.32
1987	62		26	83	239			0.31
1988	71		41	122	192			0.34
1989	111		50	112	215			0.45
1990	88		58	111	185			0.52
1991	124		51	126	186			0.40
1992	112	183	64	129	207	695	0.09	0.50
1993	105	153	54	135	246	693	0.08	0.40
1994	156	206	70	100	238	770	0.09	0.70
1995	115	221	91	144	187	758	0.12	0.63
1996	145	254	115	142	189	845	0.14	0.81
1997	134	249	137	117	174	811	0.17	1.17
1998	165	273	180	181	211	1010	0.18	0.99
1999	186	388	271	257	179	1281	0.21	1.05
2000	220	382	438	469	209	1718	0.25	0.93
2001	219	433	643	626	231	2152	0.30	1.03
2002	243	377	919	888	241	2668	0.34	1.03
2003	259	341	1164	1034	224	3022	0.39	1.13
2004	287	334	1303	1655	246	3825	0.34	0.79
2005	295	366	1463	2127	197	4448	0.33	0.69
2006	341	412	1923	3768	231	6675	0.29	0.51
2007	375	444	2387	3903	252	7361	0.32	0.61

Source : Compiled from the USPTO

Table 9: Trends in patents awarded to Indian inventors in the USPTO in comparison with those awarded to BRICS (Number of patent awarded)

	Brazil	Russian Federa-tion	China Pep.R	India	South Africa	Total BRICS	Ratio of India to BRICS	Ratio of India to China
1963	17	0	4	4	30	55	0.07	1.00
1964	10	0	3	7	37	57	0.12	2.33
1965	11	0	4	8	69	92	0.09	2.00
1966	17	0	2	5	48	72	0.07	2.50
1967	12	0	9	10	52	83	0.12	1.11
1968	13	0	5	15	35	68	0.22	3.00
1969	18	0	5	18	65	106	0.17	3.60
1970	17	0	6	16	50	89	0.18	2.67
1971	14	0	15	10	71	110	0.09	0.67
1972	16	0	8	19	54	97	0.20	2.38
1973	18	0	10	21	86	135	0.16	2.10
1974	21	0	22	17	86	146	0.12	0.77
1975	24	0	1	13	74	105	0.12	13.00
1976	19	0	5	17	83	123	0.14	3.40
1977	24	0	1	13	68	103	0.13	13.00
1978	23	0	0	14	81	119	0.12	
1979	27	0	1	14	64	98	0.14	14.00
1980	19	0	1	4	74	103	0.04	4.00
1981	20	0	3	6	111	143	0.04	2.00
1982	30	0	0	4	73	104	0.04	
1983	19	0	1	14	60	94	0.15	14.00
1984	20	0	2	12	82	116	0.10	6.00
1985	30	0	1	10	96	137	0.07	10.00
1986	27	0	9	18	88	142	0.13	2.00
1987	34	0	23	12	107	176	0.07	0.52
1988	29	0	47	14	103	193	0.07	0.30
1989	36	0	52	14	134	236	0.06	0.27
1990	41	0	47	23	114	225	0.10	0.49
1991	62	0	50	22	105	239	0.09	0.44
1992	40	0	41	24	97	202	0.12	0.59
1993	57	3	53	30	93	236	0.13	0.57
1994	60	38	48	27	101	274	0.10	0.56
1995	63	98	62	37	123	383	0.10	0.60
1996	63	116	46	35	111	371	0.09	0.76

cont'd...

	Brazil	Russian Federation	China Pep.R	India	South Africa	Total BRICS	Ratio of India to BRICS	Ratio of India to China
1997	62	111	62	47	101	383	0.12	0.76
1998	74	189	72	85	115	535	0.16	1.18
1999	91	181	90	112	110	584	0.19	1.24
2000	98	183	119	131	111	642	0.20	1.10
2001	110	234	195	178	120	837	0.21	0.91
2002	96	200	289	249	113	947	0.26	0.86
2003	130	203	297	342	112	1084	0.32	1.15
2004	106	169	404	363	100	1142	0.32	0.90
2005	77	148	402	384	87	1098	0.35	0.96
2006	121	172	661	481	109	1544	0.31	0.73
2007	90	188	772	546	82	1678	0.33	0.71
2008	101	176	1225	634	91	2227	0.28	0.52

Source: Compiled from the USPTO

Table 10: Estimated break dates and growth rates in Indian patent applications and awards in the US, 1965-2007

Breakdates	First break	Second break		Third break
1. Patent applications	1973	1983		1992
2. Patent awards	1970	1979		1997
Growth rates (%)	Period 1: 1965-1973	Period 2: 1974-1983	Period 3: 1984-1992	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

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 breakdates are 1970, 1979 and 1997. It is seen that in both cases there are two breakdates of 1992 and 1997 are during the phase of economic liberalization 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.

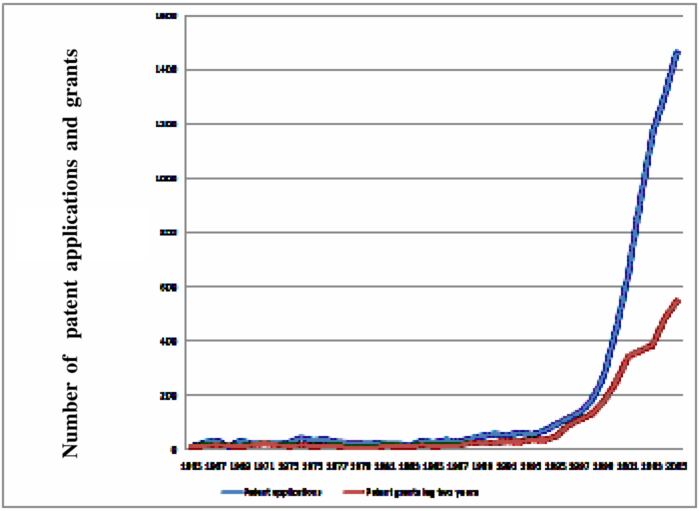

Figure 6: Lagged relationship between patent applications and awards

Source: USPTO

The lagged relationship[18] between patent applications and awards (Figure 6) 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 11 and Figure 5) shows that in 1991, domestic inventors (consisting of Government Research Institutes (read as CSIR), private sector enterprises and individuals) accounted for about 71 per cent of the innovations taking place within the country. This has since got reduced to just 39

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

per cent. The share vacated by domestic inventors have been taken up by foreign companies implying the fact that many affiliates of MNCs have started doing R&D- often enough through the outsourcing mode[19]- 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.

Table 11: 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

Source: Compiled from USPTO

Note: GRI: Government Research Institute; IOP: Individually Owned Patents

The CSIR has an extremely good patenting record until 2003 (Figure 5) and thereafter it seem to be tapering off. The precise reasons for this declining rate of patenting in CSIR require some in-depth examination. Currently (c2008) CSIR is in the process of consolidating its patent inventory. It is supposed to be having a total of 3,016 patents

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

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 7 and Table 12). A run through this list of domestic enterprises show us an interesting result, namely that almost all the 23 firms[20] 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.

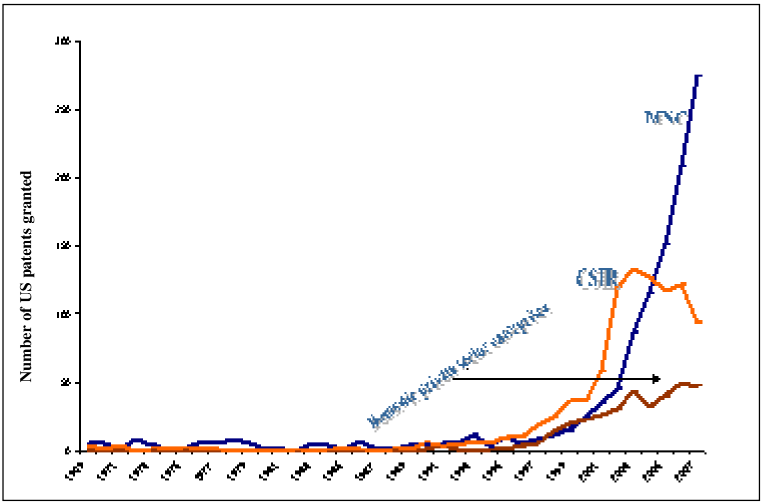

Figure 7: Trends in US patenting by MNCs operating from India, CSIR and domestic private sector enterprises

Source: Compiled from USPTO

20 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.

Table 12: Domestic private sector enterprises active in patenting at the USPTO

Sl No	Domestic Private sector enterprises	Cumulative total 1969-2007
1	Ranbaxy Laboratories Ltd	78
2	Dr.Reddy's Laboratories Ltd	33
3	Dr.Reddy's Research Foundation	31
4	Dabur Research Foundation	28
5	Orchid Chemicals & Pharamaceuticals	22
6	Panacea Biotec Ltd	16
7	Wockhardt Ltd	14
8	Lupin Laboratories Ltd	13
9	Sun Pharamaceutical Industries Ltd	11
10	Aurobindo Pharma Ltd	10
11	Torrent Pharamaceuticals Ltd	10
12	Usv Ltd	9
13	Biocon Ltd	8
15	Biocon India Ltd	7
16	Sasken Communication Technologies Ltd	7
17	Dabur India Ltd	6
18	Gem Energy Industry Ltd	6
19	Vittal Mallya Scientific Research Foundation	6
20	Alembic Ltd	5
21	Glenmark Pharamaceuticals Ltd	5
22	Tata Consultancy Services Ltd	5
23	U & I Pharamaceuticals Ltd	5
	Cumulative total 1969-2007	**335**

Source: Compiled from USPTO

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. First of all Indian IT companies are much more IT services companies where they do not have that much scope for patenting as compared to world IT companies which are more IT products oriented ones. 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[21].

However, currently most of the Indian patents in the US are 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 (Table 13) of these enterprises show that almost all of them are from the IT and IT related industries.

Thus combining the data contained in Tables 12 and 13 it is clear that Indian private sector enterprises are specializing in pharmaceutical innovations while the foreign enterprises are specializing in IT related patents. As a result, specialization of Indian patenting in the US (Table 14) has actually increased. For instance in 1991, almost sixty five per cent 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 per cent of the patenting was in just two broad areas of pharmaceuticals and IT related technologies.

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21 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 Mahaligam (2003) and Gowda (2009).

Table 13: MNCs operating from India and active in patenting at the USPTO

Sl No	MNC(1969-2007)	Cumulative total 1969-2007
1	Texas Instruments, Incorporated	180
2	International Business Machines Corporation	151
3	General Electirc Company	141
4	Stmicroelctronics Pvt Ltd	70
5	Hoechst Aktiengesellschaft	46
6	Cisco Technology, Inc	30
7	Veritas Operating Coraporation	30
8	Cypress Semiconductor Corp	28
9	Broadcom Corporation	27
10	Ge Medical Systems Global Technology Company, Llc	27
11	Honeywell Intrenational Inc	27
12	Hewlett-Packard Development Company, L.P.	24
13	Unilever Home & Personal Care Usa, Division of Conopco, Inc	22
14	Intel Corporation	20
15	Lever Brothers Company, Division of Conopco, Inc	18
16	Ciba-Geigy Corporation	17
17	Freescale Semicondutor, Inc	15
18	Novell, Inc	15
19	Sun Microsystems, Inc	15
20	Alalog Devices, Inc	13
21	Ciba-Geigy Ltd	13
22	Cirrus Logic, Inc	12

cont'd...

Sl No	MNC(1969-2007)	Cumulative total 1969-2007
23	Natreon Inc.	11
24	Stmicroelectronics,Ltd	11
25	Adobe Systems,Inc	11
26	Cadence Design Systems,Inc	9
27	Indian Explosives Ltd	8
28	Galaxy Surfactants Ltd	8
29	National Semiconductor Corporation	8
30	Monsanto Company,Inc	7
31	Aktiebolaget Astra	7
32	Hellosoft Inc	6
33	Hetero Drugs Ltd	6
34	Lucent Technologies Inc	6
35	Microsoft Corporation	6
36	Astrazeneca Ab	6
37	Aventis Pharama Deutschland Gmbh	5
38	Diebold Incorporated	5
39	Genesis Microchip Inc	5
40	Hewlett-Packard Company	5
41	Iowa India Investments Company Ltd	5
42	Osram Sylvania Inc.	5
43	Redpine Signals,Inc	5
44	Sap Aktiengesellschaft	5
45	Silicon Automation Systems Ltd	5
46	Tektronix Inc.	5
	Cumulative total 1969-2007	**1101**

Source: Compiled from USPTO

Table 14: 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

In order to find out if Indian patents are competitive or not, I computed the Revealed Technological Advantage (RTA) indices of two of the leading technologies in which Indian companies and CSIR are prolific. These are Class 424 (Drug, Bio-Affecting and Body Treating Compositions) and 532 (Organic Compounds (includes Classes 532-570). See Figure 8.

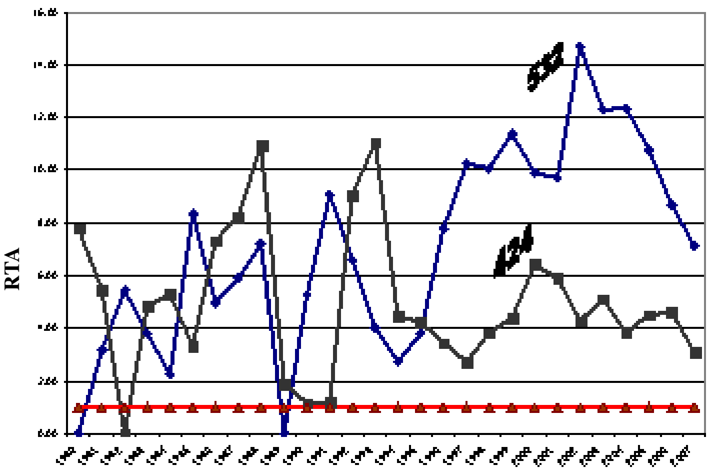

Figure 8: Revealed Technological Advantage Indices for two leading technologies

Source: Compiled from USPTO

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.

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 Organization (WIPO) and Triadic patents.

(b) 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 Table 15. According to a news item in the journal *Current Science*[22] India's CSIR is one of the most notable performers from among the developing world in terms of PCT applications.

Table 15: 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)

22 Anonymous author (2003)

In fact CSIR is supposed to be sharing the first rank along with Samsung Corporation of Korea although within the CSIR this good performance in patenting is restricted to just 5 laboratories[23] out of a possible 38. An analysis of the technology-wide distribution of these patents 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.

Table 16: Distribution of PCT applications from India-technology-wide

	Average number 2001-2005	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	1795	14.77
III- Chemistry		
Organic fine chemistry	3127	25.73

cont'd....

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

	Average number 2001-2005	Share (%)
Biotechnology	714	5.87
Pharmaceuticals	2872	23.63
Macromolecular chemistry, polymers	1182	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	**12155**	**100**

Source: WIPO (2008)

(c) 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

Table 17: Performance of India in Triadic patents as compared to BRICS and total world, 1990-2006

	Brazil	Russian Federation	China	India	South Africa	World
1990	10	21	12	12	13	32417
1991	6	36	12	8	18	29786
1992	13	45	17	7	33	29922
1993	22	34	16	8	32	30794
1994	12	51	17	6	21	32414
1995	17	60	21	11	25	35731
1996	18	58	23	14	29	39098
1997	29	69	43	22	34	41515
1998	29	94	47	34	35	42878
1999	31	60	62	40	31	45507
2000	33	69	84	45	35	47162
2001	47	56	114	85	24	45565
2002	44	48	178	106	28	46120
2003	51	51	252	120	30	48093
2004	51	55	290	122	33	50727
2005	56	64	384	133	31	50569
2006	65	63	484	136	30	51579
Growth rate (%)	18.77	10.38	27.86	20.98	8.39	3.04

Source: OECD (2009)

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. 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 17) 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 are not readily available. It may well be that (as noted in the case of US patents, (Table 11 above), 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.

(d) Patenting in India: Hitherto, our discussion was solely in terms of foreign patenting of Indian inventors. I now turn our attention to the performance with respect to Indian patenting (Table 18). Traditionally speaking foreigners have taken more patents in India than Indians at the India Patent Office. This trend has continued during the post liberalization period although the ratio of Indian patents to foreign patents has increased from 0.37 to 0.46 between pre and post liberalization implying a surge in Indian patenting. This is also reflected in the significantly higher growth rate of almost 24 per cent per annum during the post liberalization period compared to just 5 per cent per annum during the post liberalization period. An interesting point brought out by the above table is that the TRIPS compliance of the Indian patent regime appears to have signaled a surge not just in foreign patents awarded in India but also Indian ones. Analysis of technology-wide patenting (Table 19) shows that Chemicals, pharmaceuticals and biotechnology are the preferred areas while mechanical engineering and computer technologies too have registered important increases in patenting during the post liberalization 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.

iv. Among the domestic inventors, CSIR is an important entity although private sector pharmaceutical enterprises too are very important.

Table 18: Patents awarded to Indian and foreign inventors by Indian PTO, 1980-81 through 2007-08

	Indian	Growth rate (%)	Foreign	Growth rate (%)	Ratio of Indian to Foreign
1980-81	349		670		0.52
1981-82	421	20.63	936	39.70	0.45
1982-83	405	-3.80	822	-12.18	0.49
1983-84	340	-16.05	980	19.22	0.35
1984-85	263	-22.65	1206	23.06	0.22
1985-86	451	71.48	1500	24.38	0.30
1986-87	532	17.96	1594	6.27	0.33
1987-88	588	10.53	1516	-4.89	0.39
1988-89	795	35.20	2585	70.51	0.31
1989-90	519	-34.72	1371	-46.96	0.38
1990-91	379	-26.97	1112	-18.89	0.34
Average		**5.16**		**10.02**	**0.37**
1991-92	551	45.38	1125	1.17	0.49
1992-93	251	-54.45	1021	-9.24	0.25
1993-94	442	76.10	1304	27.72	0.34
1994-95	476	7.69	1283	-1.61	0.37
1995-96	415	-12.82	1118	-12.86	0.37

Cont'd..........

	Indian	Growth rate (%)	Foreign	Growth rate (%)	Ratio of Indian to Foreign
1996-97	293	-29.40	614	-45.08	0.48
1997-98	619	111.26	1225	99.51	0.51
1998-99	645	4.20	1155	-5.71	0.56
1999-00	557	-13.64	1324	14.63	0.42
2000-01	399	-28.37	919	-30.59	0.43
2001-02	654	63.91	937	1.96	0.70
2002-03	494	-24.46	885	-5.55	0.56
2003-04	945	91.30	1524	72.20	0.62
2004-05	764	-19.15	1147	-24.74	0.67
2005-06	1396	82.72	2924	154.93	0.48
2006-07	1907	36.60	5632	92.61	0.34
2007-08	3173	66.4	12088	114.6	0.26
Average		**23.7**		**26.1**	**0.46**

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

(iii) Technology balance of payments (TBoP): This is the third indicator of innovative performance that is usually employed in the literature although due to data constraints and due to difficulties involved in interpreting the results it is not a popular indicator of innovativeness like R&D expenditure and patents[24]. TBoP measures international

24 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.

Table 19: Technology-wide distribution of patents awarded in India, 1999-2000 to 2007-08

	Chemical	Drug	Food	Electrical	Mechanical	Computer/ Electronics	Biotechnology	General	Total	Chemicals+ Drug+ Biotechnology
1999-00	516	307	250	147	569			92	1881	823
2000-01	353	276	72	142	254			221	1318	629
2001-02	483	320	36	139	311			302	1591	803
2002-03	399	312	67	118	228			255	1379	711
2003-04	609	419	110	396	539			401	2474	1028
2004-05	573	192	67	245	414	71	71	278	1911	836
2005-06	1140	457	110	451	1448	136	51	497	4320	1648
2006-07	1989	798	244	787	2526	237	89	869	7539	2876
2007-08	4071	1469	88	1078	3230	2052	314	2959	15261	5854

Source: Controller General of Patents, Designs and Trade Marks (various issues) transfers of technology licencs, patents, know-how and research, 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 USA, Japan and Switzerland). I have constructed India's TBoP over the years since 1999-2000 (Table 20). It is seen that India has been 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 measure the TBoP industry-wide. But given the fact that much of R&D sourcing is confined to pharmaceutical and IT related (including telecommunications), this result, once again, substantiates, the conclusions that we reached with the aid of the previous two indicators.

In conclusion, my analysis of 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 industrial sector within the overall GERD has actually increased by a factor of 2 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

Table 20: India's Technology Balance of Payments, 1999-2000 through 2007-08

(Millions of US $)

Technology payments				
	Royalty, copyright license fees	R&D Services	Architectural, Engineering and other technical services	Total technology payments (TTP)
1999-00	311			311
2000-01	235			235
2001-02	361			361
2002-03	352			352
2003-04	444			444
2004-05	712	57	1111	1880
2005-06	729	116	1414	2259
2006-07	1030	201	3025	4256
2007-08	1088	405	3173	4666
Technology receipts				
	Royalty, copyright license fees	R&D Services	Architectural, Engineering and other technical services	Total technology receipts (TTR)
1999-00	54			54
2000-01	60			60
2001-02	22			22
2002-03	23			23
2003-04	32			32
2004-05	71	221	1417	1709
2005-06	191	395	3193	3779
2006-07	97	760	3457	4314
2007-08	157	1395	3144	4696
Net Receipts				
	Royalty, copyright license fees	R&D Services	Architectural, Engineering and other technical services	TBoP (TTR-TTP)
1999-00	-257			-257
2000-01	-175			-175
2001-02	-339			-339
2002-03	-329			-329
2003-04	-412			-412
2004-05	-641	164	306	-171
2005-06	-538	279	1779	1520
2006-07	-933	559	432	58
2007-08	-931	990	-29	30

Source: Reserve Bank of India (various issues) and government research institutes (read CSIR) has 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;
- 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;
- The not so conventional indicators too lend, although some what, further support to the above line of reasoning.

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

(i): 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. First, 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 ten 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 significant relationship between R&D and tax foregone can be rationalized by the fact that the tax subsidy covers only a very small percentage share (on an average 6 per cent) 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.

(ii) 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 per cent 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 twenty new Indian Institutes of Information Technology. Further thirty new central universities of various sorts are going to be established.

V. Summing up

India is definitely on a higher economic growth path. There is evidence to show that innovative activities in the industrial sector have shown some significant increases during the post reform process. High tech industries now contribute over 5 per cent of India's GDP;. The innovative activity is, of course, restricted to a few high 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 MNC 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 industry while it is the MNCs that are active in the latter industry. Integration of India's economy with rest of the world has opened up a number of opportunities which seems to have been capitalised by the private sector industry.

However continued rise in innovative activity is limited by the availability finance and of good quality scientists and engineers. Although the available supply appears to be very productive, its 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.

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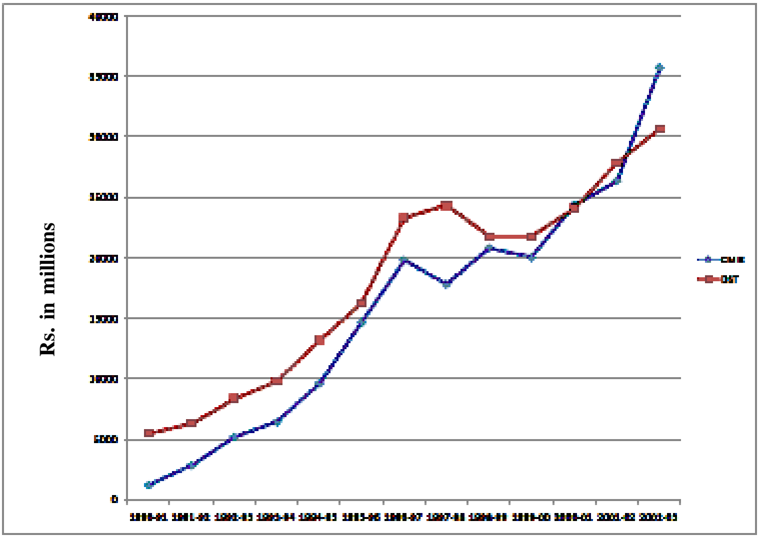
Annexure 1: Trends in private sector enterprise R&D expenditure: DST vs CMIE



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

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