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Arth Karicheye Vidya: From Innovation to Commercialisation

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Abstract

India abounds with anecdotes of gurus who imparted wisdom without expecting anything in return, with students simply providing a voluntary 'guru dakshina' (offering) in gratitude. In this regard, King Chandragupta Maurya's pragmatic advisor, Chanakya, seems to have been the only noteworthy exception, when he asserted, "Arth karicheye vidya" (create wealth from knowledge), almost 2,300 years ago. Given the deep-rooted Indian culture and the socialistic economy that democratic India pursued during 1947 and 1991, it is not surprising that unlike other OECD and emerging economies, India rarely monetised or commercialised any innovations. Since there were no monetary or other incentives for producing innovations, few significant innovations were created during the last 60 years!

During the last 15 years, the Indian economy has been gradually transforming into a 'free' market-driven economy. Consequently, a culture of producing innovations and commercialising them has slowly begun to emerge. More importantly, a strong awareness is beginning to emerge at all levels that unless there is a broad-based creation of wealth, a vast majority of India's population will continue to be deeply mired in poverty and will continue to struggle to meet some of its basic needs.

In this Background Paper, we review the changes that have taken place in India's R&D environment during the last 15 years (1991-2005), and compare these changes to both the R&D environment that prevailed in India until the early 1990s and the situation in contemporary USA (which has done particularly well with respect to innovations and their commercialisation). This comparative analysis will help us in understanding India's achievements, along with some systemic obstacles that have impeded research and innovation in the recent past and might continue to do so, if adequate measures are not taken. Finally, in this article, we also discuss our forecasts related to the growth of innovation and research, and their advanced development and commercialisation during the next 15 years (2006-2020).

1 Introduction

During the last 150 years, research and advanced development worldwide has been typically conducted, and innovation produced, in one of the following three enterprises:

- R&D laboratories for profit companies
- Garages and basements of inventors and/or coffee or chai shops, where they often meet
- Laboratories and teaching institutions that are funded by government and/or non-profit organisations

It is interesting to note that the three enterprises mentioned above are closely related to each other. For example, teaching institutions train researchers, who are later either employed by R&D laboratories or become innovators and form new companies. These R&D laboratories or newly formed companies are often located near teaching institutions. As a result, they are able to closely collaborate with the teaching and research professionals at these teaching institutions and hire other students on full-time or part-time bases. Given the various sources of innovation feeding into this ecosystem and the interrelationships among them, we discuss the status of these enterprises in the Indian context in Sections 2, 3 and 4 of this Background Paper.

Just as there are three primary sources (or enterprises) of innovation, the commercialisation life cycle also comprises the following three essential steps. Even though these steps often vary slightly from one sector to another (e.g., from telecom to healthcare) with respect to execution, they essentially remain the same:

1.1 Idea Creation (often called Ideation)

The major part of this activity is performed within each of the three enterprises mentioned above, and it consists of one or more of the following sub-activities:

- Introducing new products, services and technology ideas
- Introducing new business methods and opportunities
- Introducing small but important improvements in existing products, technologies, or business methods
- Creating and protecting intellectual property in the form of patents, trademarks, copyrights and trade secrets
- Providing strategies for new product linkages
- Conducting consumer research and providing insights; thereby creating the potential for incremental improvements
- Creating a governing process and tracking the new initiatives mentioned above

1.2 Project Selection and Execution

Usually, some part of this activity occurs within the three enterprises mentioned above, and it generally comprises the following sub-activities:

- Decision-making process and prioritising the projects
- Creating a disciplined and an effective development process
- Determining the time to market
- Creating 'Beta versions' for early adopters
- Resource allocation for creating a 'new' robust product, technology or business method

1.3 Commercialisation and Monetisation

Again, some of this activity usually occurs within the three enterprises mentioned above, and it generally comprises the following sub-activities:

- Market and investment planning
- Competitive response and timing
- Consumer profiling and segmentation
- Licensing, selling or monetising IP
- Advertising, promoting and decision making

- Product tracking, fixing errors and adjusting the products, technologies, services or business methods in minor ways, so that they closely conform to consumers' expectations

Greatly reduced costs of global communications, along with the strong and sustained economic growth rates in the developing world, imply that it is no longer necessary that all three steps in the innovation life cycle mentioned above may be performed in the same location or even in the same country. This is because of the following reasons: (a) the market for a given innovation may be different from the one in which the innovation was created, and (b) lower cost, higher or different skills, or other factors in a given location or a country may dictate as to where the project execution and prototype building are likely to take place.

In this background paper, we review the changes that have taken place in India's R&D environment during the last 15 years (1991-2005), and compare these changes to both the R&D environment that prevailed in India until the early 1990s and the situation in contemporary USA (which has done particularly well with respect to innovations and their commercialisation). This comparative analysis will help us in understanding India's achievements, along with some systemic obstacles that have impeded research and innovation in the recent past and might continue to do so, if adequate measures are not taken. Finally, in this article, we also discuss our forecasts related to the growth of innovation and research, and their advanced development and commercialisation during the next 15 years (2006-2020).

2 Innovation and Commercialisation in for-Profit Companies

Industrial research and development (R&D) is closely linked to innovation and the creation of new products and production techniques, as well as their commercialisation. Together, this activity 'engine' of industrial R&D forms is an important driver of economic growth for most countries. In OECD countries, the profit-making sector conducts more R&D than the combined efforts of the group of individual entrepreneurs and the government. For example, in 2002, the total R&D investment worldwide was approximately USD 678 billion. Of this, for-profit firms spent USD 450 billion (i.e., about two thirds), with the top 700 multinational companies spending more than USD 310 billion. Accounting for inflation, this spending has been increasing at 5 to 6 percent annually from 1990 to 2005. In addition, our research shows that this growth rate is likely to continue for the next 15 years (2006-2020).

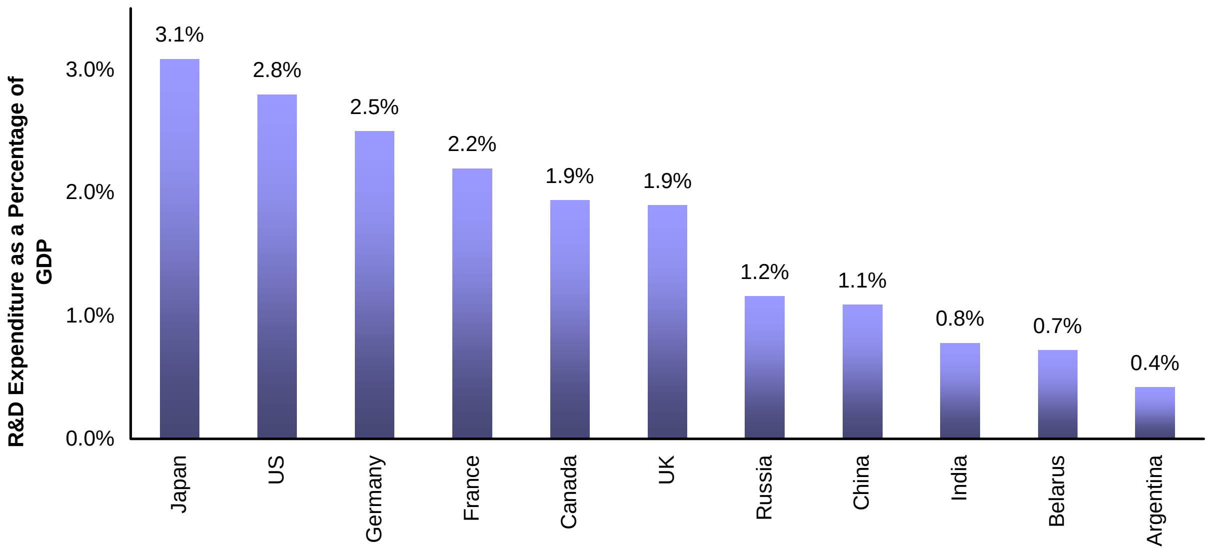
Until about 1995, the situation in India was in stark contrast to the one mentioned above. Because of the socialistic nature of the Indian economy, which significantly constrained the supply of goods, products and services, very little money was spent on R&D by Indian businesses, whether domestic or multinational. (For example, see Figure 1, which contrasts the R&D expenditure in India to those in some other countries in 2002.). In fact, the Indian government contributed more than 75 percent to the total money spent on R&D, which, in itself, was not a significant amount. Even until 2001, the total amount spent on R&D in India was only USD 2.9 billion, wherein the Indian government contributed more than half and businesses contributed about 45 percent.

This situation began to change in 2002, with more and more companies outside India realising that the country had a large pool of competent scientists, engineers and other qualified graduates who are proficient in English. In addition, as more and more companies within India realised that the country was gradually moving towards a market-based economy, they had no choice but to compete with others to maintain or increase their market share. Furthermore, companies of all types around the world also realised that research and advanced development within India could be conducted at one fourth to one fifth of the cost (as compared to other OECD countries); hence, they could potentially realise significant return on their investments.

Currently, more than 220 multinational companies and more than 130 large domestic companies conduct a significant amount of research and advanced development in India. The total R&D investment by these for-profit companies has gone up from approximately USD 1.3 billion in 2001 to approximately USD 6.5 billion in 2005; this corresponds to an annual growth rate of almost 50 percent. This, in turn, has led to the total R&D investment in India going up from USD 2.9 billion in 2001 to USD 3.7 billion in 2002 to USD 5 billion in 2003 and then to USD 8.5 billion in 2005, thereby resulting in an average annual growth rate of 31 percent from 2001 to 2005.

Figure 1 below depicts the R&D expenditures as a percentage of GDP for select countries.

Figure 1: R&D Expenditures as a Percentage of GDP Across Select Countries (2002)

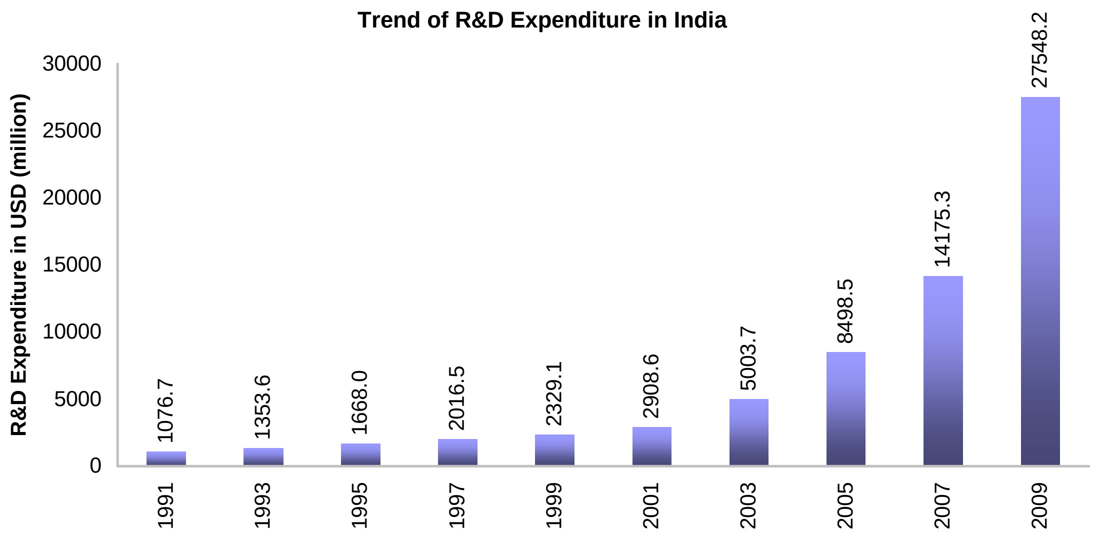


Source: UNESCO Institute of Statistics [ref.1], OECD-MSTI Nov 2003 [ref. 2]

Evalueserve estimates that expenditure related to R&D, innovation and commercialisation in India is likely to grow at an average annual rate of 26 percent to reach USD 27.5 billion during 2006-2010. It will then grow at an average annual rate of 19 percent (during 2011-15) and reach USD 64.5 billion by 2015. Further, at an average annual rate of 13 percent during 2016-2020, it will reach USD 119 billion by 2020. If we assume an annual growth rate of 12 percent (which includes inflation as well as the Indian economy's intrinsic growth rate) and a constant exchange rate of USD 1 (INR 45), then India's GDP is expected to reach approximately USD 1.4 trillion in 2010, USD 2.5 trillion in 2015 and USD 4.4 trillion in 2020. Hence, if our forecasts are accurate, R&D investments would amount to approximately 2.0 percent of India's GDP by 2010, 2.6 percent by 2015 and approximately 2.7 percent by 2020. On a percentage basis, this would be close to the R&D investments by US, Japan and many other OECD countries. Finally, the contribution by for-profit companies to this R&D investment would go up from the current approximately 75 percent to 93 percent in 2020.

Figure 4 below depicts the expenditure on R&D, commercialisation and innovation in India from 1991-2005 (based on actual values) and forecasts for 2007-09.

Figure 2: Expenditure in India on R&D, Innovation and Commercialisation: 1991-2005 (actual) and 2007-2009 (forecasted)



Source: National Science and Technology Management Information System Division (NSTMIS) [ref. 3] and Evalueserve Analysis [ref. 4]

With respect to the three steps within the commercialisation life cycle, which were discussed in Section 1, most companies – both Indian and multinational – seem to be using their R&D centres in India mainly for ideation (i.e., idea creation) and project execution (i.e., prototype development) activities. This is amply demonstrated by the following two facts: (a) The number of patent applications filed with the Indian Patent Office increased at a rate of 24 percent from about 17,466 to 23,000 in the period April 2004-March 2005 to April 2005-March 2006 [ref. 5], and (b) The number of applications filed with the US Patent and Trademark Office, wherein at least one of the co-inventors is located in India, has been doubling for the last three years and is likely to reach 3,000 during 2006.

Since North America and the European Union continue to be significantly large markets, so far, most activities related to project selection, commercialisation and monetisation have taken place outside India. Even in this regard, we are beginning to observe a gradual shift in the telecom, information technology, electronics and biotech-pharmaceutical sectors. This is because India's domestic demand for various goods and services in these sectors is increasing and a large sample of the Indian population is now available for clinical trials and beta testing of newly developed drugs and prototypes. Furthermore, because of the labour-cost arbitrage between India and OECD countries, companies will be able to save 30 to 60 percent costs, even while conducting activities of the second and third types (i.e., process selection, commercialisation and monetisation). Thus, we believe that during the next 15 years, such activities will increasingly be moved to India. Finally, even with respect to ideation, it is usually hard to link a new product, service or business method to a particular innovation that might have taken place in any specific laboratory. This is because most multinational companies have a network of R&D laboratories around the world, and these labs work collaboratively on most projects. As a result, linking the newly produced prototypes to innovation taking place in India is going to become harder in the future.

2.1 Concluding Comments and Recommendations

Overall, this healthy growth bodes really well for research and innovation in India; however, as we will discuss in Section 4, this growth can be stymied substantially (especially during 2008-2020) if the number of highly qualified graduates, engineers and scientists does not increase. Given the potential for substantial growth in the R&D sector, especially by the for-profit companies in India, the Indian government needs to ensure that the R&D investment process is extremely simple. In addition, the tax subsidies and benefits provided to such enterprises should be on par with, if not better than, those provided by the US, the UK, Japan, China, Israel, Singapore, Sweden and Finland.

3 Innovation and Commercialisation by Unaffiliated Inventors and its Ecosystem

In India, the ecosystem that supports innovation by unaffiliated groups of inventors, along with its commercialisation, is beginning to emerge in both urban and rural areas. The emerging ecosystem for urban areas seems to be closely following the one that is present in the US and other OECD countries, whereas that for rural areas seems to be unique to India (although it is quite evident that the innovations that are produced and commercialised can be sold in other regions that include China and other parts of Asia as well as some sections of Africa and South America). Given this scenario, Section 3.1 briefly discusses the ecosystem in the US, Sections 3.2 and 3.3 discuss the emerging ecosystem in urban areas (especially for innovations in the high-end products and services domain), and section 3.4 discusses the nascent ecosystem that is beginning to develop in rural areas.

3.1 The Situation in the United States

In the US, laws related to creating and owning innovation and the corresponding intellectual property are more than 200 years old. "The introduction of patent laws," said President Abraham Lincoln, "was one of the three most important developments in the history of the world," and, "the patent system adds the fuel of interest to the fire of genius." Given such a culture in the US, it is not surprising that unaffiliated inventors began producing substantial innovations as early as the mid 1800s. In fact, Thomas Alva Edison epitomised such inventors after he sold his first innovation – an unpatented stock-quotation printer – in 1876 for USD 40,000. He used this money to open a full-fledged laboratory that led to 1,093 patented innovations. Of course, one of these innovations enabled the installation of the world's first large central-electric power station (in New York City) by the Edison General Electric Co., which is today's General Electric.

Not surprisingly, this tradition of solo inventors and small groups of inventors creating innovation has continued unabatedly in the US, and the US Patent Office grants between one sixth and one fifth of the patents to such inventors (who usually have little or no affiliation to industrial laboratories or government institutions).

Once the inventors have ‘created an idea’ in a garage, a basement or a coffee/chai shop, they need the money and the wherewithal to effectively execute the second and third steps mentioned in Section 1, i.e., producing a prototype and commercialising it. In most OECD countries, the following groups and organisations provide this money and assistance:

- ***Angels:*** They usually comprise inventors’ ’friends and family’. They provide a small amount of initial funding (usually called ’seed’ finding), and often, a large amount of assistance in creating a set up to monetise and commercialise the innovation.
- ***Venture Capital Firms:*** Initially, they provide money to inventors in exchange for some equity in the start-up. Later, they provide inventors with strategic and operational help for expanding the start-up. Although there are no universal rules, most VCs fund their start-ups in two phases – an early phase, (called Stage A) where they provide money and assistance for developing a prototype, and a late phase, (called Stage B) where they provide money and assistance for marketing and selling (or licensing) the prototype or the associated intellectual property.
- ***Banks or Other Third-Party Institutions:*** They usually provide debt financing against some ’collateral’ that may be provided by start-ups or by their ’founders’ (at a personal level).
- ***Government Institutions:*** They usually provide seed funding, especially to inventors that do not have access to venture capital or angel funding.
- ***Business and Technology Incubators:*** They usually provide administrative support, office facilities, and legal, financial, technical and business expertise. At times, they also provide funding in exchange for equity or other upside related to these start-ups. Although most incubators in OECD countries are established by profit-making enterprises, some – especially those in the US, UK, Israel and Japan – are funded by government or non-profit organisations.

Although today the US, Israel, Sweden and Finland are some of the key leaders in the start-up and venture capital businesses, it is interesting to note that even in the US, the venture capital industry is only about 35-40 years old. However, during its small history, the venture capital industry in the US has recorded some significant achievements, which include the following:

- During 1970 and 2003, venture capitalists invested USD 338.5 billion in more than 21,600 US companies.
- Companies that were established and venture financed during 1970 and 2003 had created approximately 10.1 million jobs by the end of 2003. Hence, in 2003, these companies contributed to approximately 7.2 percent of the total US workforce and approximately 9.4 percent to the total US workforce in the services sector.
- Companies that were established and venture financed during 1970 and 2003 had created total sales worth USD 1.8 trillion during 2003, which represents approximately 9.6 percent of the total company sales in the US [ref. 6].

3.2 The Situation in India

Unlike the US, little significant innovation was produced in India between 1875 and 1995. The lack of significant innovation and its commercialisation in India can potentially be traced to several cultural, social and economic factors, which include the following:

- Indians harbour a profound disdain for the very idea of commercialising knowledge, which is illustrated by the following legend in Hindu culture: Knowledge-bestowing *Saraswati* and wealth-granting *Lakshmi*, wives of cosmos-creating *Brahma* and order-preserving *Vishnu*, respectively, could not live together in harmony. This reflects the Hindu discomfort in linking knowledge and wealth. Even today, it is unusual to find images or statues of *Saraswati* and *Lakshmi* next to each other in Hindu temples and homes.
- The education system in India during the British Raj was focussed on creating clerks and administrators, who could help the British rule India more efficiently. Hence, this system strongly emphasised the technique of 'learning by rote'. Sadly, even to this day, this British legacy continues unabated throughout all levels of the Indian education system (i.e., the primary, secondary, high-school, undergraduate and graduate levels).
- The socialistic economy that democratic India pursued during 1947 and1991 did not promote entrepreneurship and restricted the increase in the supply of goods and services by granting fewer licenses to companies that provided such goods and services. This, in turn, resulted in a perpetual increase in demand, and hence, less incentive for for-profit firms to innovate.

Given this socio-cultural context, it is hardly surprising that Dr. Jagdish Chandra Bose – the first to invent a wireless system that transmitted radio waves over a distance of 75 feet – was against any financial gains from his inventions. In a letter to Rabindranath Tagore, he explained why he had turned down the business proposal of a telegraph company proprietor who had come with a 'patent form in hand': "My friend, I wish you could see the terrible attachment to gain in this country, that all-engaging lucre, that lust for money and more money. Once caught in that trap, there would have been no way out for me." In 1904, frustrated by Bose's obstinacy, two of his friends, Sister Nivedita and Sara Bull, took the initiative and obtained an American patent in his name (for his invention of the galena single-contact point receiver). Dr. Bose, however, still refused to make money out of his invention. Later, Patrick Geddes aptly summarised Dr. Bose's reaction in his authorised biography: "Simply stated, it is the position of the old rishis of India, of whom he is increasingly recognised as a renewed type, and whose best teachings were ever open to all willing to accept it." Isn't it ironic that the spiritualist Nivedita had to do what the inventor Bose ought to have in the first place? Or is it simply that the British-born Nivedita was a child of industrialised Europe?

3.3 Innovation and Commercialisation in the Indian Hi-tech Sector

Fortunately, in the Hi-tech sector (which includes information technology, IT services, the Internet and other software applications and services, hardware, electronics, biotechnology, pharmaceuticals and telecommunications), things began to change in India circa 1996. This was the result of a new breed of inventors and entrepreneurs – some of whom had returned to India after spending a considerable time in the US, Canada, the UK, Australia and Singapore – innovating and forming new companies. In addition, the liquidity in the monetary system, along with the booms in the dot-com and telecom sectors worldwide, helped such entrepreneurs in obtaining sufficient funding to produce prototypes of their services and business methods and sell them both inside and outside India. Indeed, it is during this period that a strong foundation was laid for the Indian wireless industry, which is now growing faster than those in China and the US.

This nascent entrepreneurial activity in India suffered a major setback in 2000, when the dot-com and telecom bubbles burst worldwide, and the funding for new start-ups dried rapidly. Start-ups and early stage companies continued to receive funding at a low pace during 2000 and 2005 (See Table 1 given below.).

Table 1: Investment Range of Early-stage VC Deals in India (including Seed, Series A and Series B funding)

YEAR	2000	2001	2002	2003	2004	2005
Number of deals	142	36	16	13	29	19
Amount in million USD	342	78	81	48	150	103

Source: Evalueserve, IVCA and Venture Intelligence India [ref. 7]

Fortunately, because of the intrinsic growth rate of the Indian economy and the interest rate that India has peeked within the investment community worldwide during the last two to three years, this funding is again set to rise sharply during 2006 and 2010. The various types of venture funds that are operating in India are summarised in Sections 3.3.1 through 3.3.4 given below. Since India is a low-cost country (as compared to other OECD countries), Table 2 provides an approximate comparison of the typical range of Seed, Series A, and Series B funding in India, versus those in the US.

Table 2: Investment Range of Early-stage VC Deals in India and the US

YEAR	INDIA	USA
Seed funding	Up to USD 900,000	Up to USD 2.5 million
Series A funding	USD 1 to 3 million	USD 3 to 10 million
Series B funding	USD 3.1 to 9 million	USD 11 to 30 million

Source: Evalueserve Analysis [ref. 8]

3.3.1 Non-US-based Funds

These international funds largely invest in early- and mid-stage companies, and include Barings, 2iCapital Private Limited, 3i, (private equity firm headquartered in Europe), Gaja Capital, Chryscapital Management Companies, HSBC Private Equity Management (Mauritius) Limited, IL&FS Investments Managers Limited, Information Technology Venture Enterprises Limited, Indian Direct Equity Advisors Private Limited, Kotak Mahindra Finance Ltd, Merlion India Fund (Standard Chartered Private Equity), Punjab Venture Capital Limited and SICOM Capital Management Limited.

3.3.2 VC Entrants from the US

Approximately 30 US-based VC funds are already investing in India, and some prominent ones include Sequoia Capital India (which now owns Westbridge Capital), Canaan Partners, Matrix Partners, View Group, Trident Capital, Walden International, Softbank Asia Infrastructure Fund (SAIF), Oak Investment Partners, Bessemer Venture Partners, New Enterprise Associates, Sigma Partners, Helion Venture Capital and Nexus India. Fourteen other venture capital groups are in the process of raising funds for early-stage investment in India. Our research shows that if all these groups are successful in raising money, then they would jointly raise USD 4.4 billion (i.e., an average of USD 100 million per fund), which should ideally be invested during the next four to five years. Since about USD 1.75 billion (approximately 40 percent of USD 4.4 billion) has already been raised, we can safely assume that half of this estimated amount (i.e., USD 2.2 billion) will eventually be raised. Accordingly, USD 0.5-1 billion is likely to be deployed for Hi-tech start-ups in India.

3.3.3 Large Company Funds

For the last three to five years, many large companies have also been making early- and mid-stage VC investments. Primarily, such companies are investing in their own industries and leveraging their expertise with a long-term view towards potential acquisitions. Large company funds operating in India include those set up by high-tech firms such as Intel, Motorola, SAP Ventures, Siemens, Acer Technology Ventures and Cisco. In addition, several financial companies and a few Indian conglomerates have small VC funds. These include Kotak, IDFC, Reliance Capital, JM Financial, Religare (owned by Ranbaxy), State Bank of India, Banc of America Equity Partners Asia, Unitech (a large real-estate developer and manager in India) and Piramal (a well-known pharmaceutical company).

3.3.4 Funds and Incubators Set Up by the Government and Non-profit Organisations

Some funds set up by Indian state governments and non-profit organisations have begun investing in India (See Table 3.). These include SIDBI Venture Capital Limited, Aavishkaar India, Gujarat Venture Fund Limited, RVCF, APIDC, Canbank Venture Capital Fund Limited, IFCI Venture Capital Funds Limited, Rajasthan Asset Management Co. Private Ltd., KITVEN and Kerala Venture Capital Fund Private Limited. Investments from these institutions benefit from low cost of capital; hence, they are potentially attractive for entrepreneurs. However, the maximum amount of capital generally available is USD 500,000.

Table 3: Schemes and Incubators Set Up by the Government and NGOs for Funding Innovation

PROGRAMMES AND INCUBATORS	DETAILS
1983-84: MS Entrepreneurship, IIT Madras	• The Indian Institute of Technology Madras (IITM) launched this programme in 1983-84 as a formal Masters programme to foster entrepreneurship in the institute. • Its main objectives include identifying young individuals with innovative ideas, providing them with the challenges of the real world and offering the institute's expertise and infrastructural facilities to them. Students' business models would be commercialised if they are viable, thereby nurturing, sustaining and developing the entrepreneurial spirit in the former.
1991: Society for Innovation and Development (SID)	• It was launched in collaboration with the Indian Institute of Science (IISC). Its mission is to enable India's innovations in science and technology by creating a purposeful and effective channel to assist industries and business establishments compete and prosper in the face of global competition, turbulent market conditions and fast-moving technologies. • Its Faculty Entrepreneurship Programme supports start-up initiatives, wherein a faculty member provides his/her IP to run the start-up. [ref. 9]
1992: Technology Development and Demonstration Programme	• It has supported over 150 projects up to 2005, of which 65 have been completed and 31 are paying lump royalty/premium. Some projects that are supported under this initiative include the development of a switch reluctance motor, development of Xenon/Krypton-filled lamps for laser pumping, development of an industrial gas burner and an under-burden probe for blast furnaces. [ref. 10]
1992: Foundation for Innovation and Technology transfer (FITT)	• It was established in 1992 by IIT Delhi to provide an interface with the industry and promote the commercialisation of science and technology in the institute for mutual benefits. • FITT offers expertise, facilities and capabilities developed at the institute to the projects supported by it. It also helps in the commercialisation of technologies by providing services such as technology transfer, technology licensing, consultancy to the industry clients, etc. [ref. 11]
1992: Home Grown Technology Programme	• It has invested approximately USD 10 million in projects during the last 12 years. Of the 77 projects that were supported, 60 were completed and 77 percent were commercially deployable. • It has successfully transferred many indigenous technologies to the global market. For instance, it helped to set up a pilot plant for manufacture of insecticide Esfenvalerate, which was developed by the Indian Institute of Chemical Technology (IICT). The process development for esfenvalerate involved the chiral technology, which will be commercialised for the first time in respect of pesticides in India. • Similarly, it has commercialised many technologies such as 'Eco-friendly Melting Furnace', 'Gallic Acid Production by Fermentation', 'Processed Coir Pith Blocks Production', 'Industrial Microwave Dryer', etc. [ref. 12]
1994-95: Drug Development Programme	• Fifty projects have been supported, involving 22 R&D institutions and 23 industries. The projects resulted in the filing of 4 product patents and 12 process patents. [ref. 13]
1995: Advanced Materials Technology Incubator	• ARCI has helped commercialise 21 technologies, and 10 more are available for commercialisation. It has also filed 13 patents. [ref. 14]
1996: Technology Development Board (TBD)	• It has invested approximately USD 150 million in 141 agreements till 31March 2005. • TBD provided support to companies such as Shantha Biotechnics Private Ltd., which has pioneered the development of the recombinant DNA-based Hepatitis-B vaccine, a healthcare product. It has pioneered the development of this product in India by using innovative technology. This has resulted in a successful product, which, because of its low cost, is available to a wide section of society. It won the first National Technology Award, 1999, instituted by the Technology Development Board, Government of India, for the Successful Development and Commercialisation of Indigenous Technology. • It also supported Eicher Motors Ltd. in introducing the four-cylinder E483. This has been a landmark in terms of innovative design, concepts related to planning and manufacturing, experimentation and validation achieving the various targets set forth in the beginning of the

PROGRAMMES AND INCUBATORS	DETAILS
	projects. [ref. 15].
1998-99: Technopreneur Promotion Programme (TePP)	• It supported 115 projects by 2005, of which 50 have been completed and 25 have been commercialised. Some successful projects that have been taken to the market include a bullock cart with a non-hydraulic tilting mechanism'; a motor cycle (bullet) driven sprayer; an innovative cotton stripper'; development of an automatic cycle; an areca nut peeling machine; etc.
2000: New Millennium India Technology Leadership Initiative (NMITLI)	• In a short span, NMITLI has completed more than 25 pioneering technology projects, involving over 50 industry partners and 150 R&D institutions, with an estimated outlay of USD 40 million. The scheme is being implemented by the Council of Scientific & Industrial Research (CSIR). • The three most evident successes of NMITLI are the Biosuite, a herbal drug for psoriasis and a drug for tuberculosis (both from Lupin). The Biosuite, a comprehensive set of bioinformatics applications developed by 18 laboratories and institutions led by TCS, is now in its second phase of testing. • The tuberculosis drug, which is about to undergo clinical trials, is the first new one in 40 years. The new psoriasis drug, which currently seems to be the best available in the world, can change Lupin's fortunes after it enters the market. At present, no cure exists for psoriasis, and Lupin has a USD 4-billion market at its disposal.
2001: Center for Innovation Incubation and Entrepreneurship (CIIE)	• It provides services related to infrastructure support, networks for technology, finance, mentoring, consultancy, databases information dissemination, IPRs and international networking. Since 2003, 10 projects were offered incubation support, of which 6 are active and 4 are on the road to commercialisation. [ref.16]
2004: Society for Innovation and Entrepreneurship (SINE)	• It was launched by IIT Bombay to nurture entrepreneurial activity at the institute. It administers a technology business incubator that provides support for technology-based entrepreneurship. • Besides successfully incubating a number of companies, the information technology (IT) incubator created an environment that is conducive to entrepreneurship. [ref. 17]
2004: Nirma Labs	• It began with a corpus of USD 1.1 million. Currently, there are four projects, of which two will be commercialised and spun off in the next few months. Two other projects are expected to be spin off by 2007. [ref. 18]

3.3.5 Concluding Comments and Recommendations

Overall, the last 15 years have witnessed the emergence of an ecosystem that can promote innovation and its commercialisation in the Hi-tech sector in India. Though this ecosystem clearly continues to be in the nascent phase, it seems that various pieces of the puzzle are coming together. This is indicated by the following:

- Although India is beginning to produce some innovation and new technology, most innovators are technologists and scientists. They usually lack marketing and sales expertise, and a deep understanding of project selection, execution and management. This gap within the ecosystem is likely to be filled in the near future by Non-Resident Indians (NRIs) and Persons of Indian Origin (PIOs). These include those who are either moving back to India after spending one or more decades abroad or those who are likely to keep shuffling between India and their adopted country on a fairly regular basis.
- To fill some of the gaps mentioned above, a group of about 30 successful entrepreneurs and CEOs from India and the rest of the world began the Band of Angels in April 2006. In addition to providing seed funding, this group will provide constant access to mentoring, large networks (of these Angels) that innovators and entrepreneurs can tap into, and inputs on strategy and execution. In India, The Indus Entrepreneurs (TiE) is also trying to create similar groups on formal and informal bases to mentor the next generation of entrepreneurs and innovators. In a similar vein, to foster more innovation and its commercialisation, TiE, along with Canaan Partners (a US-based venture capital firm with a significant presence in India) and Evalueserve, has launched India's first countrywide business plan competition. The short-listed participants will be mentored within TiE-Delhi's 'Nurturing Entrepreneurship' Programme, and the winners are likely to receive funding to execute their business plans.
- Given that IT outsourcing to India is already well established and other Business Process Outsourcing (BPO) units will be fairly well established by 2010, we are likely to see substantial innovation taking place in the area of outsourcing management. Unlike many innovations that are disruptive, these innovations are expected to be rapid and incremental, and will be largely implemented to create barriers to entry for other companies, whether Indian or non-Indian. Such innovations are likely to provide better Service Level Agreements for the clients, with many of them geared towards creating 'supply chains for service businesses' that are similar to

the current 'supply chains for manufacturing and logistics'. For example, since the same outsourcing provider is likely to be competent at risk evaluation and origination of mortgage instruments, as well processing them, some of the innovations would simply be geared towards seamlessly 'connecting and integrating' the best providers. Similarly, other innovations would take advantage of 'overlaying services over software', so that the clients would not have to worry about introducing newer versions of software applications or internally employ domain experts to utilise these applications. Clearly, most of these innovations are likely to engender a new generation of entrepreneurs, who will be competent to provide various kinds of outsourcing services better, cheaper and faster!

- In India, innovation and its commercialisation for hi-tech products and solutions seems to be in the nascent stage. However, given the size of the Indian market, it is likely to gather momentum during the next two to three years.
- Finally, we are likely to see substantial innovation by unaffiliated innovators and entrepreneurs in India in the following rapidly growing sectors: IT and IT-enabled services, electronics, hardware and software, consumer Internet, telecom, automobiles and auto components, travel and tourism, domestic healthcare, medical tourism, retail, textiles, biotech, pharmaceuticals, gems and jewellery, and entertainment and related media. By 2020, these sectors are likely to contribute about 25 percent to India's USD 4.4-trillion economy. Further, since domestic and export revenues would contribute equally to all these sectors, substantial innovation and its commercialisation is likely to occur in most, if not all, of them.

3.4 Innovation and Commercialisation in the Indian Rural and Agricultural Sectors

As India's economy transformed from a socialistic economy to a more market-based one, both the government and some non-profit organisations almost simultaneously began setting up funds such as Honey Bee Network, SRISTI and DHAN (See Table 4.). However, this transformation seems to have taken off with the formation of two new funds – the National Innovation Foundation that was formed in 2000 and the Rural Innovation Networks (RIN) that was established in 2001. This is primarily because of the founders of these funds, who have become their brand ambassadors:

On 1 March 2000, the Department of Science and Technology established the National Innovation Foundation (NIF) of India to provide institutional support for scouting, spawning, sustaining and scaling up grassroots green innovations and helping their transition to self-supporting activities. The following two luminaries and brand ambassadors chair this foundation: Dr. R. A. Mashelkar, director general of the Council of Scientific Industrial Research (CSIR) is the Chairperson of NIF, and Dr. Anil K. Gupta, professor, Indian Institute of Management (IIM), Ahmedabad, and President, SRISTI is the Executive Vice Chairperson of NIF. For the last 17 years, the Honeybee Network and Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) have been scouting for innovations by farmers, artisans, women, etc., at the grassroots level. The Gujarat Grassroots Innovations Augmentation Network (GIAN) scales up innovations from the Honey Bee database, through value-addition in innovations to sustain creativity and ethics of experimentation. GIAN was conceived at the International Conference on Creativity and Innovation at Grassroots (ICCIG), which was jointly organised by IIM Ahmedabad and SRISTI during January 1997. It was set up on 1 March 1997 with support from the Government of Gujarat, IIM Ahmedabad and SRISTI. As on 1 October 2006, NIF had a database of over 20,000 innovations. It supports and manages these innovations and is trying to patent and license some of them to third parties [ref. 19]. It has already had success in licensing or selling more than 15 innovative products and services.

Paul Basil is the founder and one of the brand ambassadors of the Rural Innovation Network (RIN). This organisation promotes rural innovation-based enterprises and is a business incubator that turns grassroots innovations into commercial enterprises. RIN uses several points, such as Chennai's engineering colleges, agricultural universities, research institutions, patent offices, local fairs, exhibitions and banks, to identify innovations. After this, RIN conducts market research for the product to find out whether the idea is commercially viable. Then, it refines these products by making them market friendly, which involves significant engineering work and overhauling. In most cases, the innovator transfers the technology to an entrepreneur or a company for a royalty. What is RIN's role in this? "We are just enablers," says Basil. "We basically provide consulting inputs to, both, innovators and entrepreneurs. Our job is to tie the loose ends. There are several private entrepreneurs out there who want new products. We also help the entrepreneurs develop markets." RIN is working on more than 20 innovations and has already succeeded in licensing or selling at least 5 products.

Table 4: List of Non-profit Organisations and Funds Supporting Small- and Medium-sized Businesses

YEAR OF SETUP: GOVERNMENT AND NON-PROFIT ORGANISATIONS AND FUNDS	OBJECTIVES AND ACCOMPLISHMENTS
1990: Honey Bee Network	• The Honey Bee Network identifies and brings together creative farmers, artisans and grassroots innovators. It supports and rewards these people for their work, apart from helping them to protect it. [ref 20] • It aims to connect and network local experts and innovators by creating a database of knowledge providers. This would include the latter's names and addresses and would be distributing through the Honey Bee newsletter, which is circulated in six Indian languages. [ref. 21] • Setting up the Honey Bee Network was a global initiative. Currently, the network is present in more than 75 countries. [ref. 22] • Over the last 16 years, the Honey Bee Network has published more than 51,000 traditional knowledge and practices of local experts. [ref. 23] • The effort to provide institutional support to the activities of the Honey Bee Network led to the development of the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI).
1993: Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI)	• SRISTI is a charitable organisation that provides an institutional framework in the form of organisational, intellectual and logistics support to the Honey Bee Network. Besides supporting and rewarding the grassroots innovations, SRISTI also provides venture-capital support to them. [ref.24] • SRISITI is involved in various activities, such as entrepreneurship recognition, promotion of policies that favour innovation, dissemination of knowledge related to creativity and traditional knowledge, protection of intellectual property rights, etc. [ref. 25] • Some achievements of SRISTI include the establishment of the SRISTI Sansodhan Laboratory to devise the best practices for sustainable farming and livestock management, development of a framework to provide incentives for conserving biodiversity, development of a multilingual and multimedia database of 10,000 entries, etc. • Organisations such as GIAN, NIF, MVIF and AASTIIK have been established with the help of SRISTI.
1997: Grassroots Innovation Augmentation Network (GIAN)	• GIAN functions as an incubator of grassroots innovations and traditional knowledge. • GIAN is a regional arm of the Honey Bee Network setup in Ahmedabad, Guwahati and Jaipur that supports grassroots innovations in West, North-East and North India. • GIAN has achieved six technology transfers for four innovations on the district, state, national and global levels. [ref. 26] • It helped in facilitating the filing of nine patents in India and five patents in the US. [ref. 27] • GIAN has supported 30 innovative projects including five projects of social relevance.
1997: Development of Humane Action (DHAN) Foundation	• DHAN Foundation is a professional development organisation. One of its aims is to promote ideas in different areas that may help in improving the livelihood of the poor; some of these areas include microfinance, small-scale irrigation, etc. [ref. 28] • Most achievements of the DHAN Foundation are in the areas of micro-financing and the upliftment of the poor.
2000: National Innovation Foundation (NIF)	• SRISTI proposed to set up a national register of innovations and traditional knowledge practices leading to the formation of the National Innovation Foundation by the Government of India. • The Government of India started the National Innovation Foundation (NIF) by providing a corpus fund of USD 5 million. • It seeks to develop a new model for poverty alleviation and employment generation by helping convert grassroots innovations into enterprises. [ref. 29] • NIF conducts an annual national campaign in the form of a competition that aims to scout for grassroots technological inventions. Every year, the number of entries has successively increased. The number of innovations and traditional practices received by the NIF for this competition in the first four years have been 1600, 13,500, 21,000 and 14,000, respectively. [ref. 30] • NIF has also initiated a similar competition for children in collaboration with the Central Board of Secondary Education and has already received a favourable response.
2001: Rural Innovation Network	• RIN works on the principle that all rural innovations can be commercialised as micro-enterprises and they can benefit rural consumers as well as contribute to sustained wealth creation.

YEAR OF SETUP: GOVERNMENT AND NON-PROFIT ORGANISATIONS AND FUNDS	OBJECTIVES AND ACCOMPLISHMENTS
(RIN)	• RIN acts as an incubator and provides services in a variety of areas such as manufacturing, marketing, financing and selling. [ref. 31] • It works in tandem with venture capital firms such as the Aavishkaar India Micro-Venture Capital Fund (AIMVCF). • One of RIN's major achievements includes the successful marketing of the innovation of the rain gun created by Anna Sahib.
2002: Aavishkaar	• AIMVCF provides micro-equity funding within the range of USD 200,000 to 1 million as well as operational and strategic support to commercially viable companies increasing income in or providing goods and services to rural or semi-urban India. [ref. 32] • Aaviskaar has funded seven successful projects and has helped them launch start-up companies. It has five new projects in the pipeline.
2003: Micro-Venture Innovation Fund (MVIF)	• SRISTI also promoted the setting up of the MVIF. • A fund worth INR 40 million to provide means of finance to grassroots innovations and micro ventures based on traditional knowledge was set up by the government. • It works under the guidelines and framework of NIF. • The delivery functions carried out are in tandem with the regional arms of NIF such as GIAN and other collaborators. • Till date, MVIF has provided support to a number of innovations (more than 61). [ref. 33]

Unlike the hi-tech sector, innovation and commercialisation in the rural and agricultural sectors still seems to be far from any 'tipping point', neither is it expected to show rapid growth in the near future. However, there seems to be a clear realisation even among venture capitalists and other businesses that these sectors can also be large creators of wealth, and some of the recommendations given below can potentially speed up this process:

- To increase the pace of innovation in these sectors, we need to create success stories rather quickly. Further, we need more brand ambassadors and champions such as Dr. Raghunath Mashelkar and Prof. Anil K. Gupta.
- Microfinance is also emerging as an interesting opportunity; here, the money is lent to the poor who can generate substantial wealth and return the loan with interest. SKS Microfinance is one of the few companies operating in this domain. Started in 1998, it had provided approximately USD 92 million in repayable loans to 320,000 poor women in India by the third quarter of 2006; The company expects to provide more than USD 300 million in repayable loans to more than 1 million people by 2010. Although the demand for microfinance may be as much as USD 11 billion per year, most of it is so far being met by the informal sector.

3.5 Concluding Comments and Recommendations

Clearly, during the last 15 years, the cycle and eco-system for innovation and commercialisation in the hi-tech sector has been significantly different than that for the rural and agricultural sectors in India. This trend is likely to continue for the next 15 years as well (2006-2020), since the hi-tech sector will be very closely linked to the OECD and emerging countries around the world, whereas the rural and agriculture sectors in India will have to walk an un-traversed path. Nevertheless, it seems that the cultural factors (namely, the *Saraswati-Lakshmi* divide, learning by rote and the remnants of the socialistic economy) that impede innovation and its commercialisation are pervasive in both the eco-systems. We may be able to mitigate these by adopting the following steps:

- Modifying the curricula at the undergraduate and graduate levels in Education (i.e., Bachelor's in Education, Master's in Education, etc.) so that the new generation of teachers pays more importance to creativity than to learning by rote – However, this is easier said than done because (a) we will have to wait for one full generation of current teachers to retire, (b) it will be very difficult to change the mindset of the current generation of teachers that continues to believe in 'spare the rod and spoil the child' and (c) for teachers to inspire creativity among students, they will have to be somewhat creative themselves and they will have to work harder to pose captivating questions and make classes more discussion oriented. If it is any consolation, 'creativity while learning' is achieved only in a few schools even in the US, and on an average, the backpack carried by a seventh-grader in the US is only heavier than that of a seventh-grader's in India!
- Introducing talk shows on Indian radio and reality shows on Indian TV to promote innovation and commercialisation – About 60 percent of the total 198 million Indian households have TVs and a third of them (i.e., 67 million) have cable connections. By 2020, almost 60 percent of the projected 240 million households

are likely to have cable connections. Further, an average member of a household with a cable connection watches at least 10 hours of TV every week. In fact, as is the case in the USA, reality shows such as ’Who wants to be a millionaire’ and ’Fear Factor’ are quite popular in India. Given this environment, high-quality reality shows that discuss innovative ideas and their commercialisation are also likely to be big successes in India, especially if these shows can demonstrate a few really good success stories. One of the Indian satellite channels, Zee TV, started a new reality show called ‘Business Baazigar – Idea Lao Paise Le Jao’ (translated as ‘Business Magician – Bring an Idea and Take Home Money’) on 31 March 2006. Subhash Chandra, the Chairman of Zee Telefilms; Mahesh Murthy, the Chief Executive Officer of Passion Funds; and Prof. Anil Gupta of the Indian Institute of Management, Ahmedabad (also the Vice Chairman of the National Innovation Foundation, mentioned in section 3.2) judged the entrepreneurial and business acumen of the contesting innovators [ref. 34]. Though the jury is still out on whether Business Baazigar will succeed as a reality show, it is clear that at least one show from this genre certainly will!

- Creating a few highly successful cases quickly – Nothing succeeds like success, and once the entire nation witnesses the success of a few innovators and entrepreneurs becoming millionaires and billionaires (i.e., ’Crorepatis’ and ’Arabpatis’ in India), a new and strong generation of entrepreneurs is bound to emerge.
- Creating champions, role models and mentors for the next generation – There are only a few successful entrepreneurs and innovators in India. However, since a significant percentage of the 23 million Persons of Indian Origin (PIOs) worldwide have done spectacularly well, it behoves this section of the Indian Diaspora to provide guidance to the next generation. Indeed, some baby steps have been taken with the appointment of Sam Pitroda as the head of the National Knowledge Commission of India. Constituted in June 2005, this commission is engaged in promoting domestic research and innovation in laboratories and at the grassroots level, and in the subsequent application and dissemination of the created knowledge. SiliconIndia, a community network for Indian professionals, entrepreneurs and students worldwide, also seeks to provide mentorship to aspiring entrepreneurs and innovators.

4 Innovation in Government/Defence Research Labs and Non-Profit/Academic Institutions

During the last three decades, the US has clearly emerged as the global benchmark that all countries look up to in terms of innovation produced by academic institutions and their ability to create jobs and ensure overall dynamism in the national economy. According to a study published by Bank of Boston in 1997, "If the companies founded by MIT graduates and faculty formed an independent nation, the revenues produced by the companies would make that nation the 24th largest economy in the world." The report also added, "The 4,000 MIT-related companies employ 1.1 million people and have annual global sales of USD 232 billion." [ref. 35]

4.1 Situation in the United States

In 2002, US-based academic institutions spent approximately USD 37 billion on research and development. Various government sources provided USD 24 billion, industry provided USD 3 billion, the academic institutions themselves provided USD 7 billion and other sources provided USD 3 billion to garner the total amount. Total R&D investments in the US academia increased from 0.23 percent to 0.35 percent of the country's GDP between 1975 and 2005. Interestingly, although the Federal Government continues to provide the majority of funds for academic R&D, its share has been declining steadily over the past three decades. For example, the Federal Government provided 59 percent of the funding for R&D performed in academic institutions in 2001, down from 68 percent in 1972, which implies that the greater part of the funds are being supplied by the academic institutions themselves and by for-profit companies.

One of the most significant events with respect to the commercialisation of innovations that originated in the US academia was the passing of the Bayh-Dole Act of 1980.This act allows US universities to file for patents on any kind of research that was undertaken using US federal-, state- or local-government money. Soon, US universities started owning rights to their Intellectual Property, which they could license to others. They started encouraging professors and students to pursue applied research and innovation, develop IP, start their own companies (which, in turn, could license the IP from these universities) or find other means of commercialising this IP (such as licensing it to interested companies). Today, most American research universities are equipped with well-developed licensing programmes and many even have one or more 'University Technology Managers' and staff to support the mining, patenting and commercialisation of their inventions. For example, US universities filed 7,750 new patent applications in 2002, and approximately 3,700 patents were approved in that year.

In the period following 1980, members of the American university faculty and student bodies started 4,320 companies of which 2,741 were operational even till the end of the fiscal year 2002 (from those that were started in the previous years). Finally, in 2002, the universities launched 569 new products with commercial partners, thereby bringing the total number of new products launched since 1998 to 2,076. In 2002, US universities earned royalties worth over USD 1 billion on new product sales.

Table 5: University Intellectual Property Income and Start-ups in 2002

INSTITUTION	LICENSE INCOME (IN USD)	RESEARCH EXPENDITURE (IN USD)	NEW PATENT APPLICATIONS	U.S.PATENTS ISSUED	NEW START-UPS
University of California system	261,522,000	2,084,623,000	432	324	26
Columbia University	138,562,416	311,121,727	96	78	7
Dartmouth College	68,427,222	91,698,082	11	17	1
Florida State University	67,497,034	136,284,150	33	16	2
Stanford University	34,603,000	444,274,655	162	98	8
Massachusetts Institute of Technology (MIT)	30,234,664	727,600,000	180	152	31
University of Washington	30,212,714	652,100,000	72	59	6
University of Pennsylvania	26,493,392	529,554,951	84	50	6
University of Florida	26,267,649	294,700,000	121	56	6

INSTITUTION	LICENSE INCOME (IN USD)	RESEARCH EXPENDITURE (IN USD)	NEW PATENT APPLICATIONS	U.S.PATENTS ISSUED	NEW START-UPS
Georgetown University	26,000,000	123,000,000	24	16	2

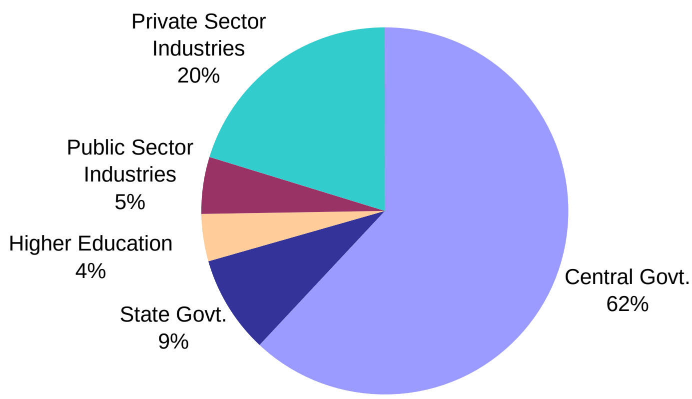
Source: Association of University Technology Managers, 2002 Review [ref. 36]

4.2 Situation in India

The total R&D spending in India was approximately USD 5 billion in 2003 [ref. 37] and 8.5 billion in 2005. R&D spending in India's academic sector has been growing at 8-10 percent per annum between 1996 and 2005 (after adjusting for inflation), and approximately USD 1 billion was spent in this sector in 2005. The Council of Scientific Industrial Research (CSIR), a premier organisation that supports and conducts R&D activities in the country with its network of 38 laboratories, spent about USD 310 million. In addition, the Indian government allocated USD 160 million to the seven Indian Institutes of Technology (IITs), which raised another USD 80 million in tuition fees, industry-academic partnerships and donations from their alumni. [ref. 38] and [ref. 39]

Figure 3 below presents the sector-wise percentage break-up of national R&D expenditure during 2002-03.

Figure 3: Sector-wise Percentage Break-up of National R&D Expenditure (2002-03)



Source: National Science and Technology Management Information System, Department of Science and Technology, Government of India [ref. 40]

Although R&D funding in the academic sector in India was only USD 1 billion in 2005, this amount was sufficient to support 41,200 R&D professionals because of the low research costs in the country. CSIR itself employs approximately one-third of these R&D professionals, and some of their achievements over the years include the development of alternative and cheaper processes to manufacture an AIDS vaccine, the development of Flosover, the development of India's first parallel supercomputer (PARAM) and the creation of Zeolite Technology based on the unique properties possessed by natural volcanic minerals known as Zeolites [ref. 41]. CSIR's patent portfolio increased from fewer than 30 US patents in 1995 to more than 720 in July 2006. The chief architect of this dramatic transformation is its Director General Dr. Raghunath Mashelkar who took the adage 'Publish or Perish' from the US academic world and converted it into the CSIR mantra, 'Patent, Publish, and Prosper'. It is interesting to note that even though CSIR has a rather meagre budget of USD 330 million, CSIR is gradually being awarded more US patents than most publicly funded laboratories in Germany, France and Japan. Table 5 reflects that CSIR is filing and being awarded almost the same number of patents annually as the Massachusetts Institute of Technology and Stanford University (whose research budgets in 2002 were approximately USD 728 million and USD 444 million, respectively.)

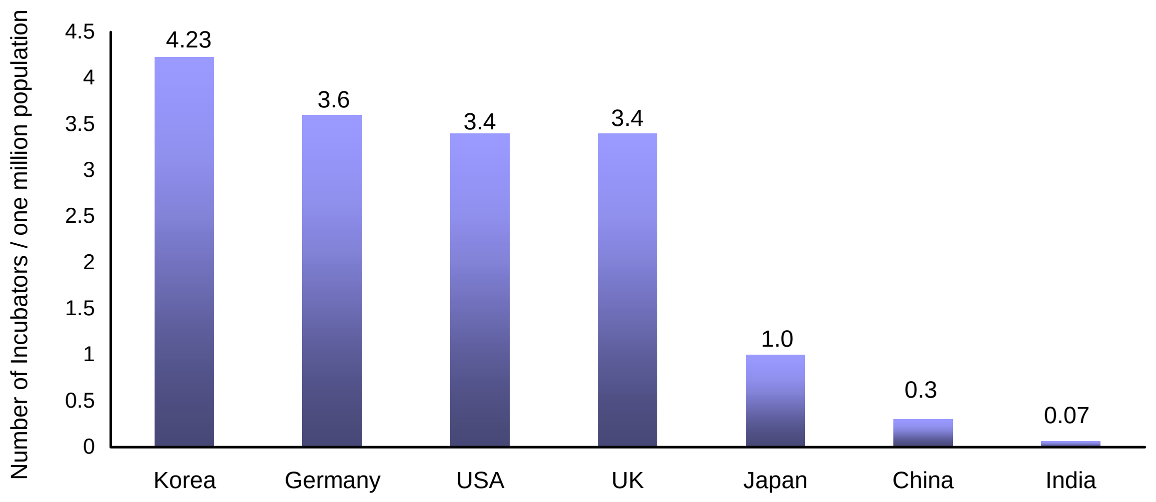
Although CSIR has licensed approximately 7 percent of its patents, (i.e., 133 of the 1,915 patents that have been granted to it worldwide), it has not even recovered the money that it has spent for patenting worldwide. However, it is worth pointing out that it took even some of the top US universities almost 15 years to recover the money that they spent in patenting after they had formally launched a patent programme. If we take into account the cost of

living and the lower wages in India, it seems that CSIR's R&D expenditure is of a similar magnitude as that of MIT or Stanford University. Hence, the next big milestone for CSIR could be to match the licensing revenue of MIT and Stanford University which is approximately USD 30 million per year.
In conclusion, it can be asserted that in spite of a few good strides made by CSIR, there are still not enough incentives for researchers in government labs, and this is one of the primary reasons why the Defence Research and Development Organisation (DRDO) loses close to 60 scientists every year to industry. [ref. 42]

4.2.1 Some Technology Incubators and Programmes That Foster Entrepreneurship:

Figure 4 below provides a comparison of the number of technology-business incubators in India compared to the numbers in the US, China, Japan and a couple of other developed countries.

Figure 4: Number of Technology-Business Incubators (per million population) across Countries



Source: University Grants Commission [ref. 43] and Population Reference Bureau [ref. 44]

Clearly, India has a long way to go. However, it is encouraging to see that following the liberalisation of the Indian economy initiated in 1991-92, a few academic institutions and other stakeholders adopted incubators and pro-entrepreneurial programmes. Some of the prominent examples are listed in Table 6 below:

Table 6: Incubators of Various Institutes to Foster Entrepreneurship

INCUBATORS AND PROGRAMMES VARIOUS INSTITUTES TO FOSTER ENTREPRENEURSHIP
MS ENTREPRENEURSHIP, IIT MADRAS
• The MS in Entrepreneurship offered at IIT Madras has nurtured the entrepreneurial spirit in many students, and quite a few of them have emerged as successful entrepreneurs after completing this programme. • Till date, over 40 students have registered for this programme, and over 20 have completed the course requirements and received degrees. Out of them, more than 10 have already set up industrial units, and a couple of them are even suppliers to IIT Madras. • A wide range of products have been developed through this programme. Some of these innovations include programmable process controllers, torque limiters, a neo-natal care system, personal computers compatible with Indian languages, etc.
FOUNDATION FOR INNOVATION AND TECHNOLOGY TRANSFER (FITT)
• As of 2006, six resident technology start-up companies have been created out of the 14 admitted since the launch of the TBI programme by FITT. • It has successfully commercialised 21 ideas from 1999 to 2003 and has many more in the pipeline. • Some of the successfully transferred technologies include the AC static watt meter, solar photovoltaic lantern, packaging material for sterile medical devices, self-excited phase-induction motors and evaporative cooling deep freeze. [ref. 45]
SOCIETY FOR INNOVATION AND ENTREPRENEURSHIP (SINE)

INCUBATORS AND PROGRAMMES VARIOUS INSTITUTES TO FOSTER ENTREPRENEURSHIP
• A number of success stories are associated with this body. For instance, Powai Labs incubated by SINE was a major success in Electronic Design and Automation Space (EDA). It works with top silicon design companies. • A similar story is associated with Herald Logic, an Intellectual-Property-intensive company operating in the area of real- time enterprise solutions. It was seeded at this business incubator and successfully graduated from it. • There are many more success stories which are noteworthy and over 10 ventures are awaiting commercialisation in this incubator. Recently, Wilcom Technologies Pvt. Ltd., which started as an incubator here, is ready for mass production. It was inaugurated on 1 November 2006. [ref. 46]
SOCIETY FOR INNOVATION AND DEVELOPMENT (SID)
• It has successfully transferred many of its ideas to the market, which are doing well. For instance, Strand Life Sciences, which develops technologies and products for research biology and drug discovery, emerged from this initiative. • Similarly, 3DSoC, an interactive 3D modelling company, spun out of Stanford University and this programme. There are many more ideas which are in the grooming stage and which can be turned into start-ups [ref. 47]

4.2.2 Lack of Innovation Clusters in India

An innovation cluster is an organisation of different companies, research laboratories, universities and governments in a geographic location with its members sharing a common vision of development and a common goal – to accelerate innovation in their fields. Innovation clusters facilitate the sharing of ideas, knowledge and expertise through frequent and strong interactions in a formal or informal manner. Many clusters have been formed around university campuses, which play the dual role of providing research inputs from professors and fresh talent – the students. Innovation clusters also give an impetus to the formation of networks that originate there. The most famous innovation clusters in the US are in the Silicon Valley (close to Stanford University, University of California, Berkeley and some other colleges and universities related to the University of California college system), Route 128 in Massachusetts (close to MIT, Harvard and other colleges in Boston and Cambridge, Massachusetts) and between San Diego and Los Angeles in Southern California (close to the Universities of California in Los Angeles and San Diego, California Institute of Technology and University of Southern California).

In the case of innovation-driven industries, the technological progress of a company depends heavily on its ability to partner with external sources of expertise and the tacit knowledge that it gains through networks and clusters. Innovation networks and clusters offer various benefits to companies and researchers, including:

- Enhanced ability to deal with the complexity of research: Since many key technological developments are complex and involve a wide range of scientific and technological fields, innovation networks and clusters enable cooperation between entities with expertise in diverse fields. This boosts the ability of individual entities to deal with the complexity of research.
- Accelerated pace of innovation: The sharing of ideas and expertise in innovation networks and clusters reduces the time spent by companies in conducting research on their own. Partnering also enables them to carry out different aspects of research in parallel. Therefore, companies benefit by increasing the pace of innovation and reducing the time to market.
- Increased scale and scope of research: Innovation networks and clusters enable companies to enter entirely new research areas and increase the scale and scope of their research.
- Shared costs and risks of innovation: The cost of research is substantially high in certain industries, such as the biotechnology, automotive and pharmaceutical industries. Innovation networks enable companies to share the costs and risks associated with research in these fields.

India is also witnessing the emergence of some clusters, and these have been listed in Table 7. However, unfortunately, such networks are by and large still missing in India. Further, the industry-academia linkages continue to be rather weak. In general – partly because of the *Saraswati-Lakshmi* divide – academicians in India do not want to be associated with for-profit companies (whether domestic or multi-national). They do not train their students to ’tinker’ more, encouraging them to rather become ’conceptual’ scientists and engineers.

Table 7: Industry – Academia Linkages and Emerging Clusters

INDUSTRY-ACADEMIA LINKAGES AND EMERGING CLUSTERS
THE PRACTICE SCHOOL – BITS, PILANI
• The Practice School (PS) is an innovative programme started in 1973 by the Birla Institute of Technology and Science (BITS); Pilani, to provide students with the opportunity of transferring the concepts learned in class to the industry. It helps students to stay abreast of the developments taking place in the rapidly changing industry. • The education process formally introduces the reality of the professional world into the classrooms. To put it concisely, it takes the classroom to a professional location for a period of six months where the students and the faculty get involved in real-life problems. Thus, the PS institutionalises the efforts to bridge the gap between the professional world and the academic world. • It differs from 'Practical Training' as well as `Sandwich Schemes' in as much as the entire education process at a PS station is supervised by the BITS faculty residing at that station. • Ever since the inception of this programme, more than 20,000 students of the institute have worked closely with different organisations. This has helped both the students as well as the organisations. • Such programmes can be emulated across the country in order to promote industry-university interaction and enhance the chances of rapid economic growth. [ref. 48]
FUND FOR IMPROVEMENT OF SCIENCE AND INFRASTRUCTURE (FIST)
• It was launched in 2000-01 by the Department of Science and Technology (DST) to provide infrastructure, impart quality education and support advanced research in the universities. It provides quality infrastructure for conducting high-quality research. • It provides support for a period of five years in two levels. In the first level, it provides moderate funding for the modernisation of labs and library facilities. In the second level, it provides substantial funding for acquiring state-of-the-art equipment and setting up labs for conducting internationally competitive research. There are many universities all over the country that are being benefited by this programme. • This programme is a resounding success but the government has to establish more funds like this to provide basic infrastructure to numerous universities, which cannot conduct quality research owing to the lack of infrastructure. [ref. 49]
AMITY INSTITUTE OF NANO TECHNOLOGY
• Established in 2003, this is the first institution of its kind in the country. This is the only institution in the country to have launched a postgraduate-level specialisation in the field of nanotechnology. • The Amity Institute of Nanotechnology has close linkages with national scientific institutions such as NPL, SSPL, IIT, DU, BARC, TIFR, CSIO and DMSRDE. • Practical training is conducted regularly in national laboratories for specific instruments, such as SEM, TEM, AFM, STM, etc. • The institute facilitates regular interactions in the form of visits and guest lectures by eminent scientists from the organisations that have been listed above. • In spite of being a privately run institution, it has secured research projects sponsored by the Department of Science and Technology.
NATIONAL PROGRAMME ON SMART MATERIALS
• This programme was launched jointly in 2000 by five government organisations including the Defence Research and Development Organisation (DRDO), Department of Science and Technology (DST), Department of Space (DOS), Council of Scientific and Industrial Research (CSIR) and Ministry of Information Technology (MIT) with a budget of USD 17 (INR 750) million spread over five years. • Under the management and administration of the Aeronautical Development Agency, 40 research efforts were initiated on smart materials in various academic institutions of repute, such as the IITs and IISC.

4.2.3 The Looming Shortage of R&D Professionals:

The liberalisation of the Indian economy has opened up a world of opportunities for fresh graduates as well as for PhDs. The burgeoning IT and IT-enabled services (i.e., BPO) industry in particular has created a large number of lucrative jobs. Consequently, most students are wary of venturing into R&D, which has been traditionally seen as a non-lucrative proposition. Almost all engineers are instead opting for secure office jobs, where they are assured of a regular and comfortable salary. This is also one of the reasons why the number of faculty members teaching at the IITs is decreasing steadily [ref. 50]. The decline in the quality of IIT professors, who have lesser motivation and interest towards research, is likely to affect the quality of students as well. In sharp contrast to the impending supply constraints on good quality R&D resources, R&D is poised to really take off among the R&D labs in for-profit technology companies, as discussed in Section 2. Table 8 shows the consequent increase in the forecasted demand for qualified graduates, postgraduates and PhDs in 2010, 2015 and 2020, respectively.

Table 8: Demand for Qualified R&D Professionals in India

	2005	2010	2015	2020
PhDs Required	27,000	56,000	87,000	110,000
Postgraduates (M.Tech, MS, ME) Required	80,000	168,000	261,000	329,000
Graduates (B.Tech, BS, BE) Required	159,000	336,000	524,000	659,000
Total Number of Researchers Required	266,000	560,000	872,000	1,098,000

Source: Evalueserve Analysis [ref. 51]

Clearly, the growth in R&D for the next 15 years can be sustained only if we are able to improve on the quality of India's technical graduates. Although India produces a large number of engineers annually, an examination of the quality of those engineers leads us to very sombre conclusions. For example, although the number of engineers produced in 2004 in India was reported to be 350,000 (compared to only 137,000 in the US) according to a Duke University study [ref. 52], the number of Indian engineers who can be compared to their American counterparts in terms of the quality of education was only 112,000. Further, the number of PhDs graduating in India is quite low – 5,700 to 7,000 per year – compared to approximately 25,000 in the US or 12,500 in China. These numbers present a rather dismal picture of the quality of higher technical education in India and underline the looming shortage of high-quality technical graduates [ref. 53]. This statistic becomes even more worrisome if we take into account the fact that a large portion of the best scientific and engineering talent in India is engaged in providing IT and other back-end services rather than in producing innovation or conducing research and development [ref. 54].

4.3 Concluding Comments and Recommendations

Given that universities and other academic institutions are responsible for creating the researchers and innovators of tomorrow, we believe that the government and non-government organisations should seriously consider the following:

- The Indian government should create an equivalent of the Bayh-Dole Act legislated in the US, which allows universities to file for patents on research aided by federal, state or local government funds.
- The government could join forces with non-government organisations and establish an accreditation mechanism, so that the quality of graduates and postgraduates from Indian colleges and universities can be improved substantially. Indeed, the number of engineers in India who are comparable to their counterparts in the US needs to go from 112,000 (2005) to at least 250,000 by 2010. Fortunately, most accreditation mechanisms do not require much money and are usually self-sustaining.
- Given that the Indian government may not have enough money in its coffers for the purposes of higher education and R&D, it should actively promote more private colleges and research institutions (at all levels) in order to ensure an adequate supply of science and engineering professionals. Indeed, the International School of Business, located in Hyderabad and funded primarily by private bodies and students' tuition, could be a good role model for institutions and colleges only providing postgraduate and doctoral degrees in Science and Engineering.
- Given that only 112,000 engineers in India (out of a total of 350,000) had the same quality as those in the US, both for-profit companies and non-profit organisations should create 'customised teaching and training programmes' so that they can bring the other engineers (and graduates and postgraduates from other disciplines) at par with their American counterparts. As a positive trend, this approach has already been pioneered in a few cases, and companies such as WIPRO, TCS and Infosys now have full-fledged training schools built into their office campuses.

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