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Universities in India's National System of Innovation: An Overview

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Abstract The status and functioning of Indian universities is explored in the Indian context from an NSI perspective. Whilst NSI is the main guiding post, the very social and economic context of Indian situation reflect the theoretical underpinning of this paper. The First part serves as a background to knowledge institutions and university sector in India. Basically, it identifies the main actors and agencies of India's NSI, namely, public research system comprising national laboratories, main science and technology agencies and councils and the university system. Given the focus of the paper on Indian universities in a macro historical perspective, the Second part is devoted to trace the growth and structure of university sector in terms of three phases, namely, 1940s to 1980; 1980 to 1990; and the era of liberalization after 1991. The Third part of the paper is devoted to knowledge production and knowledge diffusion. There are some important findings coming out of the quantitative data. It is argued that Indian production of doctorates is falling behind countries like China. Further, Indian universities are yet to achieve Humboltian goal. Finally, the paper has a concluding section which concerns with the current and future challenges facing Indian universities and their role in India's NIS.

Keywords Indian universities, national systems of innovation, research university

1. Introduction

With the dawn of 21st Century, universities have come to occupy a very significant role in building and strengthening the national science, technology

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and innovation system and at the same time to catalyse knowledge-based economies. The rise of Asian universities in the global knowledge based economy and international rankings in the last decade are closely associated with the rise of knowledge institutions of higher learning and scientific research. Two features stand out and are indicative of the trend. Firstly the feature of coupling teaching/research with innovation and at the same time forging university – industry links with various actors and agencies in the respective national systems of innovation (NSI). Universities are being re-positioned as frontiers of innovation in this NSI, where in, most new technologies (biotechnology, nano, new materials, ICTs etc) have become science based. This knowledge base for innovation is increasingly dependent on the research strength of universities. The second is the impact of globalization and the emergence of 'new' knowledge sites now extended to the Asian region.

Over the last decade perspectives on NSI has come to influence the research on understanding the dynamics of various actors and agencies (R&D labs, policies, universities, business enterprises and society's vision and culture etc) in the national innovation systems.[1] The status and functioning of Indian universities is explored in the Indian context from the NSI perspective. Whilst NSI is the main guiding post, the very social and economic context, science and technology policies including higher education and the historical understanding of Indian situation reflect the theoretical underpinning of this paper.

1.1 Actors and Agencies of India's NSI[2]

India's national aggregate gross expenditure on research and development (GERD) is about INR 413 billion in 2007-08[3]. In absolute terms, Indian GERD witnessed substantial increase of 60% from INR 249 billion 2004-05 to INR 413 billion in 2007-08. As proportion of GDP, it witnessed an increase from 0.8% of GDP in 1992-93 to 1.13% in 2003-05. However, it registered a marginal decrease to 1% for the period 2004-07

[1] NSI is defined as 'the network of institutions in public and private sectors whose activities and interactions create, import, modify and diffuse new knowledge and relevant new technologies (Freeman, 1987, 1995; Lundval, 1992; Lundval et al., 2006; Edquist 1997).

[2] Quantitative data in this section is drawn from reports on research and innovation policy from European Union Network ERAWATCH, See Analytical Country Report 2011 on India by V.V. Krishna, See http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/reports/countries/in/report_0001?tab=reports&country=in

[3] INR indicates Indian rupees throughout.

as estimated by the government sources. Notwithstanding the current ongoing economic downturn, the Prime Minister Dr Manmohan Singh announced recently in January 2011 that the government is committed to increase 2% of GDP for R&D by the end of the XIIth Plan (2012-2017).[4]

A dominant proportion of GERD around 68% is met by the government sources and 30% from the business enterprise sector. The GERD in PPP terms works out to be about INR 1,632 billion. India ranks higher as compared to countries such as Brazil, Mexico, and South Africa but is behind China, which spent 5,508 billion equivalents INR in R&D in PPP terms after United States at almost 14,552 billion equivalents INR in 2006.[5] India's endowment in terms of total human resources in science and technology is quite modest at 933 per 10,000 labor force compared with 914 for China for the same number of labor force.[6]

Except making explicit the idea of creating NSI in S&T Policy 2003 statement, India is yet to formally define her NSI as such. However the structure and network of relationships and institutional arrangements exist both in the formal and informal sense between different actors.[7] Such a structure of innovation system is mainly constituted by a) Public Research System; b) Private Business Enterprise and Transnational Corporations-TNCs (Indian and foreign); c) Higher Educational Institutions; and d) State mediation through public policies. We shall briefly explore various facets of the structure and organization of India's NSI and then devotes a separate section on the importance of state mediation.

a) Public Research System (PRS): This comprises national laboratories under a dozen science and technology agencies from space, atomic energy, agriculture, industrial research etc, and in-house R&D laboratories in large public sector enterprises in steel, fertilisers, railways, power, transport and aviation, chemicals, petroleum and energy etc. PRS is India's main actor of NSI as it accounts for 68% of GERD in 2007 and 69% (159,000) of the total 230,000 R&D personnel of the country in 2005.[8] Out of this total 230,000 R&D personnel, 71,300 (31% of total) work in major science agencies such as

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[4] The Prime Minister's speech at the 99th session of Indian Science Congress and India Today Magazine: http://indiatoday.intoday.in/story/mannmohan-singh-china-overtaken-india-in- field-of-science/1/166999.html

[5] All these figures in this introductory section are drawn from the CSSP Database, School of Social Sciences, Jawaharlal Nehru University, New Delhi, India.

[6] UNESCO Science Report 2010, UNESCO, Paris, p374.

[7] As noted earlier, NSI in the Indian context makes sense at the sectoral level of understanding rather than at the national level.

[8] Different years are used for different sets of data as per their availability from reliable sources.

CSIR, DAE, DBT etc, 32,200 (14%) work in universities and 55,200 (24%) in the government based public sector enterprises and state government laboratories. The dominance of PRS in India contrasts with East Asian economies such as Korea and Japan where over 75% of GERD comes from private sources. The role of state governments to GERD is quite marginal and State Science and Technology Councils created in almost all 28 states are just beginning to become proactive in assessing their strengths and weaknesses.

b) Private Business Enterprises and TNCs: This is the second major actor of Indian innovation system which accounts for 30% of GERD in 2007 and 31% of total R&D personnel (71,300) of the country in 2005. In 1990-91 private sector accounted for 13.8% of GERD which is increased to 20.3% in 2001-02 and to 30% in 2006.[9] The corresponding figure for GERD shows an increase from 2.4 billion Euros in 2002 to 5.5 billion Euro in 2005.

In the recent years business enterprise sector assumed considerable importance with the global competitive edge in pharmaceuticals, automotive, software, telecommunications and biotechnology. Whereas international economic crises created ripples in the US and European markets and industry in so far as the auto and IT sectors are concerned, a more optimistic market scenario emerged in the Indian case. In the midst of crises, Tata launched world's cheapest small car, Nano into the Indian market on 23 March 2009 with an advanced booking for over 120,000 cars.[10] The second Indian auto firm, Mahindra and Mahindra also launched its indigenous new model of 'Scorpio' - semi utility vehicle. Another player that will enter into the market is Bajaj with its mini car RE60 in 2012. Indian automobile production from 5.3 million units in 2001-02 grew to 10.8 million units in 2007-08. In 2006-07, the Indian automotive industry provided direct employment to more than 300,000 people and contributed 5% of India's GDP.

The other sector which witnessed robust growth and expansion is the telecommunications. Indian telecom market is one of the fastest growing markets in the world in 2009 in terms of subscribers behind China. China stands at more than 800 million telecom subscribers and India at more than

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[9] It may be noted that the figures being quoted are from the R&D statistics given by the Department of Science and Technology (DST). However, the DST figures grossly under estimate the foreign R&D inflow that has come into India during the period ending 2005-06. The estimates of a World Bank study (see Mark A Dutz, *Unleashing India's Innovation – Towards Sustainable and Inclusive Growth*', World Bank, Washington, 2007) shows that total private R&D investment has risen from half a billion Euro in 2002 to 2.45 billion Euro in 2005.

[10] India is attracting global auto manufacturers due to country's large middle class population, growing earning power, strong technological capability and availability of trained manpower at competitive prices.

500 million.[11] In January 2009 alone India added 15 million subscribers. The third sector which witnessed a reasonable growth despite economic crises is India's IT industry which contributes to over 5.8% of India's GDP in 2008-09. The industry grew by 28 to 29 per cent in the last few years but is slowed down in the current year. For instance among the top 20 firms operating in IT sector in India, all big Indian firms such as Tata Consultancy Services, Wipro, Infosys, HCL and Tech Mahindra – Satyam witnessed modest growth rates between 15 to 20% during 2007-08 and 2008-09.[12] Despite the slowdown, Indian IT-BPO grew by 12% in 2008-09 to reach US$ 59.5 billion in aggregate revenue.

The trend of the global R&D flows to India is sustained and growing in the situation of economic downslide. About 260 global TNCs operate their R&D centres or laboratories in India in Bangalore, Hyderabad, Delhi, Pune and Chennai regions. Bangalore is the most preferred destination of foreign R&D centres which accounts for 45% of the firms followed by NCR (Delhi) with 22% of the centres. Much of India's FDI in R&D has gone to major cities such as Bangalore which have developed innovation eco-system and knowledge hubs. Compared to the situation of 1980s which the firms were by and large involved in 'adaptive technology' for local market, TNC R&D centres in India in the last few years are oriented towards 'creative technology' for high end Indian industry and global markets.

The rise of business enterprise sector as an important actor of NSI is also evident from various Indian firms which followed Tata who acquired UK steel firm Corus; and Mittal's acquisition of Belgian-French firm Arcelor.

c) Higher educational institutions (HEIs): With over 447 universities with 25,000 affiliated colleges, much of the recent dynamism witnessed in the knowledge based and high technology sectors of Indian economy is the result of human resources, skills and the vast institutional base already created in the higher educational sector. In an effort to sustain this dynamism the government has increased the higher education budget by three times in 2009-10. However, R&D in HEIs in India is a weak link in India's NSI which accounts for mere 14% of R&D personnel compared to 55% of total R&D

[11] The launch of advance telecom services like 3G and IPTV will drive the future growth in India. The sector attracted $2,558 million FDI in the financial year 2009 as compared to $1261 million in financial year 2008. Telecommunications account for 9.37% share in total FDI inflow.

[12] However, big foreign firms such as Microsoft, IBM, Cisco, Oracle, Intel and Adobe witnessed only a marginal growth rate for the same period between 1 and 10%. For instance, Microsoft which registered 26% growth rate in 2007-08 declined to just 1% in 2008-09 compared to the previous year; and Hewett Packard from 30% to 2% for the same periods.

personnel of the country in PRS. Higher education R&D is less than 8% of GERD. However, universities accounted for over 52% of India's total 44,126 SCI based publications in 2007-08 which makes the sector a very important actor of the innovation system.[13] In 2006-07 the government set up the National Knowledge Commission to assess, plan and recommend the knowledge challenges of the 21st Century. Three major developments in the higher educational sector are: a) increase India's competitive advantage in the fields of knowledge by expanding the existing 400 universities to 1,500 by 2015; b) 15 year career support programme through scholarships from high school to PhD level; and c) promote university – industry links and partnerships. The Knowledge Commission's tenure is continuing with the new government in 2009 and its operations are being expanded.

According to various estimates and data from authentic sources, India produces about 2.5 million graduates every year, of which 300,000 are engineers and 150,000 IT professionals. This is in contrast to 70,000 engineers in USA, 33,000 in Germany and 600,000 in China. However, according to Farrell et al. (2005), with 14 million young university graduates (with seven years or less of work experience) India's talent pool is estimated to be the largest in the world, overlapping the Chinese talent pool by 50% and that of USA by 100%.[14]

2. Growth of Universities: Three Phases[15]

By the time India achieved her independence on 15 August 1947, the country was endowed with higher educational system structured and influenced by British colonial policies since the beginning of 19th Century. The first modern college was established at Serampore near Calcutta and three universities were established in the Presidencies of Bombay, Madras and Calcutta in the year 1857 which were modeled on the British university system. Local Indian contribution to the institutionalization of higher

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[13] However, the figure given by the DST, Government of India based on n core databases the total number of papers has increased from 59,315 in 2001 to 89,297 in 2005. These are non SCI based publications which are covered in one or the other international data bases such PASCAL data base of France.

[14] Some of the figures used here are compared with the data sets given by DST, Government of India. The figure of 14 million science graduates from Farrell et al. (2005).

[15] Figures and other quantitative data in this section are drawn from various sources of Planning Commission, University Grants Commission, Agarwal (2009) and Ministry of Human Resource Development, New Delhi during October 2011. Information and analysis in this section is also drawn from Krishna (1997, 2007).

education came about in parallel to efforts of colonial government up to 1947. By independence, there were around 30 universities and some two hundred colleges affiliated to these universities. The growth of higher education in independent India can be conceptualized in terms of three phases: 1940s to 1980; 1980 to 1990; and the era of liberalization after 1991.

2.1 Phase I: 1940s to 1980

The growth of universities and institutions of higher learning was given top priority by the government led by first Prime Minister Jawaharlal Nehru and his education minister Abul Kalam Azad in the 1940s. Nehru’s focus on the expansion of higher education base including setting up of universities was very much an integral part of the process of science and technology (S&T) institutional building and S&T policies. As early as 1947 the government set up the Scientific Manpower Committee with Homi Bhabha (father of India’s atomic energy programme) and Shanti Swarup Bhatnagar (Chief of Council of Scientific and Industrial Research Network of Laboratories) as members, among others, to plan scientific and technical human resources needed for post-war and post-independent agenda of development (See Krishna, 1994).

Secondly, Nehru’s regime was instrumental in implementing the recommendations of Sarkar Committee Report (1945), which was set up even before independence to recommend the expansion of technical education in India. This led to the establishment of All India Council for Technical Education (AICTE) to systematically plan and expand technical education in India. The first major step in giving expression to the recommendations of Sarkar Committee was the establishment of five Indian Institutes of Technology (at Delhi, Bombay, Madras, Kanpur and Kharagpur) modeled on USA’s MIT during 1950s and 1960s. Over the last four decades, these institutes have grown to establish high teaching and professional standards of engineering education and are recognized as one of the world’s eminent engineering institutions. Similarly, in the early 1960s two of India’s most eminent management institutes were also set up in Ahmadabad and Bangalore modeled on the lines of Harvard Business School and MIT’s Sloan School of Management.

Thirdly, in an effort to systematically plan India’s higher education and expand the university system, the government established University Grants Commission (UGC) in 1953 under the Chairmanship of S. S. Bhatnagar. The phase between 1947 and 1980, from the perspective of India’s science, technology and higher education policies, is marked for building India’s S&T infrastructure in more than dozen S&T science agencies in agriculture, industrial research, medical, atomic energy, space, electronics, among others. For this reason there has been an overwhelming domination of governmental support in building higher education system in the public domain. As shown in Table 4 universities expanded fivefold from just 25 in 1947 to 132 in 1980; and colleges expanded tenfold from around 450 in 1947 to 4,738 in 1980. Correspondingly, from a less than half million students in higher educational institutions in 1940s, the enrolment grew to around 3.5 million in 1980. Even though the government dominated the higher education scene in this phase, as the recent study of Agarwal (2009) points out, the government encouraged and partnered private initiatives in higher education with the introduction of a policy measure known as Grant-in Aid (GIA) institutions or private aided institutions. In 1980s one third of colleges were in fact private aided colleges. In retrospect, from an overall perspective this phase reflects the realisation of a Nehruvian vision of building a reasonable base in science, technology and higher education infrastructure. Though there were initiatives from the private sector such as from Tata's in building Indian Institute of Science, Bangalore and Tata Institute of Fundamental Research, Bombay and Birla's in building Birla Institute of Technological Sciences, Pilani, the public support played an important part.

2.2 Phase II: 1981 to 1990

The growth of higher education is seen to have entered a new phase after 1980. Even though the government support to higher education and expansion of university sector continued, the role of private sector in higher education began to emerge in this phase of growth. Another development that came about in the phase was the introduction of distance education besides further expansion of private aided and self-financing colleges. As the government experienced resource crunch for the rapid expansion of higher education after 1980, the private sector was given some incentives to enter the higher education sector. The fields of engineering and technology, medicine, teacher education and other fields such as hospitality and hotel management courses after 1980s witnessed rapid growth in the private sector compared to public sector as shown in Table 3 Professional Higher Education Institutions: Growth and Private Share. Hence the main feature of this phase was the emergence of public-private partnership in higher education.

Whereas the total enrolment increased from 3.5 to nearly 5 million between 1980 and 1990, the university sector expanded from 135 to 175 universities and college sector expanded from 4,738 to 7,346 colleges during the same period. Whilst the number of students in the distance education sector accounted for 6% of total enrolment in the earlier phase (1947-1980), the proportion increased to 11% in the current phase (1980-1990).

2.3 Phase III: 1990s and Beyond – Reforms and Expansion of Private Sector

Until 1980s the policy discourse on reforms of higher education and the issue of assigning relatively a greater role to private sector was at low key. For instance, even the National Policy on Education (1986)[16] downplayed the role of private sector. It is only since the early 1990s the role of private sector in education drew more and more policy attention as part of liberal economic policies. The period after 1991 in India is generally seen as an era of reforms initiated by P.V. Narasimharao government under his finance minister (who is the current Prime Minister) Manmohan Singh. As Agarwal (2009:47) draws our attention the 8th Plan (1992-1997) signaled the 'first indication of this paradigm shift' to promote the role of private sector. This was followed up by Special Action Plan of Prime Minister in 1998 and later a renewed focus on the role of private sector was given in the 10th Plan (1998-2003). Among other liberal economic reforms which were initiated in this phase, the government introduced a bill in Parliament to establishment private universities in 1995. Even though due to lack of political consensus the bill is still under pending, an indirect path to foster and promote private universities found its way through ratification of similar initiatives by state government legislatures. Education under Indian constitution is in the concurrent list or under the state subject which can be regulated and new reforms introduced.

The first private university that came up in India was Sikkim Manipal University of Health, Medical and Technological Sciences in the State of Sikkim in 1995. Another pathway that was chalked out by the government and the UGC to promote private universities was through the higher education policy measure of granting Deemed University status to private institutions. This was indeed an interim measure and an alternative to the pending private university bill. 1990s witnessed initiatives from five state governments such as Sikkim, Uttar Pradesh, Gujarat, Himachal Pradesh, among others, to set up private universities. Currently there are 21 private universities in India which have recognition from UGC.

The major expansion in private unaided sector of higher education in this phase is witnessed in terms of private unaided colleges which have increased more than 138% from 3,202 to 7,720 colleges during 2000 and 2006 in five years. As already noted in an earlier section, much of the expansion of private higher education since late 1990s is reported from professional subjects including engineering and medical as shown in Table 3. For instance, private unaided engineering colleges increased almost tenfold from 145 in 1990 to

[16] http://www.ugc.ac.in/

1,402 colleges in 2007, whereas the government and aided colleges increased just 30% from 164 to 215 for the same period (see Table 3).
From an overall perspective of higher education, the enrolment in higher education increased from 5 million in 1990 to nearly 13 million in 2009-10. The global average in 2011 is around 26%. About 30% of total enrolment of students in 2008-09 is in the private unaided institutions.

2.4 Contemporary Reforms in Higher Education

Apart from focusing on private sector's role in the 1990s, the government did not bring in any major reforms till the turn of the present century. A major policy initiative to revamp higher education system in India and its expansion, particularly in the public domain was set in with the establishment of National Knowledge Commission (NKC). Sam Pitroda, who is credited with championing the telecom revolution in the country, was made the Chairperson to lead NKC. The agency directly reports to the Prime Minister and works in close coordination with the Planning Commission and other governmental bodies concerned with education. The primary objective of NKC has been to plan and formulate appropriate policies related to human resource development and knowledge institutions for the 21st century knowledge based society and economy.

The second Report to the Nation submitted in November 2007 covered 20 subjects and outlined about 160 concrete action items. The Commission submitted its recommendations on education, to coincide with the final deliberations on the XIth Plan (2007-2012) document of the Planning Commission. The XIth Plan budget allocations to higher education resulted in over four fold increase over the Xth Plan (2002-2007). Together with the higher education focus both in the NKC and XIth Plan, there has been a notable policy focus to strengthen and revamp the technical education at the level of Industrial Training Institutes and vocational education. National Knowledge Commission has recommended the target of creating 1,500 universities by 2015. This includes establishment of 50 national universities.[17]

A further policy initiative in higher education reforms came about with the submission of a Report on 'Renovation and Rejuvenation of Universities' under the Chairpersonship of Yash Pal (former Chairman of UGC and India's one of the eminent space scientist). The committee submitted the report to the Ministry of Human Resource Development (MHRD) on 24 June 2009. Main recommendations which were accepted by the government included:

[17] For the reports on various issues of higher education and recommendations of the NKC see http://www.knowledge-commission.gov.in/.

a) Scrapping of deemed varsities and their transformation to full-fledged universities;
b) Reiteration of NKC recommendation of creating 1,500 universities through identification of top colleges; and
c) Creation of higher education commission which in a way replaces or takes over all the existing bodies such as UGC, engineering, medical and other regulatory bodies and councils.

Another noticeable feature of higher education since 2007 has been the focus on inclusive policies on higher education. Both the education ministry and the UGC, in particular, initiated various policy measures and programs to promote inclusive policies to bring in under privileged and various other backward class sections of society under the ambit of higher education. The affirmative action implemented provides up to 50% reservation for first entry degree programs in universities and colleges. Various steps that the government initiated since the last decade to reform higher education and make it relevant to industry and society can be summarized as follows:

a) Setting up of National Knowledge Commission – establishing 1,500 universities;
b) Five times rise in the national education budget between Xth (2002-2007) and XIth Plan (2007-2012);
c) National Commission for Higher Education and Research 2010;
d) The National Accreditation Regulatory Authority for Higher Educational Bill, 2010;
e) Bill on Indian version of US Bayh-Dole Act of the Protection and Utilization of Public Funded Intellectual Property Bill, 2008. The Bill is currently pending in the Parliament. In the absence of national law, science agencies and universities have evolved their respective law governing IPR in India in 2010;
f) National Skill Development Council (2008-09) contribute significantly up-skilling 500 million people in India by 2022, mainly by fostering private sector initiatives in skill development programs;
g) President of India declared 2010-2020 as the Decade of Innovation;
h) National Innovation Council (NInC) to prepare a Roadmap for Innovation 2010-2020 under Sam Pitroda;
i) Public – private partnership in promoting HEI and skills; and
j) Promotion of knowledge hubs and innovation clusters

As with the Bayh–Dole Act, the Indian bill is premised on the assumption that university ownership of patent rights is likely to increase the number of academia–industry collaborations. And without it, industry may be unwilling to develop academic research into useful products for society.

The Foreign Educational Institutions (Regulation of Entry and Operations) Bill (2010) is part of the process to arrest import of higher education as 130,000 students go to USA, UK, Australia and Europe etc.

2.5 Types of Higher Educational Institutions (HEIs)

The institutional structure of higher education comprises different types of universities and affiliated colleges and specialized institutions which have been granted university status. The structure that has evolved over the years is also partly based on the sources of funding from public and private sources as well as mixed funding from both these sources. From the perspective of governing and setting up of HEIs, seven different types can be seen in operation in the Indian context[18] :

a) Public universities or institutions which are promoted and set up by the central government;
b) Universities set up by the state governments;
c) Private universities or institutions set up and funded by private sources;
d) Government dependent private institutions which are set up by private sources but are aided to some extent by the government;
e) Among c and d there are universities which are given the title of ‘deemed university’;
f) Institutions of national importance and those which are set up by state legislatures; and
g) University affiliated colleges which offer undergraduate and graduate courses. These are also given the title of deemed universities. Deemed and private universities relatively enjoy greater autonomy compared to public universities and those of aided universities.

The Table 1 shows the growth of different types of HEIs during 2002 and 2007.

[18] The UGC is the apex body which regulates the universities as a whole. However, HEIs in engineering, management and other professional areas are regulated by AICTE and medical institutions are regulated by Medical Council of India.

Table 1 Growth of Different Types of Universities and HEIs

University level institutions	2002	2007	2011
State universities	178	232	250
Deemed universities	52	114	140
Central universities	18	24	25
Private universities	n/a	11	34
Institutes of national importance	12	13	13
Institutes set up by state legislature	5	5	5
Total no. of all universities	265	399	467**
Colleges affiliated to various univ.	16,885*	18,064	25,951

*Figure for 2003-04; ** some institutions are notified.
Source: http://www.ugc.ac.in/; http://www.education.nic.in/

2.6 Enrolments in Higher Education

Total enrolment of students in India's HEIs increased to 11.5 million in 2007 spread over nearly 447 universities and 25,000 colleges. A cursory look into this table shows that it took 13 years to touch the figure of 1 million students from 1947 to 1960 and then added a million students every decade up to 1980 touch a figure of 3 million. In the last two and a half decades the higher education enrolments increased over almost 3.5 fold to a total of 11.5 million in 2007. Out of this total, about 60% are male and 40% women students. However, India lags behind other developed and developing countries in Gross Enrolment Ratio (GER). For instance, GER's for USA, Australia and UK are 82, 72 and 60 respectively. On the other hand GER for India is 11 compared to 29 in Malaysia and 19 in China for 2004 (Duraisamy, 2008).

Table 2 Higher Education Enrolments in Public and Private Institutions

Type of Institutions	00-01	05-06	Growth(00–06)
Government	3,443	3,752	309 (9%)
Private Aided by Government	3,134	3,510	376 (12%)
Private Unaided	1,822	3,219	1,397 (76%)

Source: Data drawn http://www.education.nic.in/; http://www.ugc.ac.in/

Table 3 Professional Higher Education Institutions:
Growth and Private Share

Course	99-00	06-07 (07 July)	Total Increase(%)	Private Share(%)
Engineering	669	1,617	142	91
Pharmacy	204	736	261	95
Hotel Management	41	80	95	94
Architecture	78	116	49	67
Computer Applications	780	999	28	62
Management	682	1,150	69	64
Teacher Education	1,050	5,190	395	68
Medicine	174	233	32	50
Dentistry	45	189	420	59
Physiotherapy	52	205	294	92
Total	3,775	10,515	178	80

Source: Agarwal (2009)

As noted earlier, the most notable feature of enrolment in higher education came about during Third Phase 1990 with the expansion of private sector's role. During 2000 and 2006 as the Table 2 shows, whilst the enrolments increased between 309,000 (9%) and 376,000 (12%) in government and government aided private institutions respectively; the enrolments in private unaided institutions increased almost four fold to 1,397 million (76%). Much of this expansion is witnessed in professional disciplines, particularly engineering and medicine. As the Table 3 shows, engineering, medicine and management subjects take a lead in the private sector expansion to the extent of 80% compared to 20% in the public institutions for the data available for the period between 1999 and 2007.

As per detailed break up available from the UGC, nearly a third of total 11.5 million students in higher education, that is 30%, are from science and engineering[19];

[19] This includes medicine, agriculture and veterinary sciences

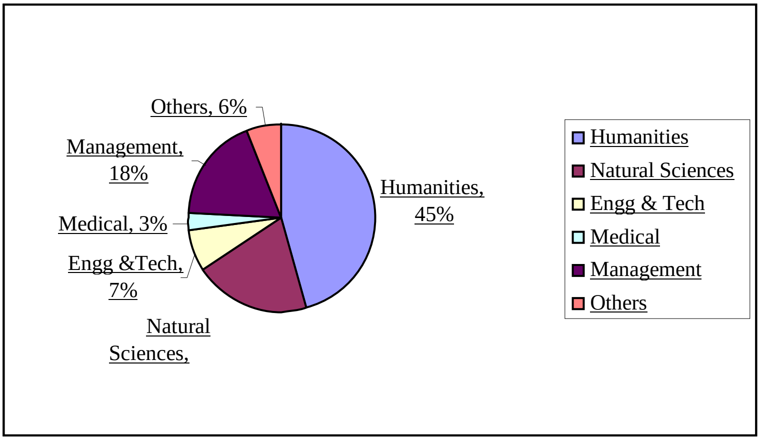


Figure 1 Discipline-wise Enrolments of Students in Universities 2007-08

Table 4 Cumulative Growth of Institutions of Higher Education and Enrolments

Year	Universities	Colleges	Enrolment
1947	25	500	300,000
1955	38	n/a	800,000
1960	50	2,000	1,000,000
1965	68	n/a	1,600,000
1970	87	3500	2,000,000
1975	105	n/a	2,700,000
1980	132	4,100	3,000,000
1985	138	n/a	3,600,000
1990	175	7,000	5,000,000
1995	179	n/a	6,500,000
2000	278	12,296	8,400,000
2005	330	n/a	10,480,000
2007	399	18,064	11,500,000

Source: Data compiled from the Association of Indian Universities (AIU) (2000) *Universities Handbook*, New Delhi: AIU, p.1111.

Table 5 Teaching Faculties by Designation in Universities and Affiliated Colleges

Year (05-06)	Prof.	Assoc.Prof /Reader	Sr. Lect.	Lect.	Tutors /Demons.	Total
Univ.	16,591	24,986	12,059	23,260	1,923	78,819
Affiliated Colleges	23,951	100,520	61,232	210,202	13,279	409,184
Total	40,542	125,506	73,291	233,462	15,202	488,003

Source: Agarwal (2009) & http://www.ugc.ac.in/

45% from Arts and social sciences; and 23.5% from commerce, management and law faculties in 2006. As Table 5 shows, half million faculty members are engaged in universities and colleges in India. India's major strength in the human and intellectual capital comes from her HEIs. According to McKinsey Global Institute, San Francisco, study, India had 14 million young graduates in the work force with about seven years of work experience. This makes it world's largest talent pool overlapping China talent pool by 50% and that of USA by 100% (Farrell et.al 2005).[20] Despite this overwhelming knowledge and human capital in an aggregate sense, India's top ranking research based universities and science and engineering institutions have not expanded to absorb the demand in the tertiary sector of HEIs. Whereas the top institutions in science and engineering absorb just 3 to 4% of the students who write entrance exams, the other top 20% of students who fail to find places in the top institutions go out of the country. In the last decade, since 2000, on an average of 100,000 students every year went out of India mainly to USA, Australia and UK for higher studies. For instance, in 2005-06, 76,000 have gone to USA; 27,000 to Australia; 23,000 to UK; and about 30,000 students to other countries.[21]

3. Universities in the NSI

3.1 Knowledge Production: 'Narrow' Research Base of Universities[22]

[20] Quoted in Herstatt et al. (2008)

[21] France 1500; Malaysia 1800; New Zealand 3300; Canada 6000; Germany 4700; and Singapore 4800.

[22] The term 'narrow' is being used from a 'common sense' perspective to indicate that less than 25% of the total universities can be classified as research based universities with peer reviewed publications. Hence 'medium' base would then indicate about 50% of universities with research base and above 70% might be taken as 'broad' research base. Going beyond peer reviewed publications, one can correspondingly relate to number of Ph.ds and post-graduate and under graduate students etc.

Universities occupy a significant position in terms of national R&D effort in industrially advanced countries (Mowery and Sampat, 2008). Universities in OECD - 25 countries accounted for 20% and Japanese universities accounted for around 15% of GERD in 2004-2005. Whilst universities and colleges in China account for around 10% of GERD in 2005-06, Indian universities and colleges accounted for mere 7% in 2008. In contrast, the business enterprise sector accounted for 30% and public research institutions sector accounted for around 62% of GERD during 2006-08. Despite a very low level of GERD devoted to HEIs, the sector accounted for nearly two thirds of total S&T output measured in terms of peer reviewed publications in SCI Extended version data base during 1985-86, 1994-95 and 2001- 02.[23] (Table 6). Between 1980s and 2007, even though the proportion of HEIs contribution in the national output has come down from 69% in 1985-86 to around 52% in 2007, the HEI sector accounted for over half of national output.

Table 6 Publication Output of HEIs, PRIs and Business Enterprises 1980s - 2007

	HEIs*	PRI	Business Enterprises	Others	Total
1985-86 (SCIE)	16,085 (69%)	6,569 (28%)	411 (1.7%)	235 (1%)	23,300
1994-95 (SCIE)	17,302 (62%)	9,218 (33%)	496 (1.8%)	562 (2%)	27,578
2001-02 (SCIE)	23,578 (60%)	13,329 (34%)	708 (1.8%)	1,237 (3%)	38,852
2007-08 (Scopus)	22,945 (52%)	19,415 (44%)	1,325 (3%)	441 (1%)	44,126

* Universities and Institutions of national importance

As the Table 6 indicates, business enterprise is not a major factor in the S&T output as it hardly accounted between 1 and 3% during the last two and a half decades. Another important study on publication output (based on Scopus data base) by India's top HEIs reveals somewhat similar trends. For the decade 1997-2007, HEIs accounted for 52% of total cumulative S&T publications, whereas PRIs accounted for 44% for the same period. These above indicators clearly point out low level of R&D funds devoted to HEIs sector. At the same time they also raise an important issue of the extent of research base and research intensity in the universities and colleges in India. In other words, it is instructive to explore the proportion of universities and

[23] Whilst universities and colleges accounted for 46%, institutes of national importance (which are also counted as deemed universities) accounted for 20%. (Gupta and Dhawan, 2009)

colleges undertaking research as demonstrated through trends in S&T output and other measures such as post-graduate and PhDs.

3.2 Striving towards Humboldtian Goal

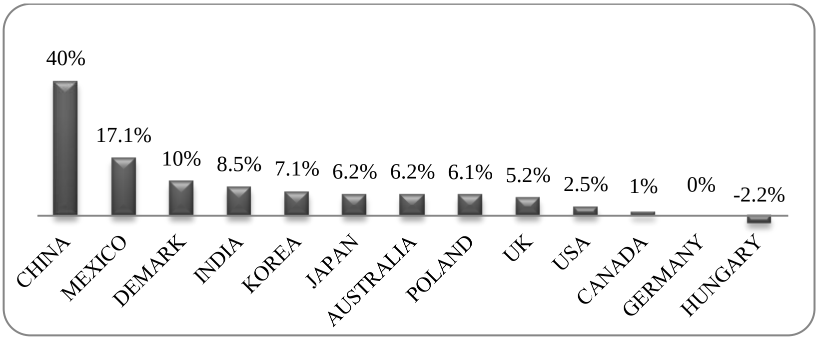
From a policy perspective, Indian universities have a long distance to travel before they are able to accomplish the goal of what has come to be known as the Humboldtian ideals. It signifies the unity of teaching and research in higher educational institutions and at the same time stands for democratic values of free thinking, research and teaching autonomy with a strong public support. However, the most fundamental aspect of this ideology or goal is the attainment of teaching and research in universities of a reasonable quality and excellence. As various writings clearly show, it is this ideology that has governed the best of European universities, particularly the German universities, in scaling the heights of excellence in teaching and research and at the same time contributing to the industrial progress and economic growth.

There are nearly 447 universities and over 25,000 colleges affiliated to these universities in India but the research output data available measured in terms of peer reviewed publications clearly indicates a narrow base of research intensity in the university landscape. Research intensity in universities is taken to mean those universities which have a reasonable publication record. Somewhat moderate research intensity here is seen in terms of at least 120 peer reviewed publications per year from a university. Studies and surveys undertaken by Gupta and Dhawan (2006, 2009) shows that only 18 to 20% can be classified as research based universities which have a publication intensity of over 120 papers per year over a period of a decade.

Further Gupta and Dhawan (2006) study has shown that 80 HEIs accounted for 72% of the total publications for the HEIs sector as a whole indicating that the rest 28% of total publications coming out from some 300 universities. Reflecting on a similar trend, another study by Gupta and Dhawan (2009) indicated that 56 universities accounted for 46.8% of total national publications (322,956) for the decade 1997-2007 based on Scopus data base.24 While the number of total universities including colleges undertaking research and publication activities increased little less than two fold from 894 in 1985 to 1,685 in 2002, all quantitative measures lead us to estimate that only a small proportion of about 20% universities can be counted as research

[24] Please note that the Table 7 indicates a total of 52% of total publications by the HEIs sector.

based universities in the Indian context in 2009.25 The quantitative analysis explored above clearly shows that there is a wide gap between the cluster of research universities and the other segment or grouping which can be characterized as predominantly 'teaching universities'26.



Source: Nature News, 20 April 2011 (Nature 472, 276-279, 2011)

Figure 2 The Rise of Doctorates

The narrow base of research in universities is further revealed by the number of PhD's awarded by Indian universities. If we take 1992-93 as base year, the total number of PhD's in science and engineering and non-science disciplines witnessed almost two fold increase from about 8,800 in 1992-93 to 17,898 in 2004-05 for which data is available from UGC. Whilst the science PhD's grew around 150%, the engineering PhD's increased by 300% during this decade. Similar extrapolations can be assumed for the current period. The growth of PhDs in Indian universities compared to other countries is relatively high as shown in Figure 2. However, this again constitutes a very narrow base of research and knowledge production compared to the total number of post-graduate and research students, which account for nearly 28% (or 3.22 million) of total higher education enrolments of 11.5 million students. Graduates

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[25] It may be noted that research based universities means which have a track record of peer reviewed research publication output.

[26] Teaching universities should not be taken to mean that there is no research activity being undertaken in these universities or no publications are coming out of these universities. These universities do have Ph.D and graduate level programs in all disciplines but it is just that their research base and publication records do not compare well (hence the tag 'teaching universities) with those of the other segment of universities which can be taken as research based universities. Further, our quantitative analysis clearly shows that a bulk of nearly 80% of universities are rather quite weak in relation to the rest 20% which account for bulk of the R&D output in terms of peer reviewed publications. Elsewhere, it is argued that India need to achieve the 'Humboltdian goal' of increasing research intensity in the university sector as a whole.

account for about 67% and 5% diploma holders for the year 2005-06 (UGC Annual Report, 2005-2006).

From a long term perspective of enrolments, in PhDs, post-graduates and technical (engineering and medicine) education, a survey from Duraisamy (2008) shows that whilst the PhDs witnessed a relative stagnation and even declined of the total enrolments from 0.9% in 1980-81 to 0.6% in 2003-04; the technical enrolments witnessed only a marginal increase from 8% in 1980-81 to 9.9% in 2003-04. Even the post graduates witnessed a decline from 9.8% to 7.2% for the same period. This again suggests the narrow base of research and knowledge production in the university landscape.

3.3 Import of Education

During the current phase, Indian is experiencing a trend, which may be characterized as 'import of education'. Every year a large number of Indian students migrate to USA, UK, Australia and other countries spending large sums on a foreign education. In a way India is importing foreign education. Some trends relating to import of education are as follows.

a) Expenditure of approximately US$ 4 billion annually on import of higher education abroad
b) The U.S. continues to remain the most popular destination. Nearly 70% are pursuing postgraduate courses in engineering and management
c) Australia is a popular destination for vocational training and course in hospitality
d) U.K. has become important because it squeezes academic sessions to one-year degrees on offer.
e) China and Russia are emerging as favored destination for medical education due to insufficient places in India.

As we have seen in the first two phases 1940s to 1980s, much of the higher education was funded and dominated by the public sector. After 1990s in the third phase, the higher education market in India is being driven by private sector participation mainly in engineering and medicine, with several high quality private institutes setting standards and pioneering growth. Much of the expansion in private higher education is triggered by the changing market demand pattern in hospitality, private health, leisure and entertainment including media, design and expanding middle class living patterns in the market. The expenditure on higher education in India is estimated to grow at 12% CAGR to reach US $ 10 billion by 2012 according to some sources.[27]

[27] http://www.rncos.com/Press_Releases/India-Higher-Education-Sector-Set-to-Grow-at-13-CAGR.htm

Private institutions account for 50% of the total medical seats and 80% of the engineering seats available in students in India.

3.4 University – Industry Relations

Historically speaking, most leading universities in Asia have been performing the roles of teaching and research so as to make an impact on the society and economy. However the feature of coupling teaching/research with innovation and at the same time forging university – industry relations (UIR) with various actors and agencies in the respective national systems of innovation has come into sharp focus in the last decade (Etzkowitz and Leydesdorff, 2000). UIR perspectives can be conceptualized at broadly two levels. From the perspective of professionals in institutions or universities, UIR can be seen to take place at the level of institution. UIR as explored in the S&T studies literature draws attention to different types of knowledge transfer underpinning UIR. Broadly four types of knowledge transfer can be easily quantifiable and explored. These are through a) sponsored research; b) consultancy research; c) patents; and d) spin-offs or start up firms which emanate from HEIs or universities.

From a macro level perspective, rather universities are being re-positioned as frontiers of innovation in the NSI, where in, most new technologies (biotechnology, nano, new materials, ICTs etc) have become science based. Universities and knowledge institutions take on a major role as important actors in training, imparting skills and networking with R&D institutions and business enterprises as part of knowledge based clusters. The impact of globalization or globalization of innovation via foreign multinational corporations has led to the emergence of 'new' knowledge R&D centers now extended to the Asian region. Universities and colleges and other knowledge institutions have become important sources of skills, knowledge and innovation activities and they have the additional task of tapping into, or networking with, this globally dispersed knowledge networks and institutional sites. From a macro S&T studies perspective, HEIs have come to play an important part in India's high technology related knowledge and innovation clusters (KICs) in major cities as shown in Table 7. From the perspective of UIR, the emergence of KICs in half dozen Indian cities such as Bangalore can be seen as a major development. More than 250 multinational corporations such as IBM, GE, Microsoft, Intel and others have established R&D labs and centers in the cities shown in Table 7. These foreign R&D centers basically take advantage of the location and supply of highly skilled science and engineering graduates.

Table 7 India's Emerging Knowledge Innovation Clusters

Cities/States	Areas	Global R&D Centers/Lab. (main city)	Public+Private Indian R&D Lab.(State)
Bangalore(Karnataka)	ICT software, aerospace, biomedical	45	107+38
Chennai(Tamil Nadu)	Automotive and ICT software	7	138+42
Pune/Mumbai (Maharastra)	Automotive, ICT software, chemical/pharma, Bollywood	22	176+105
Delhi/Noida/ Gurgoan (NCR)	ICT software, biomedical, automotive	24	93+40
Hyderabad (Andhra Pradesh)	ICT software and biomedical	9	126+36
Calcutta(West Bengal)	ICT software/biomedical	3	89+31

Table 7-1 India's Emerging Knowledge Innovation Clusters

Cities/States	Univ.+ Colleges (State)	Engin. + Medical Inst.	Paper 10Ys (State)*	Tertiary Enrol. (State)
Bangalore(Karnataka)	16+1,970	180+420	35,000(11.6%)	708,195
Chennai(Tamil Nadu)	17+1,244	270+200	48,000(16%)	841,755
Pune/Mumbai(Maharastra	20+2,487	185+330	46,000(15.3%)	1,506,702
Delhi/Noida/Gurgoan (NCR)	5+ 285	85+ 25	45,000(15%)	636,093
Hyderabad (Andhra Pradesh)	16+2,131	275+225	21,000(7%)	911,709
Calcutta(West Bengal)	16+565	60+75	22,000(7.3%)	721,762

Source: Constructed on the bases of various sources of information from State Governments, UGC, Ministry of Human Resource Development and the website of software companies (NASSCOM), New Delhi, India.
* Publications in SCOPUS '96-'06 (% of total)

As we have seen in the previous sections, higher education landscape reflects a narrow base of universities in research and knowledge production measured in terms of peer reviewed publications and the proportion of PhDs awarded compared to total higher education enrolments. Thus, given the narrow base of about 20% of universities and their affiliated colleges being research intensive, roughly about one fifth of total universities can be seen to seen to be directly relevant to industry and society. In aggregate terms, however India's higher education base is quite large with 11.5 million students in HEIs. Thus the sector provides an indirect relevance and support to business enterprises and industrial sector for the supply of skilled human resources which are indeed quite important factor in generating human and knowledge capital. Given the limitations of data and systematic indicators available for the university sector as whole for India, we will explore UIR taking five Indian Institutes of Technology (IITs) – India's leading engineering institutes.[28]

4. Case Study of IITs[29]

IITs represent a subgroup of India's premier engineering teaching and research institutions modeled on MIT. IITs have earned world recognition for excellent engineering education and in knowledge creation and knowledge transfer.[30] After the creation of Five IITs during 1950s and 1960s, two more were established in 1994 and 2001 (at Gauhati and Roorkee respectively) and three new IITs have been set up in 2008.[31] More than any other aspect, IITs have earned a big name globally for producing highly skilled engineering graduates. The IITs as a representative set of academic research institutes (ARIs) particularly in science and engineering education are known for their academic excellence.[32] Here we shall however explore on aspect of IITs, namely, their contribution to knowledge transfer during the last decade.[33]

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[28] IITs are universities categorized as Institutes of National Importance.

[29] Data on IITs is based on and drawn from, the chapter on Indian IITs, - See Krishna and Chandra (2011)

[30] The IITs have been in existence for over six decades making significant contributions in terms of knowledge production, creating highly skilled, well educated graduates and post graduates in engineering sciences and social science and management areas to a lesser extent. It is not surprising that admission into IITs is rather a highly competitive exercise in the country with nearly 250,000 students competing for 5,500 students' positions in all IITs combined together. The IITs have come to be recognized for research and innovation in the last decade.

[31] Five IITs were set up in ten year span starting from 1951 but IIT Guwahati was set up as the sixth IIT in 1994 while IIT Roorkee came into the IIT system in 2001. Three more IITs have been opened in 2008 in the states of Andhra Pradesh, Bihar and Rajasthan.

[32] IITs are recognised worldwide for the outstanding quality of engineers, scientists and managers they produce which is evident in the Times Higher Education (2006) where in the World's top hundred technology institutions they were ranked third after Massachusetts Institute of Technology (MIT) and University of California Berkley Source: http://www.timeshighereducation.co.uk/hybrid.asp?typeCode=163 accessed on 24 August 2007.

[33] Given the limitations of data and information we shall explore knowledge transfer activities of five IITs for the period during 2000 and 2005.

As pointed out earlier, four types of knowledge transfer can be easily quantifiable and explored. These are through a) sponsored research; b) consultancy research; c) patents; and d) spin-offs or start up firms. In all the five IITs, there has been a substantial increase over three fold in the value of sponsored research and industrial consultancy projects from 1999-2000 to 2004-05. As shown in Table 8, the growth has been from a little over INR 700 million to nearly INR 2,300 million in five years or an increase of 227%. This also means that the value of sponsored research and industrial consultancy increased from 17% (1999-00) to 44% (2004-05) of the total government budget. Thus these two modes seem to be the main and important channels of knowledge transfer. The increase indicates the shift in focus of IITs towards research activities.

Table 8 Combined Earnings of Sponsored Research and Industrial Consultancy Projects (SRIC) As a Percentage of Total Grants Given to IITs

(INR million)

IITs	SRIC (99-00) (a)	Gov. Grant (99-00) (b)	(a)/(b)	SRIC (04-05) (c)	Gov. Grant (04-05) (d)	(c)/(d)
Bombay	197.6	671.5	29%	380.0	1,024	37%
Delhi	185.5	820.0	23%	385.6	1,000	39%
Kanpur	84.4	628.0	13%	590.0	980	60%
Kharagpur*	121.0	1,003.0	12%	500.1	1,050	48%
Madras	112.8	943.7	12%	435.5	1,100	40%
All	701.3	4,066.2	17.2%	2,291.2	5,154	44.4%

Source: Computed from the Annual Reports of respective IITs
* IIT Kharagpur, grant-in-aid figure from 2000-01

Incubation and enterprise creation or what is known as spin-offs (we define spin-offs as companies that evolve from academic institutions through commercialization of intellectual property and transfer of technology developed within academic institutions) has come into prominence and sharp focus in the literature on Triple Helix. It is regarded as one of the main indicators for entrepreneurial universities. Creation of enterprises from the knowledge generated in academic research institutions has conventionally been the activity of TTOs in academic institutions such as IITs (see Table 9). In our study, while IITs at Kanpur, Delhi and Bombay have adopted the conventional approach of creating formal incubation units, the spin-offs at IIT Kharagpur and IIT Madras have been created without the formal incubation setup. As Basant and Chandra (2007) characterize, the process of knowledge transfer and enterprise creation in IIT Madras may be regarded as unconventional mode as this institute did not establish a TTO.

Table 9 Incubation and Entrepreneurial Infrastructure at IITs

Institution	Incubation Unit	No. of Incubatee /spin-offs (94 to June 2008)	Prominent Areas	Other Infrastructure
Bombay	Society for Innovation and ntrepreneurship (SINE); 2004	27	IT, computer science, electronics, design, earth sciences, energy & environment, electrical, chemical, aerospace	Entrepreneurship Cell
Delhi	Technology Business Incubation Unit (TBIU); 1999	19	computer science, electrical , chemical engineering, inter-disciplinary areas, life sciences, chemistry, IT, BT	Entrepreneurship Development Cell
Kanpur	Innovation and Incubation Centre (SIIC); 2001	13	IT, design, weather insurance, navigation systems	Entrepreneurship Cell; Electronic and Animation Cell; Small Scale Industry Cell
T Kharagpur	Technology Incubation and Entrepreneurship Training Society (TIETS); 2005	8	IT; computer science; ceramics; energy	Entrepreneurship Cell ; STEP; Biotechnology Park; TTG
IIT Madras	No formal set up Dynamic groups like Tele-communication Network Group (TeNeT); 1999	16	IT; computer science; physics	C-TIDES; Research Park

* STEP: Science and Technology Entrepreneurs Park;
* TTG: Technology Transfer Group
*C-TIDES: Cell for Technology Innovation, Development and Entrepreneurship Support;
* Entrepreneurship Cells are a body managed by students' initiative

The establishment of incubation units at IIT Delhi (TBIU), IIT Bombay (SINE), IIT Kanpur (SIIC) and IIT Kharagpur (TIETS) are relatively recent development in aiding knowledge transfer. Here we need to mention that such initiatives have been supported by the government of India mainly through Department of Science and Technology and the Ministry of Communication and Information Technology by extending seed grant support. The strategy for setting up of incubation units involves the selection and recruitment of start-up technology businesses such that these ventures graduate from early stage incubation to mature firms generating resources on their own. The start-up firms in the IIT campuses are provided with fully furnished offices with computers, telecom and internet connectivity. The incubator has modern support systems like meeting rooms, conference rooms which are equipped with audio and video conferencing, pantry facilities and other shared facilities. Apart from the physical infrastructure, SINE aims to facilitate networking and mentoring support, organize showcasing events for incubatee companies and conduct training programmes which are relevant for the entrepreneurs.

Table 10 Prominent Strategic Research Coalition at IITs

Location	SRCs at IITs
Bombay	Xilinx FPGA Laboratory (2004), Tata Infotech Laboratory, Intel Microelectronics Laboratory, Tata Consultancy Services (TCS) Laboratory (2000), Laboratory for Intelligent Internet Research (TCS), Texas Instruments Digital Signal Processing (TI-DSP) Laboratory, Wadhwani Electronics Laboratory (2001), Cummins Engine Research Laboratory (2004)
Delhi	IBM Solutions Research Centre, NIIT- Centre for Research in Cognitive Systems, Tata Infotech Research Centre, Intel Technology Lab, Microsoft Advanced Technology Lab, Philips Semiconductors VLSI Design Lab
Kanpur	Samtel Centre for Display Technologies (2000), Prabhu Goel Research Centre for Computer and Internet Security (2003), BSNL Telecom Centre of Excellence
Kharagpur	OPTEL - IIT Optical Fibre R&D Centre, Post Harvest Technology Centre, Space Technology Centre, Micro-electronics Research, General Motors-Collaborative Research Laboratory
Madras	Automotive Research Centre, Microsoft Laboratory, IBM Centre for Advance Studies, Tata Consultancy Centre of Excellence in Computational Engineering

A different view and insight, which is often ignored or overlooked in the case of IITs, is the significant contribution to Indian high technology industry in an 'indirect form' through their ex-students. For instance, many of these ex-students of IITs are either owners or chief managers of big firms. IIT trained engineers who have made a big name in the Silicon Valley, USA, through associations such as The Indus Entrepreneurs (TiE) and Silicon Valley Indian Professionals Association (SIPA) had a good deal of influence in the evolution of Indian software clusters in Bangalore, Hyderabad and Delhi (see Saxenian, 1996, 2002 and Krishna 2007).

5. Concluding Remarks

One of the major problems for an economy like the size of India, compared to other emerging nations and the international context, is the very low level of gross expenditure on R&D. India is spending just over 1.13% of GDP on R&D, compared to 1.2% to 1.4% for Brazil and China and around 2.2% in the case of the OECD and EU. The government is committed to increase the current 1.13% level to 2% in the coming 5 years. Government need to infuse more research funding into public R&D, particularly in the university sector in the coming decade. Otherwise India will not be able to sustain the international comparative advantage in terms of human resource base in high technology sectors of economy.

The role of universities in the NSI in India has emerged as an important factor in the decade but does not compare well with European and other Asian counterparts. Universities occupy a significant position in terms of national R&D effort in industrially advanced countries. Universities in OECD - 25 countries accounted for 20% and Japanese universities accounted for around 15% of GERD in 2004-2005. Whilst universities and colleges in China account for around 10% of GERD in 2005-06, Indian universities and colleges accounted for mere less than 7% in 2007-08.

In higher education, the major challenge in terms of access to higher education still remains the daunting task of increasing the enrolment ratio from the current 11.5% to 15%. India has over 447 universities and 25,000 colleges but the research intensity in these institutions of higher learning is quite weak. Only 20 to 25% of these institutions are research-based and the rest are teaching-based universities aspiring to achieve the 'Humboltdian ideal' of becoming teaching and research universities. This is an important challenge facing the higher education in the coming decade.[34]

In a large measure the innovation potential in the higher education sector in India is underutilized because few universities have adopted innovation policies which foster university–industry partnerships and relations.

[34] Unfortunately there is no systematic empirical data either from UGC or from the ministry of human resource development. However this insight is emanating from our discussion with various experts and commentators on the state of higher education in India.

As universities and higher education come to play a significant part both in the emerging knowledge based economy and the NSI, the government in the last few years have initiated a number of policy and structural reforms. India is yet to implement these initiatives, which are likely to strengthen the higher education research and innovation base in the country. The main thrust of these reforms is directed to make India competitive in high technology and knowledge base sectors of Indian economy at the global level.

From the perspective of university – industry relations, the universities have been quite conservative to open up to innovation and commercialization of R&D. Universities, in general still consider their main role as teaching and research. Innovation is by and large is seen as the role of R&D and S&T institutions in the public sector. The IITs and other leading universities are possible exceptions to this rule. The major challenge is to infuse academic institutions of higher learning with an-'innovation culture'. India has just articulated 'The Protection and Utilization of Public Funded Intellectual Property Bill, 2008' - an Indian version of the US Bayh-Dole Act. Many are expecting that this Bill will catalyse innovation and technology transfer from public research systems to industry and society.

The high education sector (universities and colleges) and other knowledge institutions have emerged as important actors in what has come to be known as India's leading knowledge innovation clusters located in Bangalore, Hyderbad, Chennai, Mumbai-Pune corridor, Delhi-Gurgoan corridor, among other cities. Software, biomedical, engineering and automotive and aerospace clusters are located in these cities. From a very low level of less than 134 US $ million a decade ago, India currently in 2010 attracts approximately 1.9 US$ billion for R&D every year through foreign firms setting up R&D laboratories and units in India. By 2010, about 250 multinational firms had already set up R&D labs or units. Much of India's global competitiveness in software, pharmaceutical and aerospace sectors is dependent on sustaining the human resource base in high technology sectors in these cities. This is intern is dependent on the skills and human resource base generated in the higher education sector in these cities. Much of the recent dynamism witnessed in the knowledge-based and high technology sectors of the Indian economy is the result of human resources, skills and the vast institutional base already created in the higher educational sector. A major challenge that is confronting India is to further strengthen the infrastructure and research – innovation eco-system in these cities in the coming decade.

From the perspective of population and skills, all foresight studies predict that India is endowed with good potential to take advantage of what has come to be characterized as 'demographic dividend' in the coming decades. Even by 2040 nearly half of India's 1.5 billion people will be under the age of 25 to 35 yrs. Vocational and higher education, which will infuse skills, training and knowledge base, is going to be important for Indian higher education sector. The establishment of the national innovation council and national skill development council, among other policy reform measures introduced recently are likely to play a significant part in India's global competitiveness in the coming decades.

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