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India’s Emergence as a Global R&D Center

- an overview of the Indian R&D system and potential

Raja M. Mitra

SWEDISH INSTITUTE FOR GROWTH POLICY STUDIES

ITPS, Swedish Institute for Growth Policy Studies
Studentplan 3, SE-831 40 Östersund, Sweden
Telephone: +46 (0)63 16 66 00
Fax: +46 (0)63 16 66 01
E-mail info@itps.se
www.itps.se
Lenanders Grafiska, 26690

For further information, please contact Raja M. Mitra
E-mail rmmitra@hotmail.com or mitra@post.harvard.edu

Foreword

Internationalization of research and development has accelerated significantly in the 1990s and 2000s. Much of this activity continues to take place among major industrial economies. Developing countries are, however, also playing increasingly important roles. India and China are rapidly emerging as major powers in this century, both in terms of the size of their markets and in a wide range of science and technology developments.

This study provides a strategic review of economic and R&D developments in India. It examines key trends, drivers and future prospects for R&D with a special focus on India's emerging role as a center for research and knowledge processing service industries. The study also discusses scenarios for India's emergence as a major economic and R&D power and subsequent local and global consequences.

The work asserts that current weaknesses in data and a lack of substantive examination of corporate developments in India highlights a major need for further and more in-depth analysis of Indian-related science and technology development. It is important to foster well-grounded knowledge on the nexus of longer term economic and technology related development in India and its international context. It is also argued that it is essential to move beyond fact-finding and general discussions, to move from words to deeds, in fostering India-related economic and technology relations among key stakeholders in the private and public sectors.

This report is based on a series of works by the author, Raja M. Mitra, covering economic and high-technology industry developments globally and in India in particular. Producing the study entailed research and interviewing numerous prominent experts and policymakers. The author is solely responsible for the contents and conclusions of this study.

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This report is based on a series of works by Raja M. Mitra on economic gr owth and high technology industry developments globally and Indian-related developments in particular. The study draws on desk research and on more than one hundred interviews encompassing academics, industry analysts, corporate leaders and policymakers in India, Sweden, the United Kingdom and the United States.

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About the author: Raja Mikael Mitra is an adviser and analyst with worldwide experience in high-tech industry developments, foreign trade, investment and offshoring, as well as more generally in public policy, corporate business strategy and management issues. His career began with assignments in the United States, India and numerous other countries on behalf of the Swedish government and corporate sector. Later he became a strategist and economist serving international organizations and multinational corporations. Since 1989 he has worked with the World Bank Group in Washington DC. He graduated from Harvard University and the University of Stockholm. The author can be reached at: mitra@post.harvard.edu

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Executive summary

India's potential as a major economic power and R&D-related center

India is predicted to become one of the world's leading economic powers. This poses new challenges for international firms and others willing to take advantage of India's development. It also increases the need for proper knowledge about India's corporate environment – its strengths, constraints and the implications for Sweden, Europe and the rest of the industrialized world.

India's share of the world's population is 17 percent, but it accounts for less than 2 percent of the global GDP and only 1 percent of world trade. It lags behind China and other emerging East Asian economies in key indicators such as per capita income, adult literacy rates, quality of infrastructure endowment and volume of foreign trade and investment. While India is the star performer in Asia in terms of export of software and IT-enabled services, it lags behind in computer and Internet user penetration. ICT diffusion, however, has improved quickly.

A wide range of indicators point to India's potential for catching up in economic, technology and social development. The country's adult literacy rate, for example, has increased, the number of engineering students has risen and the proportion of poor people has decreased substantially over the last few decades.

However, it must be noted that India's economy predominantly continues to concentrate on absorption of existing technology rather than development of new R&D or innovation at the global knowledge frontier. The country has much to gain from increased absorption of existing knowledge by promoting economy wide transfer and diffusion of local and internationally available technology. There is considerable scope for more effective absorption of existing knowledge by expansion of foreign investments and trade, building effective capacity among Indian corporations, public education and research institutions coupled with various forms of collaboration between Indian and foreign partners.

The Indian economy is expected to grow at a rapid rate of 6–10 percent between 2007 and 2012 and beyond. By the year 2032, China will have the world's largest economy, followed by the U.S. and India, according to a well-known scenario presented in the BRIC report released by Goldman Sachs (Goldman Sachs 2003). In terms of purchasing power parity (PPP), even today India's GDP is already the third largest in the world after the U.S. and China. While much of the country is likely to remain poor and industrially backward, other parts have the potential to grow as fast as China or other East Asian economies. Some urban areas are increasingly integrated in the new global knowledge-based economy as demonstrated by the cases of Bangalore, Chennai, Delhi, Hyderabad, Kolkata, Mumbai and Pune.

The prospects for continued growth in production as well as in R&D operations in countries like India (and China) indicate a major structural change in the national and international economic order – the full consequences of which are hard to foresee today. In India, we already observe a rapid expansion in corporate high-technology investment from both foreign and domestic investors, particularly within the ICT sector. Furthermore, India has the ambition and potential to be a major player in business processes, innovation and R&D power. The potentials for cost savings and access to technical competency and markets are among the most important factors underlying the drive for multinational companies to expand their production and R&D operations in India.

It is also essential to grasp how and why India's rapid economical and social development is constrained by a wide range of societal conditions, and understand that the pattern of economic development continues to be uneven. This is illustrated by India's major cities being well ahead of the rest of the country in economic development and the fact that their economies are becoming increasingly integrated with the global economy.

Higher education and R&D institutions capabilities

A wide range of indicators point to India's potential for catching up in economic and social development. The country's adult literacy rate rose from 58 percent for men and 31 percent for women in 1985, to 68 percent for men and 45 percent for women in 2000. Moreover, the numbers of engineering students graduating annually have risen from about 44,000 in 1992 to approximately 184,000 in 2004 compared to 352,000 for China and 76,000 for the United States. Other estimates claim that India produces about 350,000 engineering graudates per year and that this number will reach 1.4 million by 2015.

The principal factors pointing to India's potential to be a major R&D power are the size of its educated workforce, entrepreneurial traditions and a significant existing R&D-related institutional infrastructure. On the whole India has made major advancement in all of these areas in the past decades. Assessing this advancement (as well as prevailing deficiencies) and comparing them to developments in other countries is however hampered by weakness both in quantitative and qualitative information. Even official sources sometimes give completely disparate numbers on important parameters such as, for example, the number of graduates in India

Corporate R&D-related developments

India's emergence as a major economic, knowledge-based services and R&D power will clearly have wide-ranging local and global consequences. The imperative to specialize and internationalize R&D operations is driven globally by intensifying international competition, rising costs of R&D in advanced industrial economies and the scarcity of engineering and scientific manpower. In this context the increasing complexity of R&D and the need for rapid responses to changes in technology, legal and regulatory frameworks and markets are also important. At the same time, the attractiveness of carrying out R&D in India or in its emerging high-technology industry clusters is increased by the growing availability of innovative entrepreneurial, scientific and engineering skills and manpower at competitive costs, the ongoing globalization of manufacturing processes and service delivery, and substantial and fast-growing markets.

The impact of India's development is poised to be significant in major sectors such as ICT, industrial manufacturing and in other areas such as engineering, energy, agriculture, environmental technology and life sciences. Continued rapid growth is also expected in IT-enabled services, spearheaded by developments in the software industry, coupled with those in ICT hardware and telecommunications. These services include the higher-end, knowledge process industry niches (e.g. finance, accounting, insurance, education, health and other services). The knowledge process outsourcing industry has considerable growth potential in a wide range of areas. It may well employ more individuals than traditional R&D operations within the next five to ten years.

The years 2005, 2006 and 2007 were characterised by a major shift in the scale and scope of India-related corporate operations. Indian and foreign companies announced investment plans on an unprecedented scale by Indian standards. Multinational companies have pledged investments of 8.6 billion dollars in the telecom and information technology sectors in India for the financial year 2005–2006, including large new investments by companies such as Cisco Systems, IBM, Intel and Microsoft. IBM alone plan to invest 6 billion dollars over a four year period, some of which will be R&D related.

The focus of multinational company high technology investment in India has to a significant extent to date been ICT-related. It is however important to note that expansion also encompasses other knowledge-based sectors as well. It has been estimated that even the major global pharmaceutical companies will invest 1.5 billion dollars in India between 2006 and 2010, much of this also R&D related. Moreover, a large number of foreign and Indian companies plan major investments in, for example, engineering, financial and legal services. Another major development is in foreign firms stepping up their acquisitions in India while Indian IT, pharmaceutical and other companies are doing likewise outside of India. Indian companies (as well as the Indian diaspora) have recently emerged as significant entities in, for example North America, Europe, the Middle East, and East Asia.

The central role of networks, industrial clusters and the diaspora

The development of networks and high-tech industry clusters has been fostered by improved communication and by the Internet in particular. The mobility of qualified and talented human resources within India and internationally has also been one of the prominent attractions for high-tech industry and R&D developments in India.

The rapid development of industrial clusters has been a central factor in the growth of the software and IT-enabled services industries in India, especially in the export sectors of those industries. Initiatives by the central governments to establish software industrial parks were pivotal in this respect. The Indian government has promoted development through industrial clustering in IT, biotech, and engineering and in other fields. These initiatives include launching new special economic zones (SEZ). In May 2005, the Indian Parliament passed legislation providing new tax and labor laws, plus other incentives for private investment in SEZs. These zones are intended to be engines for export-oriented growth in a wide range of goods and services industries. They will also attract offshore outsourcing business, resulting in a large number of industry clusters serving global markets.

Bangalore, Delhi, Mumbai, Pune, Hyderabad and Chennai have so far been the most preferred destinations for R&D in India. Factors such as the combined presence of foreign companies, research labs and educational institutes have made these locations attractive centers for R&D operations. The strength of the attraction of locating R&D activities to these cities has been demonstrated by continued, rapid corporate expansion in all of India's major industrial centers, despite the major local challenges of physical infrastructure bottlenecks, environmental degradation, high attrition rates, wage inflation and social problems.

The development of the software and business process outsourcing industries in India illustrates the importance of skills development and networks. India's initial entrée into the software business has much to do with its access to a large pool of low cost human resources. Subsequently the country also developed a significant number of vendors capable of meeting high quality standards and conducting R&D. A key feature of the Indian talent is that it is much more globally mobile than labor in general. Indian's account for more than 40 percent of the temporary work visas issued by the United States to foreign workers. Further, the

Indian diaspora's long-established success in the United States has played a central role in facilitating the flow of talent back-and-forth between India and the United States. In short, the Indian diaspora is playing an increasingly important role in a wide range of knowledge-based industries in North America, Europe as well as Asian economies.

Challenges for India and multinational companies

India is a major player in the so-called "global war for talent" in the knowledge-based industries and in research. Generally, foreign multinational companies and major Indian firms are able to recruit and retain much of the top-level talent in India. They typically offer high salaries and advanced training, combined with attractive international career opportunities – advantages most domestic companies are often unable to match. The demand for skilled human resources is rising in India, illustrating that the competition for talent is growing more and more intense within the country and globally.

In many respects, India is still in an early phase of development in the areas of the high-tech industries and international R&D. There exists considerable scope for building on strengths and tackling weaknesses in the national innovation system and the corporate investment climate. Challenges include the critical needs of improving the physical infrastructure and the education system, laws and practices governing labor markets, taxation, land and real estate development, intellectual property rights and general functioning of government institutions at both the central and state level. Moreover, it is essential to build private-public partnerships, expand foreign investment and enhance the role of the Indian diaspora and other forms of international collaboration.

Considering these challenges, India can still emerge as one of the world's principal centers for offshoring of knowledge processing, R&D and high-technology industry investment and trade within the next 10–20 years. Multinational companies and Indian parties are already developing the capabilities of the country to undertake production-supportive and adaptive R&D and design work, as well as developing innovative means of undertaking knowledge processing work and R&D. The motives are that the cost of not having comprehensive strategies for developing economic and technology relations with India (and China) will prove to be significant, especially for companies with global aspirations.

Increasingly multi-faceted Swedish-Indian relations

Economic and technology relations between Sweden and India lag behind countries like China and Japan. Trade and investment links however between Sweden and India are poised to expand substantially in the long-term. This also applies to R&D activities by Swedish companies in India. In addition, Indian companies' operations in Sweden, and other European countries, are also on the verge of more substantive expansion, implying a new phase of development of economic and technology relationships.

Continued concerted effort is required to invigorate science and technology (S&T) links with India. This includes the implementation of a coherent S&T development strategy and concrete measures are required from both the Swedish and Indian governments, as well as academic and corporate stakeholders, to expand economic S&T collaboration schemes between the two countries.

Swedish industry has a long tradition of exporting to, and producing goods locally in India. These activities have gradually expanded and now often include production as well as sales directed at both the Indian and other markets. Furthermore, from 2003 onwards there have been significant expansions in R&D activities by Swedish companies in India. Indian private and public sector companies have a significant interest in acquiring technology from Sweden, covering a wide range of areas. Indian companies are now increasingly active in seeking trade and in offshoring business opportunities, including business process outsourcing and R&D-related operations.

The Swedish manufacturing industry is also gradually expanding its activities in India. Now, manufacturers often include production as well as sales directed at both the Indian and other markets. Over the last few years they have also expanded their R&D operations in India and several now have both adaptive R&D to serve local market requirements and innovative R&D that is mostly aimed at global markets.

The following companies have established and expanded significant R&D operations in India in the 2000s: ABB, AstraZeneca, Ericsson, Sandvik, SKF, Telelogic AB and Volvo. Alfa Laval and Atlas Copco are well-established players in the Indian market but do not conduct significant R&D in the country. Svenska Handelsbanken decided to open a representative office in India in 2006 and thereby became the first bank from a Nordic country to do so (Svenska Handelsbanken 2006). Other Swedish banks, accounting and management consulting firms and other services providers have, however, little or no BPO-KPO operations in India.

Large companies, such as Ericsson and ABB, dominate Swedish R&D activities in India. Other major multinational companies are often well-placed to establish R&D operations, as they already have significant sales and production operations in India. The situation is different for small or medium enterprises (SMEs) or newcomers. Swedish SMEs typically do not have significant production or R&D activities in the country. They often lack the financial resources and local knowledge required to set up in-house R&D centers in Asian locations. There are however, signs that SMEs are looking at India more seriously.

It is important to distinguish between short and long-term developments. In the short term it is not likely that India can be one of the top economic and R&D partners for European countries such as Sweden. India's importance needs to be viewed in terms of its long term potential as a large market, both for capital and consumer goods and as the center for a wide range of R&D operations. Larger Swedish-related companies need to be more involved with both India and China simultaneously – as illustrated by Ericsson and ABB, who have R&D centers in both locations.

A number of important initiatives can foster economic and technological relations between Sweden and India. Swedish efforts should include the following:

1 Strengthening the monitoring, dissemination and promotional activities covering economic, cultural and S&T developments in India in order to develop Swedish-Indian relations and thus enable development of a comprehensive strategic agenda for economic and S&T relations between Sweden and India.

2 Strengthening education ties and partnerships in skill development.

3 Strengthening research collaboration under the official bilateral S&T agreement and supporting the development of public- and private-sector partnerships such as workshops, exchange fellowships and joint research projects. On the private side, corporate-led commercial and R&D-related collaboration efforts between Swedish and Indian entities should also be encouraged.

4 Strengthening collaboration especially in critical technology areas such as software and telecommunications, biotechnology, bio-pharmaceuticals and infrastructure.

Finally, it is essential to move beyond fact-finding and general discussions; to move from words to deeds. It will indeed require persistent efforts, with appropriate high-level endorsements and warranted funding, to make the significant expansion of economic, science and technology collaboration between foreign and Indian parties a reality.

1 Introduction

1.1 Background

The geography of innovation and of corporate knowledge-based industrial and research operations in particular, has changed significantly in the 1990s and 2000s. Much of this activity continues to take place among major industrial economies. Developing countries are also, however, increasingly playing important roles (UNCTAD 2005a). India and China are likely to become major powers, both in terms of the size of their markets for goods and services and in a wide range of science and technology (S&T) developments. Judged on the basis of recent trends, it is evident that the world economy will undergo further structural changes, resulting in a greater role for emerging Asian economies and in an expanded scale and scope for globally distributed R&D-related work; India being a prime example (Mitra 2007).

India has witnessed strong economic performance, with a robust growth in both the goods and services sectors especially, in the 2000s. This development has been accompanied by rapid expansion in domestic and foreign corporate high-technology industry investments, particularly in the information and telecommunications technology (ICT) sector.[1] The prospects for continued growth in production as well as in R&D-related operations in countries like India (and China) point to a significant structural change in the national and international economic order – the full consequences of which are hard to foresee (Mitra 2007).

However, it must be noted that India's economy predominantly continues to focus on absorption of existing technology rather than development of new R&D or innovation at the global knowledge frontier. The country has much to gain from increased absorption of existing knowledge by promoting economy wide transfer and diffusion of local and internationally available technology. There is considerable scope for more effective absorption of existing technology and knowledge by expansion of foreign investments and trade, building effective capacity among Indian corporations, public education and research institutions coupled with various forms of collaboration between Indian and foreign institutions.

The fact that more companies (American, European, Indian and others) have increasingly internationally distributed systems for undertaking R&D is part of a broader set of globalization processes reflected in foreign trade, investment and human resource developments, covering not only goods production but also a wider range of services. This development is well illustrated in the expansion of corporate R&D in India and the role of the India diaspora is poised to result in further increases in the scale and scope of high-tech industry production and R&D operations in India. The trends, as seen in expanded corporate R&D in India, imply that India is becoming a key element in the international R&D operations of multinational companies, with stronger efforts in R&D emerging as the key factor in the competitiveness of Indian companies.

It can be argued that India's contemporary trajectory regarding industrial and S&T developments is significantly different from earlier experiences of economic catching-up in

[1] *ICT is defined here as computing and communication equipment, software and services and communication services, including Internet connectivity, broadcasting and media. The definition of IT (information technology) is limited to computing equipment and software services and their related applications in various sectors.*

Europe and East Asia. Unlike past experiences from Japan and most other countries, offshoring-oriented corporate expansions, led by both multinational corporations and indigenous companies, have been key drivers in the rapid emergence of high technology centers and industries in India since the 1990s; the software industry being a prime example. In addition, development in India's high technology industry is taking place in an era where the Internet and a wide range of global and local alliances and virtual networks are especially crucial in R&D and for innovation development, as well as more generally for economic and social development.

The confidence in India's R&D potential is evident from the following statement made by R. A. Mashelkar, Director General of the Council of Scientific and Industrial Research (CSIR) in New Delhi: "India has the potential to become the number one knowledge-producing center in the world by 2025, going by the way that things are moving" (Mashelkar 2003). Furthermore, the importance of the private sector and local connections in India's S&T development has been examined by Professor Y.S. Rajan. He states that *"Scientific and technology strengths of a country are meaningful only when they come out as economic strengths through the business of the firms and through operational systems which can serve people"(Rajan 2001).*

India's emergence as a major economic, knowledge-based services and R&D power is poised to have wide-ranging implications for the people of India and globally. These include effects on trade, investment, employment, the environment and trajectories for national industrial and technological developments.

The impact is poised to be significant in major sectors such as: information and communication technology; industrial manufacturing; construction and other engineering industries; agriculture and in the life sciences (covering pharmaceuticals, bioinformatics, medicine and healthcare). Furthermore, continued rapid growth is expected in IT-enabled service (ITES) areas e.g. business process outsourcing (BPO), including higher-end knowledge processing industry niches such as finance, accounting, insurance and education. This growth is spearheaded by developments in the software industry coupled with major investments in ICT hardware and telecommunications by both Indian and foreign companies.

India, China and other emerging Asian economies have become significant destinations for the R&D operations of multinational companies. A McKinsey survey of 5,500 senior corporate leaders of large corporations worldwide (each with revenues of at least one billion dollars) revealed that India is the preferred destination for investments in R&D; one-third of the European corporations surveyed also shared this opinion. This is evident in repeated instances of companies opting for India, in preference to other locations, for their offshore R&D operations (FICCI 2005).

An Economist Intelligence Unit (EIU) global survey conducted in 2004 found that multinational companies are redistributing their product innovation activities across the globe. Some 70 percent of the companies surveyed employed R&D people overseas; 52 percent reported that increasing overseas R&D spending was a priority. When asked to choose the most likely centers for overseas investment, India ranked third (behind the U.S. and China), attracting 28 percent of the respondents (EIU 2004a and 2004b).

Furthermore, the EIU survey found that 70 percent of companies employing R&D workers overseas considered India to be a R&D "hotspot." EIU defined a R&D hotspot as *"a place where companies can tap into existing networks of scientific and technical expertise; which has good links to academic research facilities; and provides an environment where* *innovation is supported and easy to commercialize."* India is claimed to have many of these qualities (EIU 2004a).

U.S. companies have so far taken the lead in expanding the offshoring of services to India, both at the lower and higher ends of the value added chain. Much of Europe and Asia have lagged behind the U.S. corporate sector in establishing R&D operations in India. There are however strong indications of a rapid expansion of R&D activities by a large number of stakeholders. This is illustrated by the way that British, Canadian, Chinese, German, Swedish and other companies are expanding their operations (offshoring and others) in India.

In short, in recent years a common perception has been that India can emerge as a major international R&D and knowledge process outsourcing (KPO) power and more effective absorber of existing technologies, products and manager of business origanizations. This is reflected in the statements of top corporate leaders, financial institutions, consulting firms, government officials and academics. The optimism exhibited by key stakeholders has resulted in the expansion of R&D operations of foreign and Indian companies, directed at both the local and international markets.

India does still have a long way to go before it can claim to be one of the world's principal powers in R&D and innovation. Some scholars partly question the sustainability of current trends of high economic growth and rapid expansion of multinational corporate R&D investment (Kapur 2005, D'Costa & Sridharan 2003). Many stress the possible risks associated with uneven development and the sharp socio-economic disparities within the country. These risks are associated with increased foreign financial and other dependencies, as well as weaknesses in the system of governance at central and state levels. Others point to signs of institutional decay and erosion of the human talent base in some areas of science, including basic, or theoretical, research (Arunachalam 2002).

International trade, investment and principal R&D indicators show that India is a minor player in the global context despite its large population. Future developments critically depend on forceful action by government and corporate stakeholders to build on opportunities and strengths, while simultaneously responding to risks and tackling shortcomings. Albeit the challenges, the country appears poised to become an eminent player in R&D and innovation in an increasingly wide range of areas.

1.2 Study objectives

The objective of this study[2] is to provide a strategic review of corporate R&D developments in India. It examines key trends, drivers and future prospects for R&D with a special focus on India's emerging role as an attractive location for R&D and knowledge process service industries. The work also explores the numerous factors that constrain development of India's R&D capabilities, such as human resources and infrastructure developments, the intellectual property rights legislation and compliance conditions, and overall corporate and public policy and governance issues. Finally, the report discusses scenarios for India's emergence as a global R&D power and subsequent local and global consequences, including implications for advanced industrial economies such as Sweden.

The intended audience for the report comprises the education and research community, government agencies and public policy as well as corporate decision makers.

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[2] *This report is based on forthcoming publications by the author covering economic growth, globalization, offshoring, R&D and ICT industry-specific developments in India and their local and global implications.*

1.3 Methodology, information sources and terminology

The method of enquiry for this study is that of historical and comparative review. The work uses descriptive (and some aspects of exploratory) research design. The examination is based on a critical review of published information as well as insight stimulating examples, such as company level case studies, including findings originating from semi-structured interviews conducted in India, Europe and the United States.

The study draws on a wide range of published information sources and a large number of interviews with private companies, government officials and scientists in India, Sweden, the United Kingdom and the United States. The analyses of company-specific developments based on journalistic reporting and interviews are necessary in order to provide a more comprehensive picture and to ensure that the examination is relevant and up to date.

The examination uses both quantitative and qualitative source materials. It draws on authoritative sources such as national accounts, industry and manpower surveys and legal documents. The analysis is however hampered by weaknesses in the information regarding corporate R&D and innovation, tacit knowledge, including -un- codified indigenous knowledge assets and formal, as well as informal, networks, in addition to the role of the Indian diaspora in India and internationally.

The lack of substantive qualitative and quantitative analysis of R&D inputs and outputs, corporate behaviour and private entrepreneurship, high-tech industry clustering and local and international virtual networks implies a need to define and assemble indicators and methods of analysis which are the most relevant to examining R&D developments in India. More, generally it indicates the need for further research (Mitra 2007). This task is not easy, due to the complexity of the issues involved and the deficiencies in the existing data. There are also major issues in coverage and consistency in the use of terminology (see Box: Defining R&D, offshoring and outsourcing).

Box: Defining R&D, offshoring and outsourcing

Definition of R&D. "R&D" consists of four types of activities; basic, applied, product and process research.

- Basic research is original experimental work without a specific commercial aim; frequently done by universities.
- Applied research is original experimental work with a specific aim.
- Product development is the improvement and extension of existing products.
- Process development is the creation of new or improved processes. (UNCTAD 2005a)

The boundaries between research, development and other forms of technological innovation activities are difficult to establish in reality. R&D data based on different definitions must be compared with caution. Furthermore, "R&D" is related to the broader notion of innovation. Innovation can be defined as the introduction of new products, services or processes into the market. The term is used to cover both the creation of new technologies (new to the world) and the use of existing technologies (new to a particular user or market). In this context, R&D can be seen as "one source of innovation or a particular type of innovative activity" (Karlsson 2006).

Defining outsourcing and offshoring: The terminology relating to sourcing, outsourcing, offshoring and in-sourcing has not been standardized. Generally the term "outsourcing" refers to procurement of material inputs or services by a firm outside the original firm. Outsourcing can be domestic (onshore) or international (cross-border or offshore). This report focuses on international offshoring or outsourcing. Offshoring, or offshore outsourcing, is defined as procurement of service or material input from a source in a foreign country. It includes both intra-firm offshoring (in which the foreign provider of the input is still owned by the firm) and arms-length offshoring (in which the foreign provider of the input is independent from the firm using the input). International outsourcing (offshoring) is part of a country's import of goods and services (Amiti M. & Wei Shang-Jin 2004 and Mitra 2007).

1.4 Varied images of development

Perceptions about India are often varied, reflecting the country's great diversity and varied views among different stakeholders, as well as deficiencies in existing data.

Attempts to benchmark India's social, economic and S&T developments based on readily available official statistics, journalistic writing, various consulting companies and other reports are useful, but can be misleading. While the number of publications relating to R&D, high-tech industrial and offshoring developments are growing, much of what is written is based on incomplete data and analysis of Indian realities. Much of the literature falls short in distinguishing and explaining the correlations and causality of factors driving and impeding high-tech industry and R&D development. There is a scarcity of the comprehensive and reliable information needed to assess R&D related institutional frameworks, sector and company level developments. Moreover, it is hard to come by rigorous analysis covering the interfaces between global, national and sub-national levels of development that are central aspects of high industry and R&D developments in India (Mitra 2006).

Studies seeking to describe and analyze India's overall science and technology system and achievements are often based on sporadic, outdated and scattered Indian or foreign reports. A few studies, with specific purposes, have been undertaken, at different points in time, to evaluate the performance of institutions based on various S&T data; for example, in the context of restructuring scientific institutions. There are, however, a lack of sustained and timely quality efforts at the national level in producing up to date and systematic information and impact assessments regarding the development of India's multi-facetted S&T systems (Shukla 2005).

As rightly pointed out by Rajesh Shukla, "*Unfortunately, no systematic and comprehensive empirical assessment of S&T efforts is available in the Indian context, resulting in a relatively chaotic and contradictory picture of national efforts in S&T" (Shukla 2005).* This is reflected in the widely noted duality in the images of Indian science and technology achievements.

On the one hand, India displays major advancements in areas such as, for example, software and the aerospace industries. On the other hand, however, India ranks quite low, as per indices based on S&T related development-related indicators such as the World Bank's Knowledge Assessment Methodology (KAM), the World Economic Forum (WEF) and other ranking indexes.[3] If not used carefully however, such indices can be erroneous and

[3] *The World Economic Forum (WEF) annually published Global Competitiveness Report provides comparative indices on the competitive strengths of over 100 countries, including India. Its report includes two major indexes: the Growth Competitiveness Index (GCI) and the Business*

inadequate *"Although such rankings reflect genuine challenges to the successful growth of S&T achievements in India, several scholars have also questioned the ability of such indices to adequately, accurately and comparatively reflect underlying conditions" (Shukla 2005).*

Benchmarking limited to international comparisons of per capita indicators of income, size of domestic markets, foreign trade and investment, differences in ICT and in other infrastructure developments, education attainments rates, R&D spending and patents filed, for example, can indeed be erroneous and inadequate in projecting the true, or complete, picture. They need to be supplemented with a more in-depth, issue specific, examination and historical and dynamic analysis.

India lags behind much of the world according to frequently quoted standards of per capita level economic, social and technology development indicators (World Bank 2006). It is, however, essential to keep in mind that absolute size matters in several ways. This is reflected in terms of the geographical expanse of India, and in the size of its population, many of whom are poor and lack access to basic healthcare and education. Low per capita income and other indicators, coupled with social disparities and uneven economic development more generally, also, however, indicate major scope for advancement. Moreover, India has a proven record in rapid development in the high technology industries and in a wide range of R&D activities, despite the fact that large parts of its population lag behind in social and economic development. The principal underlying reasons include the absolute size of the pool of people with higher educations, coupled with a wealth of knowledge based formal and informal networks (Mitra 2007).

Additionally, it must be noted that comparing large countries with small countries, or homogeneous and heterogeneous societies, can be misleading. Social and economic development indicators in parts of India are comparable with those of Sub-Saharan African countries. In other parts, however, the economic performance since the 1980s has been comparable with fast growing East Asian regions. Some areas of India have done as well, or even better, than the high technology industry development star performers of recent years, like Finland, Israel, Ireland, and Singapore (Mitra 2007).

In summary, there are major weaknesses in the existing data and analysis of economic and R&D-related developments in India, including corporate led developments. This has contributed to a proliferation of misperceptions or seemingly contradictory images. Moreover, it is important to note that it is especially hard to examine and generalize about India, given the country's great diversity of cultural, social and economic conditions.

Competitiveness Index (BCI). The World Bank Institute's Web-based Knowledge Assessment Methodology (KAM) is a tool developed to aid the benchmarking of a country's position relative to others. Related to this is the Knowledge Economy Index (KEI), also used in the World Bank's reports. The United National Development Program's (UNDP) Human Development Report, published annually, ranks countries with a major weight being placed on human resource development. The United National Conference for Trade and Development (UNCTAD) has developed an Inward foreign direct investment (FDI) performance index, which ranks nations by the FDI they receive relative to their economic size; calculated as the ratio of a country's share in global FDI inflows compared to its share in global GDP. Furthermore, A.T. Kearney has developed an annually updated Foreign Direct Investment Confidence Index which has been frequently quoted in the context of India-China comparisons.

The varied images of India are reflected in the perspectives of various stakeholders. While some focus on the impact on the Indian economy at large, including the poor and rural areas, others focus specifically on the impact on well-educated, urban-middle and affluent business classes. Yet others are more concerned with the implications for foreign consumers and multinational companies.

This study argues for the necessity of holistic and long-term perspectives to comprehend high-tech industry and R&D developments. We need a multi-dimensional perspective in order to understand the prospects of India becoming a major economic and technological power. This perspective must include an assessment of the country's current global position in economic and technology development, as well as a review of the historical phases of change in the contemporary structure of Indian society and in government policy developments.

The current report uses a wide range of published information, but goes beyond an understanding based on official indicators recorded by government agencies (R&D spending, number of engineers and scientists, patents and publication indices, foreign investment, trade and other statistics), as this data is incomplete and can be misleading.

This study represents a critical evaluation and synthesis of knowledge and information from a wide range of published sources, but also presents fresh data and insights. In so doing, the study attempts to provide a coherent and balanced examination. Furthermore the report elaborates on principal gaps in the available information and points out the need for further research on a wide range of developmental (and other) issues covered.[4]

[4] *A comprehensive report with a broader and more in-depth coverage of economic and high-tech industry developments, North American, European, Chinese, Indian and other corporate development, and specific policy and strategic implications for India and stakeholders world-wide is also being published by the author. See Mitra (2006b) "The rise of India as an economic and R&D power" (forthcoming).*

2 National science and technology development

2.1 Economic development in comparative perspective

Economic and social development catch up

India's share of the world's population is 17 percent, but it accounts for less than 2 percent of the global GDP and only 1 percent of world trade. It lags behind China and other emerging East Asian economies in key indicators, such as per capita income, adult literacy rates, quality of infrastructure endowment and volume of foreign trade and investment. While India is the star performer in Asia in terms of export of software and IT-enabled services, it lags behind in computer and Internet user penetration. ICT diffusion, however, has improved quickly, as demonstrated by the rise in the number of Internet users, from less than one million in 2000 to over 50 million in 2006. This number is projected to reach over 80 million by 2010 (NASSCOM 2006 and Internetworldstats 2006).

A wide range of indicators point to India's potential for catching up. The country's adult literacy rate has risen from 58 percent for men and 31 percent for women in 1985, to 68 percent for men and 45 percent for women in 2000 (World Bank 2006). The ratio of India's population living below the poverty line, as measured by the National Institute of Rural Development, has decreased from 55 percent in 1973–74 to 26 percent in 1999–2000. Moreover, the numbers of engineering students graduating annually have risen from about 44,000 in 1992 to approximately 184,000 in 2004 (NASSCOM 2006), compared to 352,000 for China (China Statistics Yearbook 2004) and 76,000 for the United States (Morgan Stanley 2005). Other estimates claim that India produces about 350,000 engineering graudates per year and that this number will reach 1.4 million by 2015 (Bound 2007).

The demographic profiling of India, with about 54 percent of the population under 25, is favorable to prospects for rapid economic growth. The demography of India points to good prospects for high economic growth for several decades ahead, which is not the case for most advanced industrial economies and China, for example.

The Indian economy is expected to grow at a rapid rate of 6–10 percent between 2007and 2012 and beyond. By the year 2032, China will have the world's largest economy (in terms of GDP at market prices), followed by the U.S. and India, according to the much publicized scenarios presented in the BRIC report released by Goldman Sachs (Goldman Sachs 2003). In terms of purchasing power parity (PPP), India's GDP is already the third largest in the world, behind the U.S. and China. While much of the country is likely to remain poor and industrially backward, other parts have the potential to grow as fast as China or other East Asian economies. Some urban areas are becoming more increasingly integrated within the new global knowledge-based economy, as demonstrated by the cases of Bangalore, Chennai, Delhi, Hyderabad, Kolkata, Mumbai and Pune.

Table 2-1 Population, literacy, R&D, and global integration indicators for selected countries.

	Population	Adult illiteracy	Researchers in R&D	Expenditure on R&D	Trade in goods	Gross foreign investment
	Million	% people aged 15 and above	Per million people	% of GDP	% of GDP	% of GDP
	2004	**2000**	**1996-02**	**1996-02**	**2003**	**2003**
India	1,080	43	120	0.85	21.1	0.8
China	1,296	16	633	1.23	60.1	4.5
Indonesia	218	13	..	..	44.9	1.7
Korea, Rep.	48	2	2,979	2.53	61.6	1.2
Malaysia	25	13	294	0.69	174.8	5.8
Philippines	82	5	..	..	94.3	0.6
Thailand	64	5	289	0.24	109.4	1.7
Brazil	184	..	324	1.04	25.1	2.1
Ireland	4	..	2,315	1.13	95	59.5
Israel	7	..	1,570	5.08	61.6	5.1
Japan	128	..	5,085	3.12	19.9	1.0
Singapore	4	..	4,352	2.15	297.8	18.6
Sweden	9	..	5,171	4.27	61	9.7
United States	294	..	4,526	2.66	18.5	3.0

Source: World Development Indicators (WDI) 2005

.. stands for not available in sources consulted.

** WDI 2006. The World Bank.*

Table 2-2 GNI, telecommunications, PC, Internet density and ICT expenditure for selected countries, 2004.

	GNI* USD Billion US$ Billion	GNI* USD per capita	Main tele-phone lines per 1,000 people	Cellular mobile subscribers per 1,000 people	PCs per 1,000 people	Internet users per 1,000 inhabi-tants	ICT expenditures	
							% of GDP	Per capita USD
India	673.2	620	41	44	12	32	3.8	24
China	1,938.0	1,500	241	258	41	73	4.4	66
Indonesia	248.0	1,140	46	138	12	32	3.1	37
Korea, Rep.	673.1	14,000	542	761	545	657	6.5	924
Malaysia	112.6	4,529	179	587	197	397	6.7	316
Philippines	95.1	1,170	42	404	45	54	6.4	67
Thailand	158.4	2,490	107	430	58	109	3.6	91
Brazil	551.6	3,000	230	357	105	120	6.3	208
Ireland	139.6	34,310	496	929	494	265	3.7	1,653
Israel	118.0	17,360	451	1,090	741	471	7.8	1,349
Japan	4,734.3	37,050	460	716	542	587	7.6	2,732
Singapore	105.0	24,760	440	910	763	571	9.9	2,498
Sweden	322.3	34,840	769	1,034	763	756	7.0	3,370
United States	12,168.5	41,440	563	1,021	749	630	9.0	3,595

Source: World Development Indicators 2006.

** Gross National Income.*

Foreign investment and trade expansion

India has lagged behind the major industrial nations, East Asian and other economies in the growth of foreign direct investment (FDI) and trade over the past decades. India currently trails behind China in FDI and high-tech trade, although official data understates India's position.[5] There are signs that India is picking, up as manifested in ICT-related FDI as well

[5] *A more rigorous examination of the Chinese and Indian foreign investment and high-tech trade development points to underlying differences in the developmental path of the two countries and the fact that there are major weaknesses in the official data as reported by the two countries.*

Official Chinese FDI data is believed to be overstating the real inflows in view of round-tripping of Chinese capital to take advantage of favorable tax treatment of FDI. Indian official figures on FDI inflows have traditionally not followed the IMF's BOP Manual. In India, much investment takes place in companies in the form of reinvestment of local profits by foreign affiliates in the country and there are also inter-corporate debt flows. These flows have not been accounted for in Indian FDI inflow data (Kumar 2005). As of 2006 the Reserve Bank of India does however publish data on FDI which includes reinvested local profits from foreign affiliates in India. It should also be noted that statistics on India's high-tech trade, as reported in international trade statistics, is incomplete and not comparable to Chinese data, one issue being the incomplete coverage of the import and export of software and other high-tech industry trade.

Furthermore, while Chinese data for FDI inflow is higher than for India (even after adjusting for differences in official data) this does not explicate a number of underlying differences such as the larger size of the Chinese economy and foreign trade, as well as the disruption of foreign business operations in China after the communist revolution and the subsequent surge following the introduction of market oriented and open door policy reforms. India in contrast to China has a as in exports and imports. FDI inflows to India have increased, from 5.3 billion dollars in the financial year (FY) 2004/05, to 7.5 billion dollars in FY 2005/06, and are expected to reach 10 billion dollars in FY 2006/07 (RBI 2006 and The Economic Times 2006a).

Furthermore, it should be noted that Indian companies (as well as the Indian diaspora) have begun to emerge as significant investors in North America, Europe, East Asia and elsewhere. The United Kingdom is a prime example of this development. Indian companies' investment in the United Kingdom has increased from a trickle in the late 1990s to a major force in the mid-2000s. Indian companies' nearly doubled their investments in the United Kingdom during 2005-06, thereby becoming the third largest overseas investor in that country. According to the UK Inward Investment Report, Indian companies invested over 1 billion pounds during 2005-06. While ICT remained the dominant sector for UK investments, there has also been strong growth in investment in pharmaceuticals and engineering (The Economic Times 2006c).

Indian companies have indeed begun to emerge generally as more significant international investors. This is shown in their acquisition of software, pharmaceutical and automobile industry related companies in several countries. Some of these investments have had a noteworthy R&D component. Moreover, much of the expansion of foreign and Indian company operations has resulted from strategic alliances, i.e. non-equity-based collaboration for which no official data is available. Rapid expansion of strategic alliances between foreign and Indian companies has been a central ingredient in the development of the Indian software product and services industry.

Furthermore, foreign institutional investment (FII) plays a significant role in India. This reflects India's developed financial and private enterprise system and investor confidence in a wide range of Indian companies. FII inflows to India have risen sharply since 1999, although with significant cyclical fluctuations as noted, for example, in 2005 and 2006. Annual FII inflows exceeded actual FDI inflows to India by a wide margin in FY 2004 and FY 2005 (RBI 2006).

India has emerged as an increasingly prominent destination or foreign investors in the 2000s. According to the Foreign Direct Investment Confidence Index 2005, compiled by A.T. Kearney, China is the most preferred FDI location, followed by India, the U.S. and the U.K. China and India are also the most preferred countries for future R&D investments, with slightly more than 40 percent of CEOs indicating they will likely make such investments over the next three years (A.T. Kearney 2004a and 2005a).

Moreover it should be noted that India is ahead of China in terms of software, and in business and knowledge process outsourcing. India's share of the world market in offshoring of software and IT-enabled services was 25 percent in 2001 (UNCTAD 2004). India has continued to be ranked as the most attractive location for offshoring KPO and IT-enabled services, well ahead of other emerging powers in this field, such as China, Malaysia and the Philippines (A.T. Kearney 2004b and 2005b)

The expansion of foreign investments in India in 2004, 2005 and early 2006 was prominent in most sectors, including infrastructure and energy related areas, automotive components and high-tech industry production and R&D. According to Mr. Dayanidhi Maran, India's Minister of Communication and Information Technology, planned FDI in the ICT sector in

continuous history of FDI as well as strategic alliances between local and foreign companies (Mitra 2007).

the next 3–4 years, as announced by companies in 2005, amount to over 9 billion dollars; a dramatic increase over previous years (Business India 2006).

Historical and comparative understanding required

Perceptions about India are often varied, reflecting the countries great diversity and varied views among different stakeholders, deficiencies in existing data and understanding of long term historical development processes. As pointed out in the introduction, attempts to benchmark India's social, economic and S&T development based on readily available official statistics can be useful but often proves to be erroneous or inadequate. Benchmarking limited to international comparisons of per capita indicators of income, education attainments, R&D expenditure, number of patents etc. does not suffice to access R&D development and potential. They can be deceptive unless they are supplemented with more in-depth, holistic and historical perspectives.

A balanced assessment of India's economic and S&T development performance must be based on in-depth dynamic understanding of how development takes place over time. India continues to lag behind Western and East Asian countries in social and economic spheres, especially if benchmarked against per capita indicators. It is however essential to take note of the fact that there have been major improvements in social and economic development indicators since India gained its independence in 1947. It can indeed be argued that India's advancement has been faster than was the case when continental European countries were transformed into modern industrial economies. It is important not to forget that it took Western countries hundreds of years to reach their contemporary stronghold in higher education and R&D, to establish a modern physical infrastructure, governmental and legal frameworks and institutions. It also took them a long time to find solutions to the problems of urban congestion, pollution, social disparities and disruption resulting from transformations into modern industrial economies.

Moreover the following have to be kept in mind in understanding the scale and scope of India's economic and S&T related developments (Mitra 2007):

- *Absolute size matters*. A singular focus on per capita numbers implies a risk of missing the point that much of India's comparative advantage in economic development, and R&D in particular, relates to the large absolute size of its economy, the size of its pool of educated labour, entrepreneurs and the scale and broad scope of competency represented in its education and R&D-related institutions. In a large country like India absolute numbers are often very large even though the country tends to lag behind in international comparisons limited to per capita statistics. On the other hand, comparisons singularly focusing on absolute numbers, e.g. number of graduates, size of the population, etc. can also be misleading because of failure to sufficiently acknowledge social and economic disparities, or uneven development, as well as general issues relating to quality of infrastructure, healthcare and education, for example.
- *Uneven economic development implies scope for catch up.* Low per capita indicators, social disparities and uneven economic development more generally, points not only to risks associated with having major socio-economic disparities within a country, it is also an indicator of the scope for catch up. This applies to improving, for example, quantity and quality in health services, education and R&D-related infrastructures. Moreover, rapid development in certain states or cities demonstrates effects that can provide positive impetus to those lagging behind.

- *Comparing large countries with small nations, or more homogeneous and greatly heterogeneous countries, can be misleading*. India is a continent. The country is culturally more diverse than Western Europe or North America and has a population comparable to South America and Africa combined. Hence it is natural that its social and economic development is varied. Social and economic development indicators in some parts of India are comparable to that of Sub-Saharan African countries. In other parts, however, the economic performance since the 1980s has been comparable with fast growing East Asian regions. Some areas of India have done as well, or even better, than star performers in high technology industrial development in most East Asian emerging market economies. Bangalore's development (and several other Indian cities) since 1990 points to the potential for India to develop high-tech industry centers; one important factor being the scope to draw from a large and geographically mobile pool of human resources and rich sets of R&D institutions and development of knowledge-based traditions and networks including those involving foreign and Indian companies, education and research institutions (Mitra 2007).

2.2 Higher education, R&D institutions and access to networks

Claims that India can be a major R&D or knowledge-based industry economic power are often based on judgments of Indian strengths in human and institutional capabilities, as well as on ICT-enabled access to international and local information and other networks.

The principal factors pointing to India's potential to be a major R&D power are the size of its educated workforce, entrepreneurial traditions and a significant existing R&D-related institutional infrastructure. On the whole India has made major advancements in all of these areas over the past decades. Assessing these advancements (as well as prevailing deficiencies) and comparing them to developments in other countries is however hampered by weakness in both quantitative and qualitative information. Even official sources sometimes give completely disparate numbers for important parameters such as, for example, the number of graduates in India.[6]

As of 2006, India and China both had larger pools of educated human resources, including engineers and numbers of new science graduates, than any other country in the world (Mitra 2007). India has invested much in expanding its higher education and R&D institutions since the 1950s. From the 1990s these efforts have begun to yield major payoffs, as illustrated by the high-tech industry developments in India and the role of the Indian diaspora in, for example, Canada, the UK, and the U.S.

India's education and research system is however diverse and ranges from internationally competitive institutions to those with inferior performances. The country's pool of young

[6] *"The 1991 Census, for instance, says that India had a total of 20.5 million graduates. Yet, two years later, the National Sample Survey (NSS) said there were 19.8 million graduates in 1993-94. For the same year, the Institute of Applied Manpower Research (IAMR), which collects data on enrolment from each institution, as opposed to the Census and the NSS that collect data at the household level, reported the number of graduates as being even fewer, at 17.6 million. For 1991, the year in which the Census said there were 20.5 million graduates, IAMR put the figure at 15.6 million, or nearly a fourth less. Not surprisingly, more detailed information such as the number of students who have graduated in science subjects is a lot less reliable. In any case, sources like the NSS and the Census do not even attempt to capture such data, leaving it to institutions like IAMR and the University Grants Commission (UGC) to collect information from individual colleges/universities" (Shukla 2005).*

university graduates (those with seven years or less of work experience) is estimated at 14 million. This is 1.5 times the size of China's, almost twice that of the U.S., and is topped up by 2.5 million new graduates every year (Farrell et al. 2005). The number of highly qualified engineering Masters- and Ph.D-level researchers is however not so large if compared to major industrial nations. India produces only about 6,000 Ph.D's annually. It should however be noted that a large number of individuals of Indian origin receive higher level education and training overseas. The IT and IT-enabled services sector has led the growth in technical human resource demands since the 1990s. The number of professionals employed in the IT and IT-enabled services industry has grown from 51,000 in 1990 to about 1.3 million in 2006 (NASSCOM 2006).

These types of observations must however be critically evaluated and put into a long-term development perspective. On a per capita basis, the number of people with higher education in India, including engineers and scientists, is still low compared to major industrial economies and countries such as Poland, Brazil, China and Russia. This point to scope for increasing the number of people with higher education. India indeed has a key advantage in the absolute number of people with a higher education. In addition, the number of people with relevant higher education, training and professional experience is increasing exponentially.

The number of people enrolled in higher education continues to increase but there are major outstanding issues in the rate of expansion as well as the relevance and quality of education and training programs. Much also remains to be done to improve literary and higher education among lower caste people, tribal communities and women**.**

Box: Education and R&D-related opportunities for women are expanding

The developments, especially in recent years, in higher-level education, as well as in software, business and knowledge processing industries have offered many professional opportunities, not only for men but also for women in India, as well as in other countries. Literacy rate, as well as the number of women in India pursuing higher education, is increasing, although still generally lags behind that of their male counterparts. Furthermore, males tend to dominate the high paying and top managerial jobs. There is however a clearly discernible pattern wherein women are playing increasingly important roles professionally at all levels in Indian society.

Rapid development of the high-technology industry, including the hiring of highly educated and skilled individuals by foreign multinationals and Indian companies, has resulted in shortages in certain areas of expertise. Only between 10 to 25 percent of India's graduates are considered suitable for employment by multinational corporations (Farrell et al. 2005). Many Indian companies are facing similar constrains. In addition, there is considerable room for improvement in ensuring that those with relevant higher education, talent and professional experience are employed in ways such that their abilities are effectively utilized.

The Indian government has traditionally had the major role in education and R&D institutional capability building. It has given priority to the provision of heavily subsidized higher education and the establishment of a large number of research institutions within the public sector. The effectiveness of these efforts has been mixed, but has improved in several areas.

The Indian government has made major investments in establishing higher education institutions. The number of graduates has expanded, but the quality of education varies significantly, as reflected in the fact that India has a very large and multi-tiered educational system. Large parts of this system are lagging behind in curriculum development and teaching and examination standards. The country also has a number of elite institutions, however, whose graduates are well-acknowledged in India, as well as internationally. They include IIT (Indian Institute of Technology), IIM (Indian Institute of Management) and IISc (Indian Institute of Science). The student intakes and numbers of such premier institutions have expanded gradually, although not at a pace commensurate with demand. Furthermore, there has been a rapid expansion in private sector training, education and research institutions, especially since the 1990s.

Despite a large number of graduates going through higher education institutions in India, the research output from academic institutions has, barring prime institutions and individual accomplishments, generally been limited. Typically students as well as faculties concentrate on teaching, while the time devoted to quality research often lags behind internationally.

Much of the education system continues to be dominated by the public sector. It is however important to note that private institutions have begun to play a more significant role in higher education, training and research since the 1990s. Growth in many of these areas is today led by the private sector. This is illustrated by the rapid growth in education and training, especially in software and IT-enabled services and in business administration. The roles of the private sector, public-private sector partnerships and international collaborations in education and R&D are gradually becoming more important and may in the long term imply a major transformation of the higher education and R&D system in India.

Moreover, it could be noted that R&D labs and library facilities are often poor if compared to that of Western, as well as many East Asian, countries. The Internet, however, has opened up access to data, information and knowledge, and has facilitated global networking among academic and corporate groups. This increased level of access has led to a major scope-shift for India (and other less developed areas), in now playing a more prominent role in R&D.

Box: Public sector education system governing

Higher education in India has evolved in divergent and distinct streams with each stream monitored by an apex body, indirectly controlled by the Ministry of Human Resource Development. The state governments mostly fund the universities. There are 18 universities however, called the Central universities (as on 31st March 2007), which are maintained by the Union Government and, because of relatively large funding, they have an economic edge over the others.

The engineering colleges and business schools in the country are monitored and accredited by the All India Council for Technical Education (AICTE) while medical colleges are monitored and accredited by the Medical Council of India (MCI). The National Council for Teacher Education (NCTE) was constituted a couple of years ago to monitor, organize and accredit all the teacher-training institutions in the country, and this apex body has started to make its presence felt. Apart from these, the country has some a large number of engineering, management and medical education institutions that are directly funded by the Union Government

Professional Councils are responsible for the recognition of courses, promotion of professional institutions and provision of grants to undergraduate programs and various awards.

The statutory professional councils are the All India Council for Technical Education (AICTE), Distance Education Council (DEC), Indian Council for Agriculture Research (ICAR), Bar Council of India (BCI), National Council for Teacher Education (NCTE), Rehabilitation Council of India (RCI), Medical Council of India (MCI), Pharmacy Council of India (PCI), Indian Nursing Council (INC), Dentist Council of India (DCI), Central Council of Homoeopathy (CCH) and Central Council of Indian Medicine (CCIM).

The Central Government is responsible for major policies relating to higher education in the country. It provides grants to the UGC and establishes central universities in the country. The Central Government is also responsible for the declaration of Educational Institutions as 'Deemed to be University' on the recommendation of the UGC.

University education. The University Grants Commission (UGC) is the apex body of the university system in the country and was established by an Act of Parliament in 1956. Its function is to fund, co-ordinate, monitor, and maintain the Constitutional mandate of co-ordination, determination, and maintenance of standards of teaching, examination, and research in the field of University and Higher Education. UGC serves as a vital link between the Union and State Governments and the institutions of higher learning. The Central Universities are completely funded by the University Grants Commission, while the state-level universities are partly funded by it. The major funds for the state university come from the respective government of the state to which it belongs.

Educational policy. So far two national educational policies (NPE) have been formulated by the Central Government – one in 1968 and the other in 1986. NPE 1986 was further modified in 1992. In NPE 1968, the stress was on quality improvement, a planned, more equitable expansion of educational facilities and the need to focus on the education of girls. The NPE 1986 provides for a comprehensive policy framework for the development of education up to the end of the century and a Plan of Action (PoA) 1992, assigning specific responsibilities for organizing, implementing, and financing its proposals. The National Assessment & Accreditation Council (NAAC) has been set up to assess their performance vis-a-vis set parameters. NAAC is a rating agency for academic excellence across India, and the country's first such effort.

Governance of higher education institutions. The Universities are of various kinds: single faculty or multi-faculty; teaching or affiliated, or teaching-cum-affiliated; single campus or multiple campus, and so on. Most Universities are affiliated universities, which prescribe to the affiliated colleges the course of study, hold examinations and award degrees, while undergraduate, and to some extent postgraduate colleges affiliated to them impart graduate instruction. Many of the universities, along with their affiliated colleges have grown rapidly in many parts the country to the extent of becoming unmanageable. Therefore, as per National Policy on Education, 1986, a scheme of autonomous colleges was promoted. In the case of autonomous colleges, whereas the degree continues to be awarded by the University, the name of the college is also included. The colleges develop and propose new study courses to the universities for approval. They are also fully responsible for conducting examinations. There are at present 126 autonomous colleges in the country.

Source: Abstracted from Shukla (2005).

2.3 R&D spending and funding

India's R&D expenditure is still low compared to major industrial economies, in dollar terms, on a per capita basis and in terms of its ratio to GDP (about 0.8 percent of GDP in 2005 according to official estimates). These figures can, however be misleading. India's official data excludes much corporate and internationally funded R&D activity. International comparisons at market prices are also deceptive. One dollar equivalent spent on R&D in India results in an output many times larger than the same amount spent in high cost economies. Indian R&D spending levels are indeed substantial on a purchasing power parity (PPP) basis. Adjusting data on R&D expenditure to differences in purchasing power is, however, a complex affair (NSF 2006). According to UNESCO data, India's R&D expenditure has increased from 10 billion dollars in 1996 to 20 billion dollars in 2000, making it the seventh largest country, in that year, for gross domestic expenditure on R&D (GERD) measured at PPP. China was the fourth largest country with R&D expenditure, estimated at 49 billion dollars in 2000 (UNESCO 2005).[7]

On the other hand, a large share of government R&D outlays in India is not utilized effectively, especially compared to spending in the private sector. One example of this is the fact that a large number of so-called scientists in government research labs do no, or little, actual R&D.

Moreover, it should be noted that the pattern of financing R&D operations has begun to change significantly since the late 1990s. One major development is increased access to local and international private financing for R&D, including funding from multinational companies and the emergence of more significant foreign venture capital industry activities (Dossani and Kenney 2001). The government has gradually placed more importance on efforts to develop venture capital (VC) funding avenues. Lately, this has been illustrated by the fact that the Planning Commission of the Government of India has established as special committee that has provided recommendations for facilitating venture capital for promoting new technology ventures. It is expected that implementation of the Commissions recommendations would lead to an increased flow of VC funds for commercialization of technology ventures, particularly those emanating from incubation centers at universities and R&D centers (Planning Commission, Government of India 2006).

2.4 Patents, publications and commercialized intellectual property

Compared to major industrial nations India has been lagging behind in numbers of patents and in the output of internationally acknowledged scientific publications. There are however important indications of progress in this regard, as is clearly manifested in raised R&D output from multinational companies and the Indian diaspora, for example. Moreover, it should be noted that improvements in industrial production through absorption of existing technology and improvement in industrial production and organizational and other efficiency gains are key factors driving increased competitiveness in goods and services sector in India. These developments are not reflected in analysis limited to patents and the scientic publication record.

The analysis of inputs and outputs of knowledge or R&D in India is hampered by weaknesses in information on corporate R&D and innovation. Key examples are tacit knowl-

[7] *China's GERD at PPP was 72 billion dollars in 2002 (UNESCO) and continued to rise rapidly in the 2003-2006 period; a trend which is likely to continue for several years to come (Mitra 2007).*

edge as well as the country's rich assets of un-codified, indigenous knowledge and formal, as well as informal, networks and innovation in business processes and entrepreneurship.

Making a balanced assessment of the outputs from India's national innovation system is perhaps even more difficult than assessing its inputs. The numbers of filed patents and internationally acknowledged scientific publications from India are still small despite the country's large pool of graduates and academic faculty. In addition, India receives very little in worldwide royalty and license fee payments.

India's number of patents and publications does not fully reflect R&D and innovation capabilities however. In the India-specific context, several factors have hampered incentives to file for patents and to publish in foreign academic journals. Filing for patents is, in many quarters, considered complicated and expensive, even when innovation capabilities are present. Academic faculties and scientists have traditionally had secure jobs with more-or-less guaranteed promotion, providing less incentive to publish than in more competitive environments. Most R&D in the corporate sector is in development rather than research, and applied development work typically does not result in scientific contributions. In addition, mass-scale KPO work, while often related to science, does not generally produce scientific publications or patents (Mitra 2007).

The number of cited scientific research publications from India has increased significantly since the mid 1990s, although not to the same extent as for China (NSF 2006 and Department of the Navy 2006).

Furthermore, there has been a significant increase in the number of India-related patentable innovations since the early 1990s. New patent registrations, patents granted to the international R&D companies operating in the country and number of Indian patentees are some of the indicators that show significant growth (Bowonder et al. 2006). The number of patents granted by the United States Patent and Trademark Office (USPTO) to North American and European owned R&D establishments has increased rapidly since the late 1990s. An increasing trend is also discernable in the number of patents granted by the Indian Patent Office (Patent Facilitating Center, TIFAC 2006). There has also been rapid growth in the patent applications filed in the United States from inventors of Asian origin, namely Israel, South Korea, Taiwan and subsequently also from China and India. In 2003, inventors from India filed almost 1,200 U.S. patent applications, up from 58 in 1990; and inventors from China filed 1,034 U.S. patent applications, up from 111 in 1990 (NSF 2006).[8]

While still lagging behind industrial economies, India has experienced an increase in terms of patents and publications since the 1990s. Gradually the national innovation system has provided greater incentives to undertake work that can result in patents and publications. Both Indian and foreign companies are playing a major role, but much of their activities are still not fully reflected in the published statistics. Moreover, patent-based indicators provide a measure of the output of a country's R&D, i.e. its inventions. The methodology used however can influence the results. Simple counts of patents filed at an intellectual property office are affected by various kinds of bias, such as weaknesses in international comparability (home advantage for patent applications) and highly heterogeneous patent values (OECD 2005).

[8] *An analysis based on an OECD patents indicator called triadic patent families (indicator designed to capture all important inventions and to be internationally comparable) broadly confirms that India is still lagging behind in terms of patents, but that the number of triadic patent family patents for India is growing, although not quite as rapidly as in the case of China (OECD 2005).*

The Indian-based R&D centers of companies such as Texas Instruments, General Electric, IBM, Hewlett-Packard, Hoechst, Intel, Cypress Semiconductors, ST Microsystems and Unilever have contributed significantly to a sharp rise in patent filings from India in the 2000s. Major Indian firms that showed an increase in patents granted in the first half of the 2000s include CSIR, Ranbaxy, Dabur, Dr. Reddys Research Foundation, Orchid Pharmaceuticals, Biocon, Torrent Pharmaceuticals, Aurobindo Pharma and Wockhardt limited (Bowonder et al. 2006).

Looking ahead, the number of Indian patents granted by the USPTO, the European Patent office (EPO) and the Indian Patent Office is poised to expand significantly. Furthermore, industry analysts expect a significant expansion of competition and collaboration between the Indian and foreign R&D entities. Several Indian universities are also strengthening R&D programs. Overall, India's record in patents and internationally acknowledged scientific publications is likely to improve significantly over the next 5 years and beyond (Mitra 2007).

Finally, it should be noted that the number of patents and academic publications originating from Indian nationals working overseas is significantly larger than that coming from Indian-based R&D activities and is poised to continue to grow (Mitra 2007).

2.5 Innovation in business organization and entrepreneurship

The corporate sector in India remains highly diverse in corporate governance practices, degrees of internationalization, technology, innovation and general performance. It consists of long standing well established companies such as the Tata Group, Mahindra & Mahindra Ltd. and new internationally competitive firms specializing in software, pharmaceuticals, finance and other sectors which now are making major efforts to become international players by expanding subsidiaries overseas, placing greater efforts in rapid absorption of new technology and making in-house R&D investments. Moreover, India has a large number of companies (SMEs and others) which or have limited interest in or are unable to face international competition and which have no significant R&D activities.

Several Indian companies are now at par with foreign subsidiaries in terms of management performance while others typically lag behind in governance and other corporate performance indicators. Much of India's corporate sectors have, however, gradually become more internationally competitive, and hence dynamic, in adapting new technology solutions and management practices. Major efficiency improvements have taken place in industrial organization systems much of India's goods and services industries since the 1990s.

The rise of "new sets" of Indian corporate images is illustrated by the emergence of several Indian companies capable of meeting high quality standards and being cost-competitive. The examples of Infosys Technology Limited (a leading exporter of software services) and Bharti Telecom Limited (a leading domestic low-cost telecommunication services provider) point to innovations in business processes and phamaceptial companies such as Ranbaxy. Companies such as Infosys also represent important role models for a new generation of Indian private entrepreneurship and international class corporate governance (Khanna and Palepu 2001). These and several other newer, as well as older, Indian corporate success stories (the Tata Group for example) point to the argument that Indian corporate and offshoring developments illustrate a shift in the global business environment in which India can play a major role in both goods and services sectors, spearheaded by business organization and entrepreneurship dynamism and innovation coupled with increasing emphasis on investing in R&D.

2.6 National S&T development phases and economic reforms

India's S&T achievements date back to the ancient times. Furthermore, during the British Raj world class educational institutions were established in major Indian cities. Many Indians played key roles in local R&D as well as outside of India; for example in engineering work in British colonies. After independence, the first Prime Minister, Jawaharlal Nehru stressed the need to invest in higher education and research.

R&D aimed at serving local requirements has a long tradition in India, stemming back to Nehru's policies emphasizing nation-building and self-reliance. Starting with the period of economic liberalization in the 1990s, there has been a shift in the Indian S&T landscape and corporate-led R&D operations have become increasingly important.

From the early 1990s, the Indian economy has significantly opened up to foreign trade and investment. Indian companies have thus been forced to be more proactive in keeping up with new technologies to maintain their competitiveness in the local market and to compete globally. There has been a major change in the strategic mindset of large Indian industrial conglomerates. In addition, a new breed of smaller and medium size entrepreneurs who are inclined to think and act more internationally are playing key roles in vitalizing the Indian economy. Perhaps the most significant examples of the latter are the dynamic expansions of India's software, telecommunication and BPO-KPO industries. The development in these sectors has served as a catalyst to connect India globally (Mitra 2007).

The greater reliance on market forces and thereby associated increased exposure to international competition and technology developments have induced a pattern of economic development which is more supportive of commercially oriented R&D in ICT, the manufacturing industry and in other areas.

As noted by Rishikesha Krishnan, the impact of economic liberalization on innovation in the rest of the economy has, however, been mixed: *"In the two-wheeler and pharmaceutical industries, regulatory changes, demand conditions, competitive forces and entrepreneurial initiative have resulted in the development of innovative capabilities, as reflected in a number of successful products. Government support and links with government research laboratories have facilitated the process of innovation in the pharmaceutical industry. In many other industries however, changes in the innovation profile have been limited"* (Krishnan 2003).

Much of the growth in the software and knowledge processing industry has come from external demand. In many (but not all) instances, this has implied that spillovers in terms of locally oriented demand and innovation system developments have been limited.

2.7 S&T policies, incentives and intellectual property rights

Government policies and incentives more conducive to R&D

Three major S&T policy statements have been adopted since India gained its independence: the Science Policy Resolution of 1958, the Technology Policy Statement of 1983, and the Science and Technology Policy of 2003. The Technology Information Forecasting and Assessment Council (TIFAC) have also undertaken a comprehensive technology foresight exercise under the leadership of Abdul Kalam and Y.S. Rajan. This was termed *Vi-*

sion 2020 and a summary of the exercise has been published. This helped various agencies to have a unified vision about the future trajectories for economic and technological development (Kalam A.P.J. Abdul and Y.S. Rajan 2003).

In the S&T Policy launched in 2003 the Indian government recognized the inevitability of the globalization and liberalization processes of the Indian economy. The S&T Policy from 2003 articulated new policy directions. It did however not include a full-fledged operations action plan to implement its policy statements. Among other things, its policy statements articulated the need for reconstruction of the academic scientific system, technology development through appropriate reward mechanisms; measures to increase the active involvement of industry in both basic and applied research, generation and management of intellectual property (Bowonder et al. 2003 and 2006).

The S&T Policy from 2003 points out the need for examining efficient funding mechanisms for S&T development. It points to the need for either new structures to be created or the existing ones restructured and strengthened, to promote basic research in science, medical and engineering institutions. It also stresses the need to facilitate value-driven export of technologies and technology-led exports and the need for intensive networking of capabilities and facilities within the country. It also emphasized the necessity to strengthen international collaborative programs, and participation in international mega science projects, in order to encourage basic research in academic institutions and laboratories.

In addition, economic liberalization policies pursued since the 1990s have fostered competition and internationalization. Important reforms in a number of areas have contributed to accelerated growth in foreign trade and investment, including R&D related activities. These reforms include the tax regime, liberalization of foreign ownership and exchange regulations, and improvements in industrial and other regulatory frameworks and the intellectual property rights regime. The Indian government has also launched a wide range of initiatives targeted at specific industries such as software, electronic hardware and telecom, biotechnology-pharmaceuticals and the automotive industry. This is illustrated by special incentives announced in the Union Budget for 2005-06, namely:[9]

- A tax deduction of 150 percent on in-house R&D expenditure in the automotive sector.
- Zero custom duty on items bound under the IT agreement for the software sector.
- Increase in telecom FDI equity stake limits from 49 percent to 74 percent.
- Corporate tax for pharmaceutical companies reduced from 35 to 30 percent, and exemption for 100 percent deduction of profits of pharmaceutical companies carrying out R&D (Ministry of Finance 2005).

[9] *The Union Budget for 2006-2007 included some further R&D sector-specific measures. For example, as noted in the budget, the National S&T Entrepreneurship Board has set up a number of Technology Business Incubators with seed funding from the Technology Development Board. The government has expressed that it would be happy to provide enabling concessions to the incubator-entrepreneurs.*

Table 2-3 The changing scenario for pharmaceutical R&D in India.

Earlier	**Now**
Lack of intellectual property (IP) protection	India has adopted the IP regime formulated by the World Trade Organization (WTO) in 2005.
MNCs – restricted* from undertaking research on New Chemical Entities (NCE) in India	Regulations* on NCE have been relaxed. Leading MNCs such as Pfizer and Eli Lilly have started research on NCEs in India.
Good Clinical Practices (GCP) compliance not mandatory	Adherence to GCP guidelines has been made mandatory since December 2001
Government imposed high customs duties on the import of clinical trial samples	Custom duties have been waived on clinical trial samples. The government is also offering other financial incentives for R&D investment.
Schedule Y and the resultant 'Phase lag' Permission for clinical trials given for one phase behind the status in the rest of the world Only limited trials on about 100 patients required for new drug introduction	Proposed amendment to Schedule Y allowing parallel phase clinical trials in India.

Source: Evalueserve Analysis as presented in FICCI (2005).

*Authors note: * Not legal restrictions to undertake R&D.*

Intellectual property rights regime strengthened

Since 2003, the Indian parliament has passed a series of laws protecting intellectual property rights (IPRs). In 2005, it passed a patent regime that is compliant with World Trade Organization (WTO) standards. The legislation is aimed particularly at pharmaceutical manufacturers, but has also raised confidence that other industries will receive protection.

India's intellectual property rights regime has improved significantly with legislation having changed significantly since the mid-1990s. In 1994, the Indian Copyright Act was amended to clearly explain the rights of a copyright holder and the penalties for infringement of copyrighted software. The 2005 amendments to the Indian Patent Act were amended to adhere to the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement. These developments have boosted the confidence among international players in seeking R&D locations in India and to seek Indian patents for their innovations. The new patent legislation has expanded product patent coverage to include pharmaceuticals and agro-chemicals.

It is well acknowledged that India's IRP legislation has improved and fares well compared to most other developing countries. Major Indian software and pharmaceutical companies (Biocon, Dr. Ready's Lab, Ranbaxy and others) leveraged growth opportunities by means of compliance with new patents laws. Some stakeholders, such as multinational corporations, have however continued to press for further improvement in IPR protection due to what they perceive to be inadequate laws and ineffective enforcement. Key concerns include security, data protection, limitations of the patent act and its enforcement in industry and the consumer mass market (e.g. piracy of standard software and the need for strong enforcement of IPR laws and greater publishing of police raids and other enforcement measures).

United States Trade Representative (USTR) has retained India in its 'Special 301' watch list of 48 countries on the grounds of inadequate IRP protection. The USTR have continued to argue that India should improve its IPR regime by providing stronger protection for copyright, trademarks and patents, as well as protection against unfair commercial use of undisclosed test and other data submitted by pharmaceutical companies seeking marketing approval for their products (USTR 2006).

The USTR argues that India should be encouraged to join and implement the World Intellectual Property Organization (WIPO) Internet Treaties. Moreover, it argues that India's patent protection regime improved when it passed the amended patent law in 2005 to provide for product patents for pharmaceuticals and agricultural chemicals. While this was a positive step, the new legislation has omissions that detract from India's patent regime. Furthermore the report states that India's copyright laws and enforcement system are weak. Piracy of copyrighted works remains rampant, particularly for software, films, popular fiction works, textbooks, and cable signals. Although the Government of India has pledged to improve its trademark regime, foreign trademark owners experience difficulties due to procedural barriers and delays. India's criminal IPR enforcement regime remains weak, with improvements most needed in the areas of border enforcement against counterfeit and pirated goods, police action against pirates and counterfeiters, judicial dispositions resulting in convictions for copyright and trademark infringement, and the imposition of deterrent sentences (USTR 2006).

The US-India CEOs Forum has put forward a number of proposed initiatives to strengthen India's IRP regime. They include the following areas:

- National coordination of IPR enforcement efforts in India must be stepped up. Today, enforcement is handled at the state level, and the results vary dramatically. Many of the specialized police units set up by the states are barely active and lack training, manpower and resources.
- Specialized intellectual property courts should be established to handle both civil and criminal matters.
- A national initiative to crack down on piracy in the educational and research sectors should begin now.
- India and the U.S. must reach agreement on Cyber Security to include data privacy, IPR, etc. and create universal standards in data privacy to build confidence in Indian IT providers (US-India CEO Forum 2006).

According to the US-India CEOs Forum, the goal should be a national unit dedicated to IPR enforcement and with powers of enforcement across state borders. As a first step, a single centralized body should be designated to coordinate IPR enforcement efforts, identify and publicize best enforcement practices at the state level and direct national resources to IPR enforcement (US-India CEO Forum 2006).

Box: India's patent ordinance as of 2005

The new ordinance amending the Indian Patents Act of 1970 came into effect on 1 January 2005. India now conforms to the TRIPS Agreement of the WTO. India's previous Patent Act had not allowed product patents in drugs, food and chemicals, but only process patents in these fields for up to seven years. The most significant changes brought about by the new ordinance are as follows:

- It extends product patents for all fields of technology, including medicine, food and chemicals, offering 20 years' protection. The ordinance eliminates exclusive marketing rights (EMRs), which were providing patent-like protection without the grant of patents. It also allows for the patenting of software that has a technical application; thus, embedded software can now be patented.
- It provides that 'mere new use' for a known substance cannot be patented.
- It also strengthens patent opposition proceedings by allowing for both pre-grant and post-grant opposition. The processing time limits for examination of patents have also been reduced from 48 to 36 months.
- It has a provision for granting compulsory licenses for the export of medicines to countries that have insufficient or no manufacturing capacity, to meet emergent public health situations (in accordance with the Doha Declaration on TRIPS and Public Health). This means that Indian companies will be able to produce and export AIDS drugs to African and South-East Asian countries.
- An additional modification is the introduction of a provision making patent rights for mailbox applications available only from the date of granting the patent and not retrospectively from the date of publication. This will save many Indian companies from being attacked for infringement of patent law by multinational companies which might otherwise have obtained patents for drugs that Indian companies had already put on the market.
- There are also concerns that the domestic pharmaceutical and agricultural sectors will be affected, as the new ordinance will make it possible for multinational corporations to dominate the Indian economy. 97 percent of all drugs manufactured in India however are off-patent and so will remain unaffected. These include all life-saving drugs, as well as medicines for daily use to treat common aliments.
- The ordinance also has a provision for outright acquisition of the patent to meet national requirements.

Note: The patent ordinance from 2005 differs in some parts from the patent act subsequently passed by the parliament. Source: Adapted from Unesco 2005.

Original source: http://iplg.com/resources/articles/india_new_patent_ordinance.html.

2.8 The multi-layered organization of India's S&T system

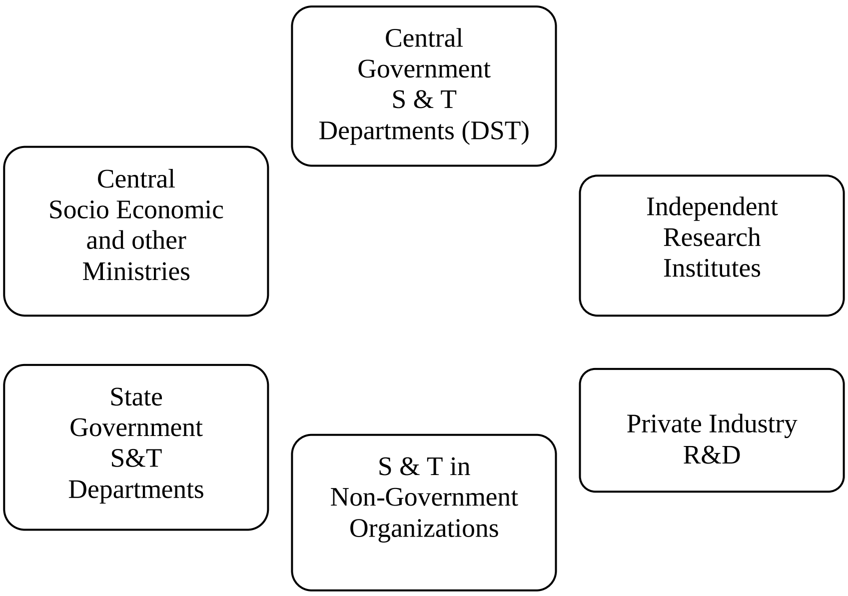
The system for science and science administration is complex and multi-layered. It consists of governmental agencies, autonomous institutions, university systems and industrial R&D, in both the public and private sector. In broad terms the S&T system can be classified into the following categories:

- Central government S&T departments/agencies,
- State government S&T departments,
- Central government socio-economic ministries,
- R&D in private industry, S&T in non-governmental organizations, and
- Independent research institutes.

The S&T departments functioning under the auspices of Central Government are: the Department of Science and Technology (DST), the Department of Scientific & Industrial Research (DSIR), the Department of Atomic Energy (DAE), the Department of Space (DoS), the Department of Biotechnology (DBT) and the Department of Ocean Development (DOD).

Furthermore, the central government has established the Technology Information, Forecasting & Assessment Council (TIFAC), an autonomous organization under the Department of Science and Technology with the aim of keeping a technology watch on global trends and formulating preferred technology options for India.[10]

Figure 2.1 India's science and technology system.



Source: Department of Science and Technology 2006.

[10]. The TIFAC was established with the following objectives: (i) to undertake technology assessment and forecasting studies in selected areas of national economy, (ii) to watch global trends and formulate preferred options for India, (iii) to promote key technologies, and (iv) to provide information on technologies. Its role also includes a special patent facilitating center.

Box: The role of the Department of Science and Technology

The Ministry of Science and Technology established the Department of Science and Technology (DST) in 1971 to promote S&T in the country by organizing and coordinating various S&T activities. The department acts as a central agency, coordinating various programs including the following:

- Formulating policies on S&T.
- Providing support for basic and applied research in national Institutions throughout the country.
- Facilitating international cooperation by the establishment of joint R&D ventures.
- Promoting socially oriented S&T intervention in rural areas and creating employment opportunities.
- Providing meteorological services for agriculture, water resources management, disaster warning, civil aviation and also providing seism city data through the India Meteorological Department.

DST has a variety of programs, aimed at research for the development of society. Some of these programs include S&T applications for rural development and weaker sections of society, tribal sub-plans, special component plans for development, science communication and popularization, state S&T programs, and the utilization of the scientific expertise of retired scientists. The DST also conducts numerous programs for the empowerment of women.

The S&T International Cooperation Division of the DST deals with international scientific and technological affairs, including the negotiations and implementation of bilateral and multilateral S&T cooperation agreements. The government efforts in international R&D collaboration has gradually become increasingy ambitios as reflected in bilateral, regional and multinateral collaboration agreements which now also includes efforts to promote industrial R&D collaboration. As of 2006, India had bilateral S&T cooperation agreements with over 63 countries (see further appendix).

The examples of major wide-ranging S&T policy related developments in recent years include the establishment of the Knowledge Commission, private industry associations (NASSCOM, CII and others) and various academic and public-private sector partnership initiatives.

2.9 The diverse range of public sector R&D undertakings

The central government has been the major investor in higher education as well as in R&D in the country since the 1950s, as noted earlier. It has established a diverse set of R&D institutions. The government's commitment to spending on R&D is reflected in its budget allocation for the Department of Science and Technology (DST). The department's budget is 17,750 billion rupees for the fiscal year 2007-2008 (appr. 4.3 billion USD) compared with 11,770 billion rupees for the year 2006-2007 (www.indiabudget.nic.in/ub2007-08/eb/vol1.htm).

Public sector R&D has been carried out by different government entities, and the prime examples are the Council of Scientific and Industrial Research (CSIR), the India Council of Applied Agricultural Research, the Indian Council of Medical Research (ICMR), as well as public enterprises and the universities. In addition, R&D is conducted by many laboratories in departments and ministries, such as those concerned with atomic energy, electronics, space, ocean development, defense, environmental and non-conventional energy sources. The CSIR and the DST, part of the Ministry of Science and Technology and universities, are the premier organizations that support and carry out R&D in the country (CSIR 2005 and 2006).

The DST is primarily entrusted with the responsibility for the formulation of S&T policies and their implementation, identification and promoting thrust areas of research in different sectors of S&T; technology information, forecasting and assessment; international collaboration, promotion of science & society programs and coordination of S&T activities in the country.

The Council of Scientific and Industrial Research (CSIR), with its 40 institutes dedicated to research and development in well defined areas (and around 100 field stations), is the major organization under the DSIR. Other major programs of the DSIR include support to R&D by industry, programs aimed at technological self-reliance, schemes to enhance efficacy of transfer of technology and a National Information System for Science and Technology (NISSAT).

The DAE, the main aim of which is to pursue efforts for peaceful uses of atomic energy, is mainly engaged in establishing the production of safe, economical nuclear power, using the country's resources of uranium and thorium. It also extends non-power applications of nuclear energy in agriculture, healthcare and industry, to improve the quality of life. It builds research reactors and develops technologies related to accelerators and lasers and supports basic research in areas related to nuclear energy and other frontier areas of science, through its well equipped multi-disciplinary R&D Centers.

The DoS operates through a major set-up, the Indian Space Research Organization, which is responsible for planning and executing a viable space program for developing satellites and launch systems and provides space-based services in the areas of communication, meteorology, resource survey, management and sustainable development.

The DBT is primarily responsible for identifying and supporting specific R&D programs in biotechnology and biotechnology-related product manufacture. It also supports training of young scientists in the field of biotechnology at various universities and institutes. DBT is gained the reputation of one of the most dynamic governmental R&D initiatives in recent years, including public-private sector partnership activities.

The DOD concerns itself with the task of establishing policies for marine R&D, survey of living and non-living resources of EEZ and the continental shelf of the country, exploration of deep seabed mining, harnessing wave energy and consolidation of Antarctic research.

Among the S&T organizations associated with other Central Government Ministries, the Defense Research & Development Organization (DRDO), under the Ministry of Defense, the Indian Council of Agricultural Research (ICAR), under the Ministry of Agriculture and the Indian Council of Medical Research (ICMR), under the Ministry of Health & Family Welfare, have large R&D infrastructures.

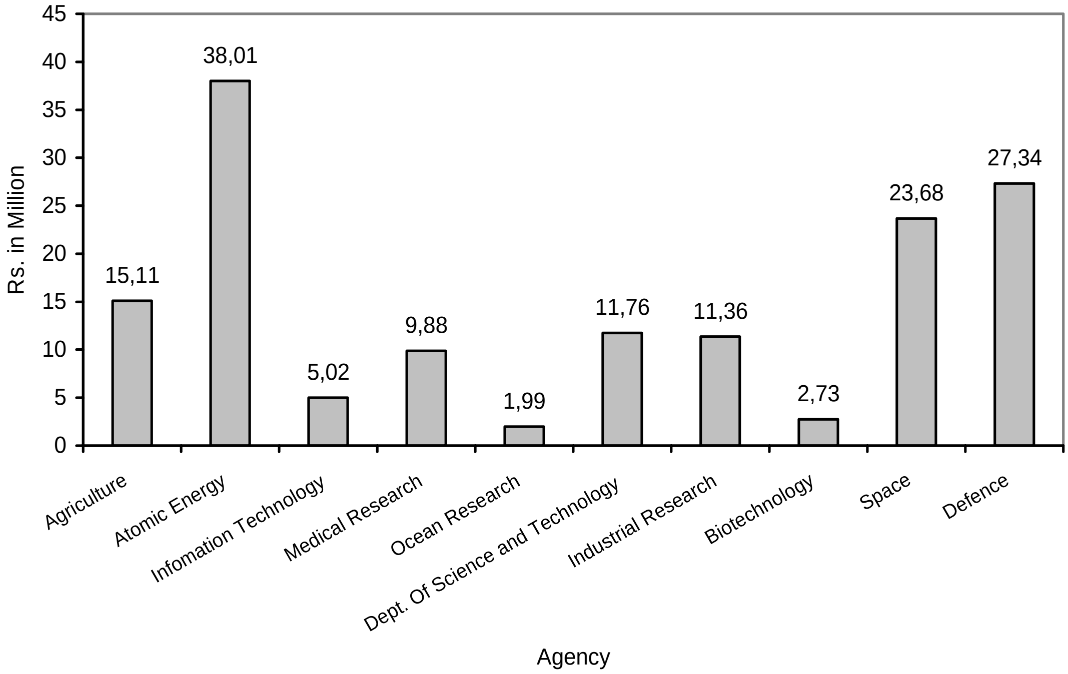
There are about 200 national laboratories and an equal number of R&D institutes in the Central Sector as well as about 1300 R&D units in the industrial sector. The number of people employed in these R&D establishments is estimated to be around 300,000.

In addition to R&D establishments, the other major entities pursuing S&T activities include the university system, comprising more than 162 universities, 32 institutions deemed to be universities and 10 institutes of special national importance. The number of universities and institutions deemed to be universities has continued to increase significantly. Despite the government stated ambitions to foster government research, the results have however been mixed with bio-technology and space being examples where significant progress has been made while progress has been limited in areas such as non-renewable energy.

Since the 1990s there have been numerous changes in government R&D focus. Spending on defence has increased and the pattern of industrial research has changed. The government has increased its allocation to various scientific agencies. The CSIR has started a new initiative on emerging technologies through targeted consortia research. The CSIR has also embarked on a new initiative for targeted innovation in priority areas: New Millennium Indian Technology Initiative. This has already started delivering results. In each of these projects, a number of labs, as well as selected experts, are involved. Government R&D is becoming more result oriented and mission-based. This is likely to enhance the effectiveness of government oriented R&D. The linkages are evolving as consortia research is increasing and this will induce the national system of innovation to be a networked one. There has been an increase in demand pull innovations after the economic liberalization due to the intense competition from global firms (Bowonder et al. 2006). In addition, efforts by government and private sector entities have been made to try to develop closer links between the country's universities and the corporate sector.

The CSIR is the largest government entity that carries out research, with a network of over 38 laboratories that form the core of India's public sector industrial R&D activities. The organization has been a principal player on the Indian R&D scene since the 1950s. It represents R&D infrastructure investments worth over 220 million dollars and a workforce of over 25,000, including 6,000 scientists and 2,500 Ph.Ds. Further, the CSIR has bilateral scientific collaborations with over 35 countries and spends over 110 million dollars on R&D, files about 250 patents, and publishes more than 2,000 scientific papers every year. The CSIR network of laboratories undertakes basic as well as applied research, and earns about 20 percent of its revenues by contract research. The R&D capabilities of these laboratories have been leveraged by several multinational companies, including General Electric, Boeing, DuPont, Akzo Chemicals and Novo Nordisk. The DST promotes basic research, scientific services and societal development (CSIR 2005 and 2006).

Figure 2.2 Government R&D expenditure by major scientific agencies, 2004.



Source: Government of India

In conclusion, government and state enterprises have played and continue to have a central role in S&T-related development and in other conditions influencing R&D in India. The record in public investment and speed of implementing S&T related institutional and policy reforms has however continued to be mixed in terms of efficiency and effectiveness. The government's role in S&T has, however, gradually shifted towards a greater emphasis of commercially oriented R&D and private-public sector partnerships, as illustrated by the reforms carried out to enhance the relevance and effectiveness of the CSIR labs. A major perceptible change in government R&D is that the mission-oriented projects are replacing open-ended research programs (Bowonder et. al. 2006).

Finally, it should be noted that private R&D institutions, such as the Tata Institute of Fundamental Science in Mumbai, as well as several agriculture focused R&D centers have a long history of significant contributions in research.

3 Corporate developments

3.1 Overall R&D expenditure growth

While still lagging compared to industrial economies, R&D in India has expanded significantly. R&D expenditure grew at an annual rate (CAGR) of 45 percent in the 2002–2004 period. Outlays have more than tripled between 1997 and 2004, reaching about 6.8 billion dollars in 2004 at current market prices. On a PPP basis, R&D expenditure is however larger by a factor ranging from three to five times depending on the coefficients used in calculating PPP (Mitra 2007). It is indeed important to note that R&D spending in India typically yields significantly higher value (output) per dollar spent compared to high-income economies.

The public sector has traditionally been the major source of R&D spending. According to DST data, the central government accounted for 62 percent of India's total national R&D expenditure in FY 2002–03. The state governments have accounted for 8.5 percent, higher education institutions 4.2 percent, public sector industries 5 percent, and private sector industries 20.3 percent (DST 2005). This type of data should be interpreted with caution, particularly since many private R&D activities, including those by foreign companies, are not captured fully.

The R&D setting has gradually changed, however. Multinational company India-based R&D and Indian companies R&D spending has increased significantly since the 1990s, albeit from a low base. The Indian public sector, state enterprises, education and research institutions have increased spending, although not at the same rate as corporate R&D. The central government decided to privatize some public enterprises during the first part of the 2000s. Thus, for example the private Tata consultancy services (TCS) and other parts of the TATA group became dominating stakeholders in the previously fully state-controlled Videsh Sanchar Nigam Ltd. (VSNL) and Computer Maintenance Corporation (CMC). In addition, government research labs have gradually become more inclined to develop partnerships with foreign and Indian private corporations.

Furthermore, prior to the 1990s, corporate R&D was limited, both in terms of foreign and Indian companies, and much of the so-called R&D efforts focused on adapting products or technologies to local conditions. Following the economic policy liberalizations from the 1990s onwards, a larger number of Indian companies (but still only a minor share of the total) have become more inclined to invest in R&D as it is understood to be essential to sustain and further develop their competitiveness in domestic as well as in international markets.

The expansion of the outsourcing business into more advanced high-technology areas and the establishment of foreign company R&D centers in India are helping develop the technological and innovative capabilities of Indian companies. Indian company and research institution collaborations with foreign multinational companies have provided multiple advantages in terms of linking local industry, universities and research institutes to worldwide R&D networks. The expanded scale and scope of international corporate R&D operations, trade and interaction with financial and consulting organizations as well as expanded international academic collaborations and human resource mobility, have made important contributions to strengthening international awareness and inculcating a more competitive and commercial culture in the Indian research community.

Much of the foreign corporate R&D growth in India continues to be based on in-house operations, but outsourcing to Indian companies or contract-based R&D collaboration with local research institutes is also expanding. At present, the R&D requirements and strategies of multinational companies mostly originate from outside of India, but there are also examples of initiatives by Indian subsidiaries or by domestic companies in India.

3.2 Push and pull factors driving internationalization

Push and pull factor synergies driving growth and internationalization

Examining the factors contributing to internationalization of R&D is a complex affair requiring analysis both of the global context (push factors) and the India specific context (pull factors) (see box below). Key drivers for the acceleration of internationalisation of R&D, including India specific development, as identified at the UNCTAD expert meeting held in Geneva in January 2005 are summarized as follows:

> *"One key driver is the increased competitive pressure created by liberalization and technological progress (not least in the area of information and communication technologies), which forces firms to spend more on R&D and speed up the innovation process, while seeking to reduce costs and find the necessary skills. For some developing countries, this has opened new avenues to link up with global innovation networks. Various supply and demand factors, along with policies, were identified as important explanations to why, and in what locations; the globalization of R&D takes place. They include the desire to supply large and fast growing markets; physical proximity to global manufacturing bases; and the search for low cost overseas R&D personnel and for new ideas and innovative capabilities. Dramatic changes in design methodology and organization on the supply side have also contributed to a greater need to globalize R&D work. In India, the existence of reputed national research institutes and the management style of local companies, for example, were also mentioned as specific factors attracting FDI in R&D. The presence of Indian nationals in the R&D centres in developed countries could also influence the choices of MNCs in locating their overseas laboratories in India" (UNCTAD 2005b).*

Box: Push and pull factors driving internationalization of R&D

Push and pull factors driving R&D internationalization to locations outside of the EU, Japan and USA is summarized as follows in the UNCTAD World Investment Report 2005:

"R&D internationalization to new locations outside the Triad (EU, Japan and the United States) is driven by a complex interaction of push and pull factors. On the push side, intensifying competition, rising costs of R&D in developed countries and the scarcity of engineering and scientific manpower along with the increasing complexity of R&D, reinforce the imperative to specialize as well as to internationalize R&D work. On the pull side, the growing availability of scientific and engineering skills and manpower at competitive costs, the ongoing globalization of manufacturing processes, and substantial and fast-growing markets in some developing countries increase their attractiveness as new locations.

The expanding pool of talent in selected developing countries and economies in Asia, South-East Europe and the CIS is very important in this context – notably in science-based activities – especially for companies that fail to find a sufficient number of skilled people in their home countries. In recent years, there has been a dramatic increase in the number of people enrolled in higher education in developing countries and economies in transition. In 2000–2001 China, India and the Russian Federation together accounted for almost a third of all tertiary technical students in the world. In addition, more scientists and engineers are staying in, or returning to, China and India to perform R&D work for foreign affiliates or local firms, or to start their own businesses. In Bangalore, for example, some 35,000 non-resident Indians[11] have lately returned with training and work experience from the United States. Reflecting the growing importance of the human resource factor, both developed and developing countries are now adopting new policy measures to attract skills from abroad.

The internationalization of R&D is also facilitated by improvements in ICT and associated cost decreases, new research techniques that allow greater "fragmentation" of R&D and better information on research capabilities that are available worldwide. At the same time, overall improvements in host-country investment climates have all contributed to creating a more enabling framework. Important policy developments relate, for example, to intellectual property rights protection, reform of public research activities, infrastructure development, and investment promotion efforts specifically targeting R&D-related FDI and R&D incentives" (UNCTAD 2005a).

Furthermore, the factors driving the expansion of international corporate R&D has been summarised as follows by Magnus Karlsson. "The drivers to extend R&D beyond company borders include the need for adaptation to local markets, support for foreign manufacturing and increasingly, to reach globally for knowledge, technologies and talent. R&D abroad is dominated by development but the share of research is increasing. Companies are also responding to the fact that innovation itself is changing. First, the process of turning knowledge into commercially viable products and services is occurring more rapidly because barriers of geography and access have come down. The development of communications technologies is an important enabler. Second, the process is increasingly complex and collaboration across disciplines and specialties is necessary. Third, innovation is collaborative, requiring active cooperation between scientists, engineers and leading end-users, as well as between the design, manufacturing, supply and marketing functions of the company. Fourth, it is becoming more expensive to develop new products and services, and external partnerships can reduce cost and risk. Finally, the innovation process is becoming global in scope. Knowledge is created at centers of excellence around the world" (Karlsson 2006).

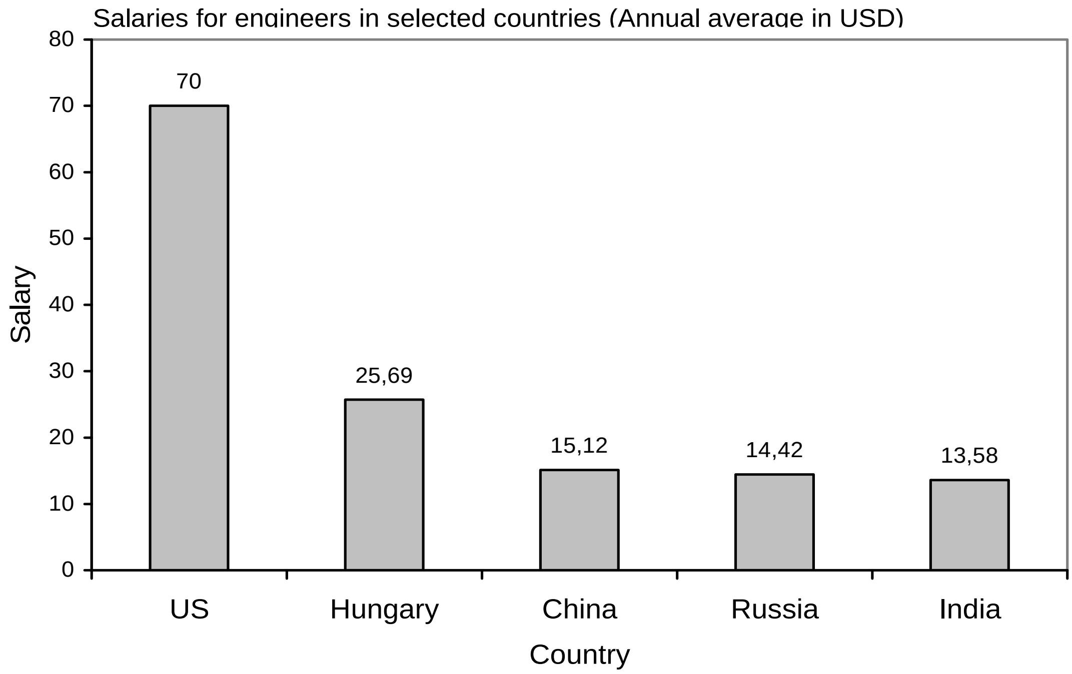
India specific drivers and constraining factors

India possesses a large reservoir of technically talented, hard-working, English-speaking professionals, capable of learning quickly and carrying out R&D in a variety of fields. The presence of a significant number of researchers and engineers enables R&D organizations to scale up within a short period of time.

The main expenditure in R&D is typically on salaries. For example, the salary of researchers account for about 45 percent of the total R&D expenditure in the U.S. The cost of undertaking R&D in India is much less than that in developed countries. In India, the annual salary of an electronic circuit designer with a Master's degree and five years of working experience is about 18,000 dollars, compared to 84,000 dollars in the U.S.; a senior engineer in India would earn between 30,000 to 40,000 dollars, compared to 150,000 to 200,000 dollars in the U.S. (FICCI 2005, adapted from www.workforce.com). This generally translates into a savings of 30 to 40 percent, even after accounting for the hidden costs of managing offshore R&D units.

[11] *Figure not confirmed in official statistics.*

Figure 3.1 Average annual salaries of engineers in 2003 in different countries.



Source: FICCI 2005, adapted from www.workforce.com

According to a study by the McKinsey Global Institute, India had the lowest labor costs for university-educated employees among the 16 countries studied. Additionally, Indian graduates work the longest hours; they work, on average, 2,350 hours a year compared to their U.S. and German counterparts, who work 1,900 and 1,700 hours, respectively. Indian graduates are also more geographically mobile than their colleagues in other countries (McKinsey 2005a and 2005b).

India also offers lower construction costs and overheads in addition to lower salaries for administrative staff, compared to the U.S. and other countries.[12] Savings realized on construction costs are estimated at 25–30 percent, whilst savings on salaries for supporting staff are 60–70 percent in India (FICCI 2005).

The recent rapid expansion of the high-tech industry in India has driven up wages and other costs. High attrition rates and shortages of highly skilled technical staff and experienced project managers have resulted in a sharp rise in wages in years with rapid high-technology industry growth (such as the 2004–2007 period).

While access to a large pool of human resources is a key consideration in corporate investment decision-making, several other issues also come into play. The following India

[12] *Overheads account for 17 percent and the capital expenditure on the construction of laboratories accounts for 4 percent of total R&D costs in the United States (FICCI 2005).*

specific factors can be identified as principal driving forces for foreign companies to have R&D-related operations in India:[13]

1 *Human resources and competency.* Availability of a large, diverse and geographically mobile skilled workforce that enables rapid expansion in a wide range of fields. Strong human resource competency potential for executing quality software and engineering work, including IT applications and quantitative work, as well as proven ability to work in international teams. India's richness in competency of entrepreneurship and within private, public and NGO institutions.

2 *Costing.* Competitive wage levels and other cost advantages.

3 *Infrastructure.* Gradual improvement in infrastructure as illustrated by better telecom connectivity, development of industrial parks and more recently special economic zones offering infrastructure, fiscal, labor laws and other incentives.

4 *Institutions and legal & regulatory frameworks.* Well-established democratic institutions, financial and legal systems, including a favorable track record in intellectual property rights compliance in industrial R&D. Existence of a diverse set of education and R&D institutions and options for collaboration with Indian companies.

5 *Government policy, incentives and governance.* Increasingly favorable trade and foreign investment policy regimes, plus special provision of tax incentives for R&D. Gradual and reasonably predictable processes for economic reforms and improvement in corporate governance.

6 *Markets and production proximity*. Proximity to markets and production, including the potentially large Indian market and a wide range of goods and services production capabilities coupled with proximity to other fast-growing Asian markets. Time zone advantages, enabling a 24-hour working cycle.

7 *High-tech industry clusters, networks, industry specific corporate, individual champions and experiences.* Demonstration effects of corporate success stories and the role of inspiring industry champions providing arguments for companies to invest. Individuals finding that the country generally provides an attractive living environment such as professional challenges and rich social and cultural life (Florida 2005). Global and local network-related dynamics, including virtual networks, development of industrial parks or clusters and the role of the Indian diaspora.

While each of the above mentioned areas are central driving forces explaining growth in corporate R&D-related operations in India, there are also major constraining factors in all of the above-mentioned areas. Major constraining factors include:

1 *Human resources and competency.* Capacity and quality limitations in higher education and training institutions resulting in uneven standards and shortage in supply of competent engineers, PhD's and project managers.

2 *Costing.* Wage inflation and high attrition in heated market conditions.

3 *Infrastructure.* Weaknesses in physical infrastructure such as transportation and communication systems, and general provision of energy and other utilities including

[13] *Findings are based on interviews conducted for this report, as well as reports from A.T. Kearney, the Boston Consulting Group, Evalueserve, Forrester Research, Gartner, IDC, McKinsey & Co and PWC.*

insufficient new capital investments and major deficiencies in maintenance of existing systems.

4 *Institutions, legal & regulatory frameworks and governance.* Concern over deficiencies in institutions, the enforcement of legal and regulatory frameworks and the length of time than can be required to get various types of permits from government authorities as well as in settling legal disputes. Weaknesses relating to intellectual property rights regimes that give rise to concerns regarding security, data protection, limitations of the patent act and its enforcement. Weaknesses relating to industrial, labor laws and regulations hindering flexible use and reallocation of labor, small scale industry, education and other reservation/affirmative action policies.

5 *Government policy, incentives and governance.* Concern over performance records in terms of speed, scale and scope of public and private sector reforms; accountability and transparency (and associated issues of trust and corruption); communication gaps; and impediments to innovation and institutional change (e.g. reluctance to share information; strong hierarchy, timelines and other issues related to bureaucratic inertia and political economy impediments to rapid decisions and implementation of public sector, central and state level economic and other reforms.)

6 *Markets and production proximity*. The size of the Indian market is still relatively small in many product niches compared to the world's largest economies. Remoteness from advanced industrial markets, production facilities, R&D centers, corporate headquarters and other decision making and knowledge centers.

7 *High-tech industry clusters, networks, industry specific corporate, individual champions and experiences.* Demonstration effects of examples of firms and individuals, i.e. especially newcomers to the Indian environment, finding it hard to handle red tape, governance and other obstacles in expanding Indian-based operations. Individuals, especially foreigners and some Indian nationals who have lived abroad can find it hard to adjust to local business and living environments. Bottlenecks in social and economic infrastructure development in rapidly growing major cities with high-tech industry.

In summary, a nexus of external and India specific factors have resulted in a rapid expansion of R&D operations. Access to manpower and cost factors are central, but a wide range of other issues such as competency development, quality performance, intellectual property rights management, links to production and access to markets and are also important considerations. Furthermore, the role of corporate success stories, industry champions and individual perceptions of the local living environment compared to that of other countries influence developments. Many factors continue to constrain expansion of public and private sector R&D efforts but significant progress has been made in education, infrastructure, legal and regulatory frameworks and more generally in market conditions, providing greater incentives to expand the scale and scope of R&D in the private sector in particular.

3.3 Indian companies expanding operations

The rise in corporate R&D spending has been significant in terms of both Indian and foreign firms. Most Indian corporations, however, still spend nothing or very little on R&D compared to their counterparts in advanced industrial economies. This traditional pattern has begun to change however starting in the 1990s.

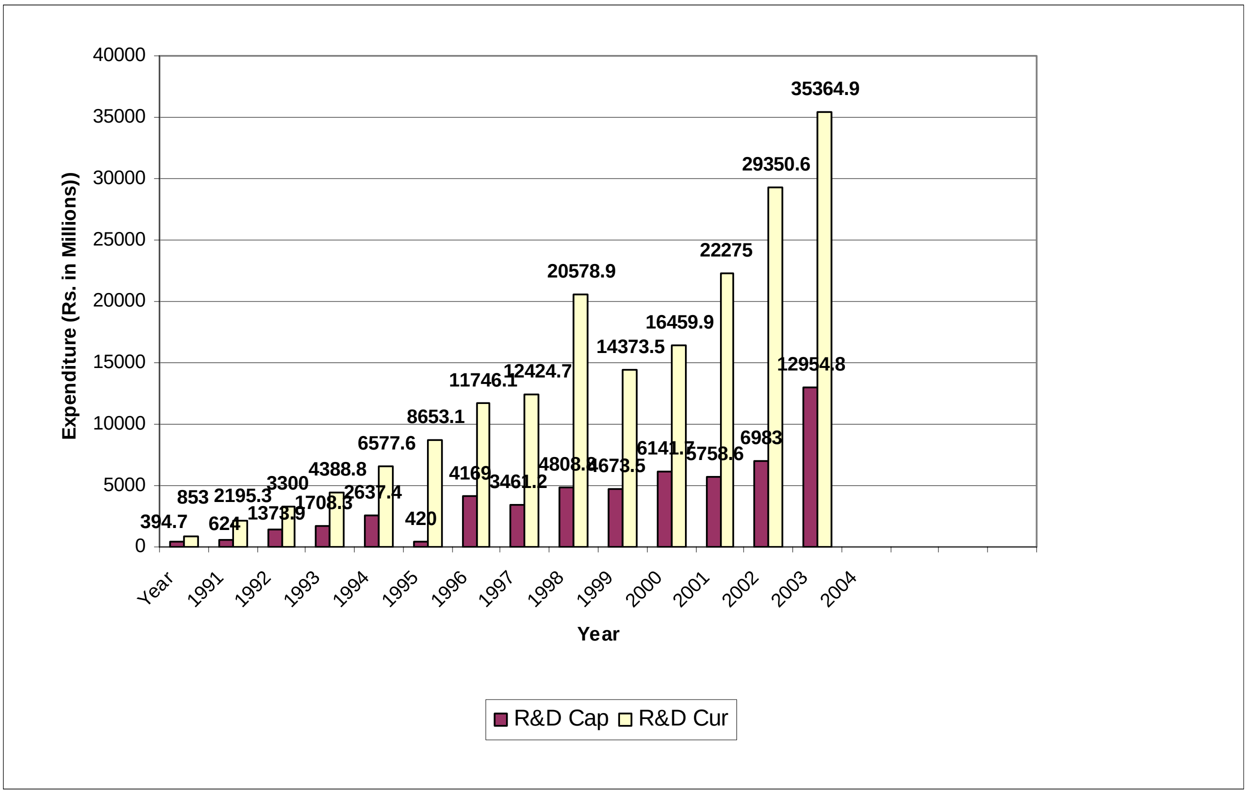
While it is clear that corporate R&D investments have been growing significantly, albeit from a low starting point, readily available data on private sector R&D current and capital expenditure is scant. This applies to both Indian and foreign firms.[14] Many Indian corporate activities classified as R&D may not really be R&D in the strict meaning of the term (this also applies to the public sector). Basic research is limited, but expenditure in development has been growing in the pharmaceutical and certain engineering related sectors in particular. That larger Indian IT, pharmaceutical and auto companies have ambitions to compete with foreign multinational corporations locally as well as in the global market implies greater emphasis on keeping up with new technology and also more R&D investment.

Data as reported by companies is typically incomplete or inconsistent, but it is nevertheless clear that the R&D intensity (that is the ratio of R&D expenditure to sales or revenue) is typically low in India's corporate sector compared to advanced industrial economies and as well as in many East Asian countries. Compared to China for example, India has been a latecomer in terms of corporate R&D investment. The trend from the 1990s, and especially in the 2000s, does however point to a shift towards greater emphasis on corporate R&D in India. In many instances this development has been spearheaded by foreign multinational companies locating R&D in India (in-house and outsourced) but there is also a pronounced trend in the Indian corporate sector to allocating more resources to R&D and developing products on their own (Mitra 2007).

The private sector did not invest much in R&D or innovation prior to the economic liberalization, barring a few examples such as the Tata group. The major R&D providers prior to 1991 were the state/central governments and the public-sector enterprises. A few larger public-sector enterprises were the principal spenders in the 1990s and before that. The post-liberalization era has brought about significant changes in this traditional pattern. R&D, both current and capital expenditures, have grown significantly. This is reflected in that the corporate R&D intensity (i.e. R&D expenditure as a percentage of sales) has increased from only 0.07 percent in 1991 to 0.51 percent in 2004 as per data on registered Indian firms as reported to the Department of Company Affairs (see figure below).

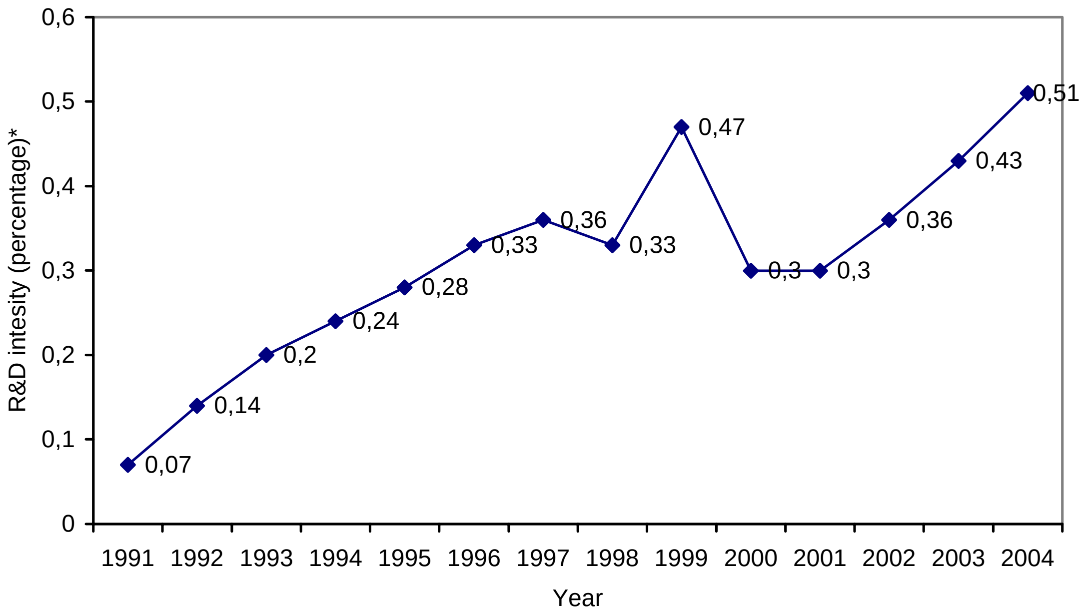
[14]*Key data sources for information on corporate R&D spending in India include the statistics available from the Department of Company Affairs and CMIE. This type of information, however, is in parts incomplete and can be misleading. A more rigorous analysis needs to include more detailed examination of individual company reports and case studies (Mitra 2006).*

Figure 3.2 Current and capital R&D investment growth by registered Indian firms, 1991–2004.



Source: Based on figure adapted from Bowonder et al. 2006. Data refers to reported expenditure on R&D by firms to the Department of Company Affairs, Government of India.

Figure 3.3 R&D intensity for registered Indian firms, 1991–2004.



Source: Based on a table adapted from Bowonder et al. 2006. Data refers to reported expenditure on R&D by firms to the Department of Company Affairs, Government of India. Authors comment: Explanation for the extra-ordinarily high figure for 1999 is not given and is not consistent with other data series. There are generally major error margins in data on corporate R&D as reported by the Department of Company Affairs as well as CMIE.

**R&D intensity measures R&D expenditure as a percentage of sales.*

An examination of the R&D expenditure by company ownership, as of the year 2004-2005, shows that about 20 percent of the central government companies have reported R&D investments and about 10 percent of the state and government commercial enterprises. On the other hand, in the case of foreign private companies registered in India, 24 percent perform R&D. Indian private companies have increased their R&D spending from 347 million Rupees to 32,779 million Rupees from 1991 until 2004. In the case of the central government enterprises this was only 9,955 million Rupees in 2004. The growth rates of R&D spending by Indian private companies have been higher than that of government enterprises. The growth trends show that in 1991 central government firms traditionally dominated the R&D scene but that private companies have superseded them by 2004 (Bowonder et al. 2006). Several larger Indian companies such as BHEL, BEL, DRL, Ranbaxy, Tata Motors, Wockhardt and IOC have began to make significant investments in R&D and to focus on commercializing innovations (Bowonder et al. 2006).

Key sectors where the Indian corporate sector has significant R&D activity include:

- IT and telecom, including software.
- Pharmaceuticals.

- The electronics and transport industry, including the auto sector, machinery (electric and non-electric).
- Chemicals other than pharmaceuticals, basic metals, industrial and mineral products and plastics industries.
- Agriculture, food processing and beverages industries.

R&D expenditure by top 20 Indian private companies in 2004 as per data compiled by CMIE is shown in table 3.1.

Table 3-1 Sales and R&D expenditure for the top 20 Indian companies in terms of R&Din India, 2004.

Company name	Company sales (Million Rs)	R&D expenditure on capital account (Million Rs)	R&D expenditure on current account (Million Rs)	Total R&D expenditure (Million Rs)
Tata Motors Ltd.	202,766	0	3,647.8	3,647.8
Ranbaxy Laboratories Ltd.	42,753	682.7	3,313.9	3,996.4
Hindustan Aeronautics Ltd.	38,064	0	3,091.4	3,091.4
Dr. Reddy's Laboratories Ltd.	17,293	459.7	2,518.2	2,977.9
Bharat Electronics Ltd.	32,281	123.5	1,147.9	1,271.4
Mahindra & Mahindra Ltd.	76,495	0	1,106.2	1,106.3
Bharat Heavy Electricals Ltd.	108,008	275	977	1252
Oil & Natural Gas Corpn. Ltd.	481,013	105.4	947.3	1,052.7
Cipla Ltd.	24,009	91.8	892	983.8
Indian Oil Corpn. Ltd.	1,599,844	484.4	772.9	1,257.3
Lupin Ltd.	12,186	76	760.1	836.1
Infosys Technologies Ltd.	68,681	0	743.9	743.9
Sun Pharmaceutical Inds. Ltd.	10,457	418.4	741.4	1,159.8
Cadila Healthcare Ltd.	11,823	322	710	1,032,0
Steel Authority Of India Ltd.	331,854	13.3	592.2	605.5
H E G Ltd.	5,461	186.3	590.5	776.8
T V S Motor Co. Ltd.	33,213	207.1	510.3	717.4
Wockhardt Ltd.	8,816	185.6	507.2	692.8
Torrent Pharmaceuticals Ltd.	5,404	168	505.2	673.2
Nicholas Piramal India Ltd.	13,951	589	495.4	1,084.4

Source: Data complied based on CMIE Database. Information adapted from Bowonder et al. 2006.

3.4 Foreign companies expanding operations

Growth in foreign investment, strategic alliances and other collaboration forms

Traditionally foreign companies operations in India have focus on selling and producing existing technology solutions. Sometimes this has entailed work for modifications to Indian market conditions which has been undertaken outside or inside India. However, investments directed at research or original innovation has been limited. By and large this is still the case but foreign companies have since the 1990s also began to undertake more significant R&D operations in the country.

Foreign companies locating R&D in India has been a key driver for revitalizing the Indian R&D scene in the 2000s. Foreign multinational companies, mid-size, as well as small firms in advanced industrial countries generally have a longer tradition of prioritization of R&D when compared with contemporary India. Moreover, in line with trends towards internationalization there has been a major trend since the 1990s for major companies from advanced industrial economies to increasingly distribute R&D-related operations internationally, to other developed countries but also to developing countries such as India.

Generally, multinational companies began to explore India's potential as a knowledge-based services and R&D destination in the 1980s. In the late 1980s and early 1990s, some companies set up R&D facilities in the country. In this early stage, most companies focused on productive support or R&D for adaptation of technologies to the domestic market. Many companies had manufacturing operations in India, motivated partly by government policies and the fact that the Indian market itself was large enough to warrant local operations.

In the 2000s, multinational companies continued to expand their India-based knowledge-based services and R&D operations. Foreign companies began to set up innovative R&D operations to cater for the technology needs of their global markets. Texas Instruments was a pioneer of innovative R&D in the mid–1980s. General Electric and Intel have followed, as have other global high-tech companies like Cisco, Microsoft, Motorola, Oracle, Hewlett-Packard, Ericsson and many more. The trend gained momentum when not just large companies but also small and medium-sized enterprises (SMEs) expanded their R&D operations in India.

More than 150 foreign companies carried out R&D in India in 2006. Over 100 of them started their operations between 2002 and 2006. Foreign companies have invested over 1.1 billion dollars in R&D between 1998 and 2003 (TIFAC 2006). There has been a further marked increase in multinational company interest in investing in R&D operations in India in the 2004–2006 period.

The years 2005 and 2006 were characterized by a major shift in the scale and scope of India related corporate operations. Indian and foreign companies announced investment plans at an unprecedented scale by Indian standards. They include investment commitments in infrastructure, real-estate, energy, agro-business, mining, metal and petrochemical industries, financial, healthcare and other services, ICT and other areas.

The years 2005 and 2006 were also characterized by a major shift in the scale and scope of India related corporate R&D operations. Multinational companies have pledged investments of 8.6 billion dollars in the telecom and information technology sectors in India in the financial year 2005-06, according to the data compiled by Ministry of Communications and Information Technology in May 2006. These include the following investment programs covering the next 3–4 years:

- Microsoft 1.7 billion dollars,
- Intel 1 billion dollars,
- Cisco Systems 1.1 billion dollars, and
- IBM 6 billion dollars.

In addition, a consortium of non-resident Indians (NRI's) propose to invest 3 billion dollars to set up the first major silicon chip manufacturing facility in the country. Furthermore, several new R&D investments in telecom and networking were announced in 2005 and 2006. They included investments in the range of 80 to 250 million dollars by firms such as Alcatel, Ericsson, EMC Elcoteq, Flextronics, Nokia, Samsung and Siemens (The Economic Times 2006b).

The focus of multinational companies' high technology investment in India has to a large extent been ICT-related. The expansion, however, covers other knowledge-based sectors as well. It is estimated that the major global pharmaceutical companies will invest 1.5 billion dollars in India between 2006 and 2010, much of it R&D related, according to a McKinsey study. Moreover, a large number of foreign and Indian companies plan major investments in, for example, engineering, financial and legal services. Another major development is that foreign firms generally are stepping up their acquisitions in India and that Indian IT, pharmaceutical and other companies are doing likewise outside of India.

It is important to note that the expansion of foreign R&D in India takes place both in the form of in-house and outsourced operations. The fact that many foreign firms are increasingly active in acquiring Indian companies and the strategic alliances (non-equity based collaborations) between foreign and Indian firms is an important aspect of the expansion of foreign corporate India-related R&D operations. The latter is not included in official statistics.

IBM's, GE's and many other foreign companies' large investment and strategic alliance plans imply a major shift in the scale and scope of multinational company involvement in India, not only in software services but also in software product development, IT hardware, telecom and business and knowledge processing and other industries.

India is a major player in the so-called "global war for talent" in knowledge-based industries and research. Generally, multinational companies are able to recruit and retain much of the top-level talent in India. They typically offer high salaries and advanced training, and attractive international career opportunities – advantages domestic companies often are unable to match. The rapid expansion of foreign as well as major Indian companies' (Tata Consultancy Services (TCS), Infosys Technologies, Wipro and others) high technology business (including R&D related operations in ICT and other fields) has resulted in a major rise in demand for skilled human resources. This illustrates that the fact the competition for talent is growing more and more intense within India and globally.

Box: General Electric's multi-sector expansion plans

Most foreign companies' R&D operations have focused on one or two prime sectors. General Electric (GE) is an example of a company with multi-sector R&D related operations. In 2006 the company announced that it is targeting 8 billion dollars in revenues in India by 2010 compared to 1.1 billion dollars in 2005. GE's operations are expanding in a wide range of areas such as IT, healthcare, infrastructure and financial services, all of which include R&D oriented activities.

GE's second-largest research center in the world, the John F. Welch Technology Center in Bangalore, was inaugurated in September 2000. The establishment of this center (and of other multinational companies' operations) is a significant demonstration effect, pointing to Indian potential in corporate R&D. The scale and scope of GE's R&D operations in India has gradually expanded both in terms of in-house and outsourced work. More broadly, GE business strategy in India covers the following phases: (i) in the 1970s; in which the company's R&D in India was small and generally focused on adaptation of technology for the local market. The local market was too small to justify major R&D operations; (ii) the 1990s; India's related R&D expanded with a major emphasis on offshoring to serve global markets; (iii) from the mid-2000s and onwards; India-related R&D appeared poised to expand much more in terms of both serving global and local markets, the later gradually becoming of sufficient substantial size to justify major local R&D operations.

In May 2006, General Electric (GE) announced the target of 8 billion dollars in revenues in India by 2010 compared to 1.1 billion dollar in 2005. Much of this expansion is envisaged to occur in Indian infrastructure and healthcare projects and in financial services. Moreover, GE's future strategy for India would imply greater efforts to adapt its research and development capability for India (The Indian Express: May 31, 2006)

As of 2006, GE employed 36,000 engineers in India, most of whom are doing very little for R&D for India. GE plans to expand its efforts to develop technology and design products designed to meet specific Indian needs. For example, the "HF Advantage" X-ray system was developed at the John F. Welch Technology center in Bangalore. The HF Advantage is an affordable, general radiographic system providing outstanding image quality and diagnostic precision, while creating a safer imaging environment for patients and doctors, with lower radiation doses. Another example is a hybrid technology model developed at the GE Global Research Center in Bangalore, which combines various forms of renewable energy to provide customized power solutions based on availability of local fuel resources. This is being used in GE's Rural Electrification Program in India (General Electric 2006).

Country origin

North American corporations (ICT firms in particular) have spearheaded the expansion of R&D operations based in India (as well as Ireland and China, for example) followed by British and other European firms (principally of German[15], Dutch and Nordic country origins). The recent years have also seen investments from Asian countries such as Japan, Singapore, South Korea, Malaysia, Taiwan and mainland China. Indian firms and the Indian diaspora are also extending their R&D related operations to advanced industrial economies (USA and the United Kingdom in particular) and emerging economies (China, Singapore and others).

Entry modes

Entry modes for foreign companies typically include the three principal choices, namely: acquisition, Greenfield and joint venture. As is often the case in emerging markets, Greenfield and joint ventures have been more prevalent. U.S. software majors, that entered late, have typically focused on Greenfield or joint ventures. Several players have preferred to have their own in-house R&D operations rather than joint ventures, one reason being concerns over intellectual property rights.

Acquisition, which is a major entry mode form in more advanced countries in particular, is likely to become more common in India in the years ahead. Acquisition is still not a common form of entry to the Indian market but could potentially become more important in the long run in areas such as KPO.

Types of R&D operations

Foreign R&D operations in India are carried out in three principal ways:

- *in-house R&D*, which means that it is performed by a fully owned or principally controlled subsidiary of the multinational company in India
- *collaboration* with other companies
- *contracts* or other forms of collaboration with private entities, public sector laboratories and universities

A common feature of R&D work has been that a team in India (Indian or foreign organization) works in tandem with teams based in other countries. Foreign companies often use Indian teams to support the work of a larger, or project management, team based in another country.

In-house R&D has been a principal form for larger multinational companies, although they often outsource and pursue contract research in parallel. Thus, the strategy is often based on a combination of operational modes. In-house and other forms of equity-based operations offer more control and are preferred in instances when activities are highly complex,

[15] *Examples of German companies with major R&D offshoring in India include Deutche Bank, Deutsche Leasing (software development in the financial sector), SAP and Siemens. A comparison of German and British companies clearly demonstrates several differences. British companies are typically more inclined both to on-shore and offshoring outsourcing compared to German. Also they have a more global spread of their offshoring operations including a major focus on North America and India. German companies offshoring to Eastern Europe has increased sharply while they lag behind in terms of the scale and scope of offshoring to India and other Asian locations.*

when there are major concerns about intellectual property rights or when the intra-company communication is of high intensity.

Collaboration with other companies, for example outsourcing to Indian companies, including strategic alliances, is also an important avenue for foreign R&D operations in India. This is demonstrated in the software industry in particular.

The third mode, contract research, is also growing. Many biotechnology firms use such a mode of operations. Some of these include Biocon, Strand Genomics, Shanta Biotechnics, Bharat Biotech, Avesthagen, Syngene and Affymax. Another recent activity is very large scale integration (VLSI) design. Indian firms such as Wipro, Sasken, Mindtree, Kshema Technologies, Daptec etc. are active in design software. Many firms have started VLSI design work for global firms. The design capability is, thus, evolving in newer technological segments. This specialization and movement into higher value added activities is also supported by knowledge networks. This activity is also taking place in the same clusters, such as Bangalore, Hyderabad and Pune. This essentially indicates that clusters can have significant positive externalities. Silicon Valley, Cambridge (UK), Hinsha (Taiwan) etc. have reported similar knowledge network effects (Bowonder *et. al.* 2005).

Several technical institutes are working on various R&D projects in close collaboration with various multinational companies and Indian companies in India. Some examples are provided below (FICCI 2005):

- IIT Kharagpur undertakes research in collaboration with MNCs such as, Motorola, Compaq, Oracle and GE Caps.
- IIT Chennai and Hewlett-Packard (HP) run a joint laboratory at IIT's campus. This lab develops technologies for emerging economies. HP Labs are also partners with IISc Bangalore, BITS Pilani and the National Institute of design, Ahmedabad.
- Intel has formed alliances with the IITs, IISc and IIIT at Bangalore to conduct Curriculum Development Workshops for the faculty of engineering colleges, which help to bridge the gaps between academia and industry. Intel strives to promote R&D activities based on its design, through its Intel Technology Laboratories (ITL) at IIT Mumbai, Chennai and Delhi; IISc Bangalore and at the National Center for Software Technology (NCST), Mumbai.
- General Motors (GM) has teamed up with 21 institutes in India, including the IITs and IISc. It conducts research with the IISc on fuel alternatives and light-weight engine materials.
- IBM collaborates with the IITs, C-DAC Pune, IITs, and IISc Bangalore
- Texas Instruments has set up its Digital Signal Processing (DSP) laboratory at IISc Bangalore and IIT Bangalore.
- Samsung undertakes designing of color televisions, washing machines and air conditioners in collaboration with IIT Delhi's Industrial Design Department. It also has a Consumer Laboratory at IIT Delhi that undertakes usability studies
- Hindustan Lever Limited collaborates with the IITs, IISc and the University of Mumbai's Department of Chemical Technology.

4 Sector and company-level developments

4.1 Overview of R&D by stakeholder and sector

India has gradually developed a capacity as a center to undertake R&D-related work in a wide range of areas, including ICT (software and hardware), life sciences (including biotechnology, pharmaceuticals and bio-informatics), engineering (including manufacturing, consumer durables and infrastructure construction), space, aviation, nuclear and other energy technologies, agricultural, chemical and material sciences. In addition, India has developed R&D and knowledge processing industry capacities. Moreover, the capabilities to undertake R&D have gradually expanded in scale and scope in terms of process as well as product development in software and other industries.

Foreign companies knowledge-based services and R&D operations in India have gradually expanded. Albeit the fact that research and innovation traditionally has not been given high priority baring some organizations. As in other geographical locations, corporate R&D in India has typically mostly concentrated on development and processes rather than basic research. Some of this development or processes work has gradually moved up the value chain, a much-noted example being India's role in software product development. It is however difficult to make any general statement about R&D-related activities as there are great variations among organizations regarding types of R&D operations and more generally the actual R&D spending levels. Figure 4-1 provides broad estimates of R&D activity levels by stakeholder and key sector.

Table 4-1 Estimated R&D activity levels by stakeholders and sectors in India, 2006.

Stakeholders	**Basic Research**	**Applied Research**	**Product Development**	**Process Development**
Indian government, public enterprises and academic institutions	Medium	Medium	Low	Low
Indian companies	Low	Low	Medium	High
Foreign companies	Low	Low	Medium	High
Sectors				
ICT: software services and products, IT hardware and telecommunication	Low	Low	Medium	High
Life sciences: biotechnology, and pharmaceuticals	Low	Low	Medium	High
Engineering and related industries: automobile, industrial and other machinery, textile, consumer durable goods, and other manufacturing, energy and other utilities, infrastructure and construction related industry and environmental	Low	Low	Medium	Medium
Space, aviation, defense, nuclear technology	Medium	Medium	Medium	Medium
Agriculture, chemicals and material sciences	Medium	Medium	Medium	Medium
Other R&D and knowledge processing industry related capacities including financial, accounting, insurance legal, education, health, publishing and other humanities, social and natural science related disciplines	Low	Low	Medium	High

Source: Estimates derived from published information and interviews and the sector review sections (Mitra 2007).

Note: Estimated levels of activity (low, medium and high) are broadly defined in an India-specific comparative context covering levels of R&D expenditures, numbers of employees, patents, technical publications and product and process development. Activity level as used here differs from research intensity, which is often defined as R&D expenditure as a percentage of sales/revenue/expenditure at the company level, or as GDP at the national level. Estimates for stakeholders and sectors are based on preliminary generalized observations and do not reflect that there are significant variations in levels of R&D activity within each sector, industry and individual entities.

R&D priorities have varied significantly in accordance with the type of stakeholder. Government and public-sector R&D typically have national development goals such as a need for basic competency in humanities, social and national sciences, plus special national security related research, such as nuclear, defense and space technology capabilities. Indian corporate R&D has traditionally focused on adopting technologies to local markets and has only recently become substantive in terms of serving international demand. Industrial research has focused on IT, pharmaceuticals, chemicals and consumer electronics. Foreign companies have emerged as a key factor in the internationalization of R&D with much of the expansion focusing on the need to serve global markets, IT and the automobile industry being prime examples.

In addition to the above-mentioned sectors, India has experienced a rapid growth in knowledge processing industry operations, parts of which are closely related to R&D competency (see special section below). It should also be noted that India has a long tradition in codified and tacit knowledge ranging from humanities to social and natural science related knowledge. This heritage has however not been commercially exploited globally, with the exception of a few examples such as ayurvedic medicine

Key drivers in international corporate R&D have by and large been similar for most sectors, namely: availability of competent human resources and institutional capabilities, proximity to production facilities and markets plus quality and/or cost advantages. Software however had a head start, which in turn created a demonstration effect. The example set by the software industry in terms of globalization, competition and interest in R&D (with multinational companies playing a central catalytic role) subsequently helped to inspire other sectors.

4.2 ICT: software, IT hardware and telecommunication

Software and IT-enabled services are expanding in scale and scope

The Indian ICT industry has expanded rapidly in software products and services and, in recent years, also in computers, electronics hardware and telecommunication products and services. The industry is comprised of more than 100 major foreign companies and a larger and more diverse group of Indian companies, ranging from large organizations with global operations to smaller companies focusing on exports or the domestic markets. The industry displays considerable variations in technology and organizational sophistication, cost structures, market focus and growth performance.

India accounted for 65 percent of the global market in offshore IT software and 46 percent of the global BPO market in 2004, according to a National Association for Software and Service Companies (NASSCOM). India's export of software and services (broadly defined as including ITES-BPO) has grown from 4 billion dollars in 2000 to an estimated 23 billion dollars for the fiscal year 2005-06. The number of people employed directly in the sector is estimated at close to 1.3 million employees for the financial year 2005-06 (NASSCOM 2006).

According to NASSCOM, the strong, consistent performance so far and the positive prognosis bode well for the IT-ITES industry in India, putting it on track to exceed the current 60 billion dollar export target for 2009-10. *"However, the opportunity for India is much larger. With less than 10 percent of the current addressable (offshore) market captured till date, there is significant headroom for growth" (NASSCOM 2006b).*

The growing offshore software and BPO industries also face a number of challenges, including a shortage of skilled workers. Currently only about 25 percent of technical graduates and 10–15 percent of general college graduates are suitable for employment in the offshore IT and BPO industries (NASSCOM-McKinsey 2005). India needs to ramp up the number of knowledge workers fluent in languages such as French, German, Japanese and Spanish. Since salaries and other costs are rising by 10–15 percent per year, India-based IT and BPO providers must find ways to reduce total costs in order to continue to offer customers cost savings of around 40 percent. Thus, they must continue to innovate in service lines and operational excellence (NASSCOM-McKinsey 2005).

Another major challenge for India is to strengthen its physical infrastructure, one of the principal bottlenecks in the nation's development. India's larger cities require appropriate urban planning and major investment in infrastructure in order to sustain economic growth; including investment in the high-technology industry. In addition, major efforts are required to accelerate industrial development in second- and third-tier cities.

The software industry in India continues to focus on services. There has, however, also been significant progress in product development especially in the 2000s. Much of this is driven by multinational companies' in-house and outsourced operations, but there are also examples of "own efforts" by indigenous companies to develop products for international and local markets. According to NASSCOM, revenue earnings for the category "IT engineering services, R&D and software products" increased from 2.9 billion dollars in 2003-04, to an estimated 4.8 billion dollars in 2005-06 (NASSCOM 2006).

The software industry is moving up the value added chain. According to NASSCOM, the key factors driving the rapid growth in software and services export and offshoring are:

- *Productivity. Quality and Rate (PQR).* These factors form the core of India's attraction as an offshoring destination for software and services.
- *Focus on margins and cost pressures.* Outsourcing to India has helped companies achieve 40–50 percent cost savings. Companies are also able to generate higher free cash flows due to reduced investments in physical infrastructures, telecom and equipment. Wage arbitrage has also led to increased cost savings.
- *Growing demand for a high quality, skilled workforce.* India has a large pool of educated, highly skilled, English speaking manpower.
- *Increasing focus on core competencies.* The need to focus on core competencies to remain competitive is driving more companies to offshore outsourcing. Offshoring helps free up resources and help higher management focus on core business requirements. Offshoring also allows for access to new technologies and talent to help strengthen business offerings.
- *Global quality accreditations.* In an increasingly competitive economy, customer demand and expectations of highest levels of quality. Indian vendors are quality-centric and have adopted several industry standards such as SEI-CMM, ISO, TQM, 6 Sigma Quality and COPC.
- *Secure environment.* Indian companies as well as the Government have been proactive in taking appropriate steps to tackle security concerns. Most Indian companies are aware of, and are opting for, international security standards such as ISO 17799, BS7799, COBIT and ITSM. NASSCOM, along with the Indian government, has laid the foundation for the required legal framework. The IT Act, 2000 includes laws and policies concerning data security and cyber crimes. Other than the IT Act, the Indian Copyright Act of 1972 deals with copyrights issues in computer programs.

Table 4-2 IT industry sector-wise break-up (US billion dollar revenue).

Sector	**FY 2003/04**	**FY 2004/05**	**FY 2005/06***
IT services	10.4	13.5	17.5
Exports	7.3	10.0	13.2
Domestic	3.1	3.5	4.3
ITES-BPO	3.4	5.2	7.2
Exports	3.1	4.6	6.3
Domestic	0.3	0.6	0.9
Engineering services and R&D, software products	2.9	3.9	4.8
Exports	2.5	3.1	3.9
Domestic	0.4	0.7	0.9
Total software and services	16.7	22.6	29.5
of which are exports:	12.9	17.7	23.4
Hardware	5.0	5.9	6.9
Grand total for IT industry	**21.6**	**28.4**	**36.3**

Source: NASSCOM 2006.

**Preliminary estimates. Total may not match due to rounding off. The table shows reclassified NASSCOM estimates as per February 2005. Revenues from "Engineering and R&D services and Software Products" are reported separately. Historical values for a few segments have changed compared to prevision data sets. For ease of comparison, details for two preceding years have been restated as per the new classification.*

IT hardware with major growth potential

India has been lagging behind China, Japan, South Korea, Taiwan and other Asian economies in developing a competitive hardware industry. Several initiative steps have, however, been taken by the government in the 2000s to develop India's IT hardware and electronics industry to serve global markets as well as increasing significant local demand. The country has already attained an eminent position in semi-conductor and other hardware product design and several companies plan to establish more significant hardware manufacturing in India in the next five years.

Since the early 2000s, several investors have turned their attention to the country's potential for manufacturing chips for the rapidly expanding domestic market (chips for credit cards, medical devices, mobile phones, TVs, DVDs, set-top-boxes, personal computers, etc.). They are also set to enter the export market for chips and other hardware products (ISA 2006). One example of a significant development in this area is the company SemIndia, a consortium established by Silicon Valley-based individuals of Indian origin. In 2005, it announced plans to bring major semiconductor manufacturing facilities to India. The consortium will be supported with technology and equity funding from Advanced Micro Devices (AMD), the major international supplier of integrated circuits. SemIndia has declared investment plans worth 3 billion dollars over a four-year period in Hyderabad. Hyderabad is competing with Bangalore, Chennai and others to develop a hardware industry as it has advanced plans to develop a so-called Fab City near Hyderabad's airport (SemIndia 2006).

Foreign investments in IT and telecom sectors are witnessing explosive growth

A large number of foreign companies have established in-house and outsourced software, IT hardware and telecommunication R&D-related operations in India (see Table 4-3).

Table 4-3 R&D activities by multinational companies in India: software, IT hardware and telecommunication sector examples, as of 2006.

Major In-House R&D Operations		**Major Outsourcing of R&D to Indian Parties**
Adobe	Hewlett-Packard	Alcatel
American Express	IBM Global Services	Cisco
Baan	Intel Novell	Computer Associates
Cadence Design Systems	Microsoft	Ericsson
Cisco	Motorola	Farmer's Insurance
Citigroup	Oracle	General Electric
Computer Associates	Philips	General Motors
Cognizant	SAP	Home Depot
Deutsche Leasing	Siemens	IBM
EDS	Sun Microsystems	Lucent
Ericsson	Synopsys	Motorola
General Electric	Texas Instruments	Nokia
General Motors	Yahoo!	Nortel Networks
Google		Xerox

Source: Compiled based on TIFAC 2006, company reports, Times of India, Business Standard, Financial Times and interviews.

Note: R&D and sector demarcations are broadly defined. List is intended to be illustrative.

The following investment plans were announced in the last quarter of 2005 and the first half of 2006:

- IBM announced in 2006 that it would invest 6 billion dollars in India over the next three years, tripling the size of its current investments in the country. A significant share of this investment will be R&D oriented (IBM India 2006).
- Microsoft announced that it would invest 1.7 billion dollars over four years to expand its operations in India and increase its staff from 4,000 to 7,000. Half the proposed investment would go into making India a major hub for Microsoft research, product applications development, services and technical support, covering requirements of both the local and global markets.
- Cisco Systems announced it would invest 1.1 billion dollars over three years, and triple its staff in India to 4,200. It may also be considering setting up major hardware manufacturing facilities.
- Intel presented an investment plan totaling more than 1 billion dollars over five years, focusing on expanding its R&D center in Bangalore as well as marketing, education and community programs and the setting up of a venture capital fund.

- Accenture has announced plans to open a R&D Lab in Bangalore, India at the end of 2006. Accenture Technology Labs India will focus on systems integration and software engineering R&D, with a focus on reducing the cost and improving the quality of technology solution delivery and other IT-related service (Accenture 2006).
- EDS announced in 2006 that it would invest 380 million dollars to merge its operations with Mphasis, an Indian-based Indian IT and BPO services provision company. The merger follows EDS' acquisition of a majority stake in Mphasis in June 2006. EDS declared that it aims to expand its India-based workforce from just a few thousand to over 20,000 employees by the end of 2006 (Business Week 2006).

Other major plans announced in 2005 and 2006 included:

- SemIndia, a consortium of non-resident Indians (NRIs), proposed investment of 3 billion dollars to set up a silicon chip manufacturing facility in India (SemIndia 2006).
- General Electric (GE) announced in 2006 that it is targeting 8 billion dollar revenues in India by 2010 compared to 1.1 billion dollars in 2005. Its operations are expanding in a wide range of areas such as IT, healthcare, infrastructure and financial services; all of which include R&D oriented activity.

In addition to the above foreign investments, 2005 and 2006 also marked a shift in the scale and scope of major Indian IT companies operations. This is illustrated by them bidding for large international contracts (several hundred millions and more) and also acquiring companies in North America and Europe. The rapid expansion of both Indian and foreign companies' India-related operations implies an escalation of international competition in the offshoring business; in the IT and BPO sphere in particular. The increasingly fierce competition among foreign and indigenous companies to secure highly skilled Indian labor is clearly reflected in the size of a large number of multinational companies including both the higher and lower end of the value added chain. Although wages are rising in India, labor costs on the whole remain significantly lower than in high-income industrial countries.

Box: IBM's 6 billion dollar investment plan

In June 2006 IBM announced that it would invest 6 billion dollars in India over the next three years, tripling the size of its current investments in the country.

At the time of the announcement, IBM's investments in India were already the largest of any multinational company in the country, totaling around 2 billion dollars and employing more than 43,000 people in 14 cities. Much of the new investment will be allocated towards expansion of the firms operations in Bangalore but operations in several other Indian cities will also expand resulting in thousands of new job opportunities both the higher and lower end of the value added chain.

IBM's new investment in India is to be allocated in a wide range of areas, including software labs, research bases and testing and delivery centers. The company has been keen to emphasize that its interest in India extends beyond BPO and back-office operations, and the scope of its planned projects suggests it is increasingly seeing India as a global hub for its software and IT-services enterprises. BPO is a major part of IBM's business in India nonetheless: in 2004 it bought Daksh e-Services, then India's third-largest business outsourcing firm, which employs around 20,000 people in low-cost outsourcing and call-centre services (EUI, 2006 and IBM India 2006).

The immediate steps in IBM's increased investment in India as announced in June 2006 include the following:

- Establishing the first in a new breed of Service Delivery Centers in Bangalore, deploying new processes and technology that will greatly automate IT service delivery to provide clients with enhanced flexibility and increased worldwide access to skills, service offerings and continuous availability at lower costs.
- Creating the IBM Systems & Technology Group (STG) Innovation, Development and Executive Briefing Center in Bangalore, focused on IBM infrastructure solutions, technologies and innovations and providing performance benchmarking, testing, data migration and competency building capabilities.
- Locating a Telecommunications Research & Innovation Center at its India Research Lab that will serve as a key resource to IBM's telecommunications clients around the world.
- Increasing the capabilities and staff of the High Performance On Demand Solutions Lab in Bangalore, a specialized software and services lab driving automation and virtualization of complex IT infrastructures.
- Inaugurating "The Great Mind Challenge," which is designed to improve the software development skills of Indian students as they work to solve issues facing businesses today" (IBM India 2006).

Telecommunications witnessing explosive growth

Telecommunication has been one of the fastest growing sectors in the country. China, India and the U.S. are today the largest markets for mobile telephony. The size and growth in the Indian market, combined with the government's decision to raise the foreign investment ownership cap in the sector, has generated considerable interest among multinational companies locating production as well as R&D to India. Re-regulation, competition, and mergers and acquisitions have created new opportunities and challenges for Indian and foreign companies in the sector.

In 2004, the mobile subscriber base exceeded the number of fixed line connections. Fixed line communications registered an increase of 24 percent in the number of new connections in 2003. According to a study by the International Data Corporation (IDC), the non-voice market (message and data services) for mobile operators registered a growth of 139 percent year by year in 2004. Ernst and Young estimate that revenues from the telecom sector should reach 25 billion dollars by 2007.

Multinational companies' R&D (as well as Indian companies) in the IT and telecom sector became more significant in the 2000s. The IT/telecom R&D market in the country is expected to show further growth in coming years. According to Frost and Sullivan estimates, the IT R&D outsourcing market in India is expected to reach 9.1 billion dollars in 2010, from 1.3 billion dollars in 2003 at a CAGR of 32 percent. The R&D offshoring market for the telecom industry is estimated to increase from 0.7 billion dollars in 2003 to 4.1 billion dollars in 2010 at a CAGR of 28.7 percent (FICCI 2005).

VLSI chip design, nano-technology and embedded technology, computing architecture, network security, software engineering, video servers, wireless technology, signal processing and business support systems are some of the sectors showing high growth in the telecom industry. According to the VLSI society of India, India hosts 70 to 100 VLSI companies with approximately 5,000 engineers providing semiconductor design services. R&D conducted in these companies will further boost the industry (FICCI 2005).

Most multinational companies' investments in the telecom sector focus on production (mainly assembly of components), bidding on infrastructure projects, and on distribution and sales. In 2004 multinational companies announced a number of plans to expand manufacturing, for example Japanese Kyocera which acquired the mobile equipment division of CDMA technology pioneer Qualcomm, which is setting up a mobile phone manufacturing plant in India for the Indian market, and it also plans to expand shipment of phones to Africa, South East Asia, Australia and New Zealand.

- Alcatel plans a cell phone manufacturing facility in India with an annual capacity of 2.5-5 million units to cater for the Asia-Pacific markets. In 2006 Alcatel announced plans for new investments amounting to 80 million dollars (The Economic Times 2006b).
- LG recently started assembling phones in India.
- Siemens announced 500 million dollar expansion plans in India over the next four years.
- Nokia plans to set up a manufacturing plant with an investment of 100–150 million dollars.
- Ericsson has announced an investment of 250 million dollars for telecom manufacturing and research and development in Chennai and Jaipur.
- Flextronics and Elcoteq announced in 2006 that they plan an investment of USD 100 million each in the country.
- Telecordia Technologies, a telecommunications network software and services provider, inaugurated its research and development center in Chennai in 2006, which is the first of its kind for the company outside of the United States. Its purpose is to cater to the Indian market as well as providing services globally. The company has plans for the Chennai center to ultimately employ 500 people. In addition Telecordia will continue their partnership with several Indian information-technology firms, including Wipro (EUI, Business Intelligence India June 21, 2006).
- IBM announced, in June 2006, major investment in the Telecommunications Research & Innovation Center at its India Research Lab in Delhi; one of the eight IBM research labs around the world. The center is envisaged to focus on such areas as advanced analytics to identify useful information from telecom call center records, network management technologies for improved transaction process monitoring and technologies to allow telecom companies to offer location-based services to their customers (IBM India 2006).

Swedish-related ICT companies expanding operations

Ericsson is a Swedish multinational company with long standing sales, production and more recently R&D operations in India. Since the beginning of the 20th century, Ericsson has contributed to almost every facet of telecommunication development in India. As of 2005, Ericsson provided 45 mobile networks for 12 major operators in India (Ericsson 2005).

In the 2000s, Ericsson began developing Mobile Internet in the country. As a part of this initiative, an Ericsson Mobility World center has been set up in Gurgaon (in the New Delhi area). This facility enables Ericsson to collaborate with application and solution developers, as well as network operators, to develop new applications and solutions for the Indian market. Furthermore, Ericsson has set up a Systems Integration Competence Centre, also in Gurgaon, to create solutions for Indian operations. This center is expected to grow to about 100 telecom professionals. In addition, a Customization Design Center has been set up with an initial manpower of 50 experts (Ericsson 2005).

Ericsson has recently expanded its existing manufacturing facility in Kukas, Rajasthan, from AXE switching manufacturing to GSM Radio Base Stations (RBS). The GSM RBS has been adapted to Indian conditions and will help resolve challenges like higher operation and maintenance costs, severe climatic conditions, prolonged power cuts and voltage fluctuations. Local manufacturing will ensure easier handling of repair and returns, and flexible inventory management will reduce operator costs (Ericsson 2006).

In 2005 Ericsson announced its intention to set up its own R&D center in Chennai, a global services delivery center (GSDC) in Gurgaon and upgrade its GSM radio base station manufacturing facility in Rajasthan. The company's R&D center in Chennai will conduct research in cutting-edge technologies, while the GSDC in Gurgaon is focusing on developing managed-services offerings in India. The GSDC includes the systems integration competence center, the product customization center, the regional network-operating center and the mobility world center. The company also announced plans to upgrade its RBS manufacturing facility at Kukas, Rajasthan, and commence manufacturing of mobile switching centers (MSC) and base station controllers (BSC) (Business Standard 2005a).

Ericsson has for several years partnered with the Indian IT company Wipro to outsource R&D as an important element of Ericsson's overall R&D strategy. Ericsson has significant R&D-related outsourcing arrangements with two other, major Indian ICT companies as well: Tata Consultancy Services (TSC) and Sasken. Outsourcing operations to these three companies combined, accounted for approximately 1,000 man-years, as of 2005.

Examples of other Swedish-related ICT companies with significant software R&D operations in India include TietoEnator and Telelogic. TietoEnator AB (a company with principal operations and shareholders in Finland and Sweden) has expanded its India-centric operations after acquiring a German software firm which already had operations in Pune. Telelogic, a prominent example of a provider of solutions for advanced systems and software development for the defense and aerospace sector, set up a product development lab in Bangalore in 2004. This was Telelogic´s 4th product development lab, the others being in the U.S., the UK and Sweden. The Bangalore lab initially focused on performing tests and quality assurance for the firm's integrated product offerings. It was to serve both international and Indian domestic market needs. As of 2006, the firm has employed more than 100 engineers in its Bangalore operations.

4.3 Biotechnology and pharmaceuticals

The biotechnology and pharmaceuticals sector related industries appear poised for major long-term development, both in term of scale and scope.

The biotechnology and pharmaceuticals sector comprises pharmaceuticals, bio-services, bio-agricultural, bio-industries and bio-informatics. As of 2004, the biotech industry in India generated revenues amounting to 1,070 million dollars, with pharmaceuticals accounting for 811 million dollars. The biotechnology and pharmaceuticals industries could emerge as one of the major industries in the country, but it is still in an early stage of development. Revenues are projected to reach 5 billion dollars by 2010. As of 2004-05, the sector employed nearly 9,000 scientists and engineers and attracted an estimated 216 million dollars in new investments in 2005 (BioSpectrum 2005).

Recognizing the potential of biotechnology and pharmaceuticals, the government and private industry have focused on developing the sector by strengthening legal and regulatory systems, harmonizing international standards, providing financial support to early-stage development, developing bio-tech industrial parks and providing tax incentives for Indian and foreign companies. The central government's of Department of Biotechnology is playing a significant role in developing the sector.

This significant cost advantage is, although not the only driver, a powerful incentive for multinational companies to undertake R&D initiatives in India. It has been estimated that pre-clinical R&D costs are 10 percent in India, compared to that of developed countries. Clinical research is also much cheaper in India. The following table shows that the cost of clinical trials at different stages in India is about 50 percent less than in the U.S., according to Rabo India Finance. Table 4.4. shows that the cost of pharmaceutical R&D is indeed about 50 percent in India, compared to the United States (FICCI 2005).

Table 4-4 Cost of Clinical Pharmaceutical Research – India vis-à-vis the United States.

Study phases	**Average U.S. cost (million USD)**	**India-cost advantage**
Phase I (tests on small groups of healthy humans)	20	50 percent less
Phase II (tests on individuals afflicted with the condition for which the drug was developed)	50	60 percent less
Phase III (tests on large groups of afflicted patents)	100	60 percent less

Source: Hindu Business Line as presented in FICCI 2005.

The domestic sales and manufacturing operations of the pharmaceutical industry have expanded rapidly, and recently there has been significant growth in exports and R&D investments. Both new drug discovery research and novel drug delivery system programs can be conducted in India at a significantly lower cost than in developed countries. Products based on molecular biology, including software packages, DNA-sequencing and molecular modeling are candidates for R&D offshoring to India.

Multinational companies have been partnering with Indian companies to carry out R&D in the entire value chain, from drug discovery to clinical trials, with an emphasis on the later part of the R&D process. Their primary focus has included custom synthesis, medicinal chemistry and clinical studies.

Much of the research in India has traditionally focused on the re-engineering of bulk drugs. The country still has limited capabilities in terms of research focused on the early stages of drug discovery, although Indian and foreign companies are gradually expanding pharmaceutical R&D in India. Research at the early stages of drug discovery continues to be dominated by work carried out in the U.S. and Europe. Among the factors constraining research in India is the local availability of top-level scientists and experienced managers in specialized fields. In addition, while India has enacted new laws on compliance and intellectual property rights, there are concerns about the need to strengthen compliance with legal and regulatory frameworks (ICRA 2005).

Biotech companies' R&D operations in India are mostly built on a contract or collaborative research model. For example, Syngene, a subsidiary of India's biotech company Biocon, carries out contract research for drug discovery. A key customer for Syngene is Novartis, with which it has a three-year agreement to carry out research projects to support new drug discovery and development, primarily in the early stages and involving small molecules in the areas of oncology and cardiovascular disease. A start-up company, Avesthagen, an agro-research and medical research firm, is attempting similar activities and labels itself a research process outsourcing (RPO) company. It employs a collaborative model to share the intellectual property rights (BioSpectrum 2005).

India is emerging as a significant site for conducting clinical trials, the prime drivers being low costs and large and varied demographic profiles. Multinationals offshoring in this area expect to grow rapidly in the next 10 years and beyond, according to industry analysts.

Foreign investments for clinical research projects in India by global drug companies on an annual basis has exceeded 120 million dollars in the financial year 2005-06, compared to 65 million dollars in 2004-05. The domestic clinical research market was estimated at about 100 million dollars as of September 2005. The increased investment flow in the clinical research market signifies the growing interest of global research companies in conducting drug studies in the country, for data generation as well as registration (Business Standard 2006a).

The top foreign investors in the Indian clinical research space during the financial year 2005-06 included global drug research giants like Pfizer, Eli Lilly, Merck, Novartis, Aventis, Bayer, Atlanta, AstraZeneca and GSK. Pfizer, are one of the leading foreign firms, with research operations and about 23 clinical research studies undertaken in India through an in-house clinical research team in India as well as outsourcing arrangements with leading clinical research organizations (CROs). Of the other foreign firms, Indianapolis-based biopharmaceutical major Eli Lilly has about 15 to 20 clinical research studies being conducted in India. GSK Plc with almost 140 new products at an advanced stage of clinical development globally, has identified India as an ideal location for tapping into its global scientific research (Business Standard 2006a).

Multinational companies have also shown interest in conducting clinical trials in developing countries to reduce costs and, to some extent, ease regulatory burdens that are on the rise in the developed countries – especially Europe. China currently has 20 percent of the world's clinical research business. India' share is 8 percent but hopes to become a world leader by the 2000s. Over 100 international and 300 Indian trials were conducted in the country as of 2005 (Singh S. 2006).

While India's IPR regime has improved from the perspective of multinational companies, companies do however continue to stress needs for further improvements in areas such as patent and data protection. China is ahead of India in providing data protection exclusivity, which is essential to investors in clinical trials, for example.

The bioinformatics market in India is expected to reach 2 billion dollars by 2008, while the Indian biotechnology R&D products and services market is expected to reach 3 billion dollars by 2010 (FICCI 2005). Multinational companies have become increasingly active in offshoring IT functions across the pharmaceutical industry value chain in areas including IT systems for clinical trials, manufacturing, sales, distribution and product management (Singh, S. 2006).

Swedish-related pharmaceutical companies growth potential

AstraZeneca's operations in India cover sales and manufacturing as well as R&D. It has established four major entities in Bangalore. It has a major manufacturing unit designed to meet high international standards conforming to WHO cGMP (current Good Manufacturing Practices) norms. AstraZeneca Pharma India Limited, the marketing entity of the company, is responsible for six major therapeutic areas: oncology, cardiovascular, maternal healthcare, infection, respiratory and neuroscience (AstraZeneca 2006).

Moreover, India is the site for one of AstraZeneca's four, principal international research centers; the others are located in Sweden, the U.S. and Japan. AstraZeneca R&D in India is dedicated to advancing medicine for diseases in developing countries. The company's first research facility in Bangalore opened in 2003. It is dedicated to finding a new therapy for tuberculosis that will act on drug-resistant disease, and will reduce the complexity and/or duration of treatment. More than 70 scientists work in the center, including molecular biologists, genetic engineers and chemists. The Bangalore scientists also work closely with AstraZeneca's infection research center in Boston USA, and with external academic leaders in the field. A second research facility will open at the same site in 2006 (Business Standard 2005b). Finally, AstraZeneca Research Foundation, based in Bangalore, supports education and technological innovation by organizing seminars and symposia (AstraZeneca 2006).

4.4 Engineering: automotive, energy and other sectors

India has been developing a substantial and diverse engineering industry since 1947. Much of the industry has traditionally been protected by import substitution policies and has had little incentive to do R&D. Since the early 1990s, this situation has begun to change as Indian companies can no longer count on a protected domestic market and thus have to compete with international companies.

The report *Off-shoring Engineering Services: The Next Frontier & Potential for India* compiled by NASSCOM in partnership with Booz Allen and Hamilton provides a detailed perspective on the potential for outsourcing in engineering services and key enablers for India to address this opportunity. According to this report outsourcing of engineering and R&D services is expected to drive the next wave of outsourcing generally. The reports states that *"recognizing the benefits of offshore engineering – which include cost savings of the order of 20-50 percent, quality improvements, enhanced resource utilization and access to best practices and cutting-edge technologies – large global companies are turning to India for sourcing these services" (NASSCOM and Booz Allen and Hamilton 2006).*[16]

[16] The report provides estimates on the size of the global offshoring engineering services industry across five verticals and four service lines. India's strengths in the areas of product and component design, plant design, process engineering and plant maintenance and operations in specialized segments such as automotive, aerospace, telecom, utilities and construction and industrial machinery are discussed in the report from the perspective of global companies looking for outsourced services. The study also focuses on India's preparedness for the engineering services market and talks about whether the country can position itself as a global hub for these services (NASSCOM and Booz Allen and Hamilton 2006).

Examples of engineering and related industries with a large R&D growth potential include: automobiles, automobile components, machine tools, electric equipment and machinery, construction and civil engineering. In addition, there are areas such as steel, paper, textiles, medical equipment and bearings. Moreover, major areas with strong growth potential include infrastructure and environmental technology related R&D, including areas such as energy (nuclear, hydro-electric, hydrogen, coal, bio-fuels and wind energy).

The engineering-manufacturing sector employs over 4 million skilled and semi-skilled workers. India's advantages in this sector are its large pool of skilled engineers and managers, competitive labor costs and availability of raw materials. Over 2,500 companies have ISO 9000 certification. The domestic market allows for economies of scale, and India has a diversified industrial base with supporting ancillary industries. Strong technological capabilities exist, particularly in certain sectors such as electrical machinery, process plant machinery and general-purpose machinery.

Both Indian and foreign companies have significant and growing operations in the engineering sector. These activities tend to focus on production for local and international markets, while R&D is often limited to adaptation to the local market. There are, however, examples of companies undertaking more substantive R&D and design activities in India to serve both local and international markets.

Some of the world's leading companies with major manufacturing operations in India include: ABB, General Motors, General Electric, Ford, Caterpillar, Toyota, Sony, Honda, LG, Hyundai, Siemens, Philips, Daimler Chrysler, Fiat and Lafarge-Europe.

The Indian automotive market has witnessed a rapid growth in the first decade of post-economic liberalization (1991-2001). Indian automobile firms have traditionally focused on value engineering or tweaking existing models for better performance. This has however been changing in recent years as Indian firms have expanded their R&D operations and are now coming up with new and more efficient models, to capture a better market share; TATA Motors and Mahindra & Mahindra being the prime examples. Furthermore, a large number of foreign MNCs now have significant operations in India. Key examples of expanding MNC with operations in India in the automobile sector include firms such as Daimler-Chrysler, GM, FIAT, Ford, Hyundai, Toyota, Volvo and GM. Most of these firms have expanded their component manufacturing sourcing activities in India. As of late, they have also begun to invest in software and other engineering related design and R&D.

In summary, in view of the revitalization of the manufacturing industry in India and the increased interest by multinationals to offshore manufacturing and engineering production and R&D, the country appears poised to become a major power not only in services but also in manufacturing. The large pool of qualified engineers and engineering research institutions points to offshoring-led engineering R&D which potentially could rival the software industry. Several Indian and foreign manufacturing & engineering firms are gradually expanding their design and R&D capacities. India's strengths in the software industry implies major opportunities in embedded software development, but the range of opportunities for cost-effective engineering industry R&D is indeed much larger than that for offshoring in the software development sector.

The world's leading MNCs with major manufacturing operations in India include: GM, GE, Ford, Caterpillar, Toyota, Sony, Honda, LG, Hyundai, Siemens, Philips, Daimler Chrysler, Fiat and Lafarge-Europe.

Box: Examples of foreign companies' offshoring automobile industry design and R&D work

General Motors. GM established its R&D laboratory (India Science lab) in Bangalore recently. The lab is to complement the research carried out by its major research facility in Warren, Michigan, USA. It will also undertake new exploratory research projects. General Motors India Science Lab is GM's second major research facility outside the USA. The Bangalore Lab was started with recruitments of one-third of its researchers from India. (Company website and Internet news flow as presented in FIIC 2005.)

*Daimler-Chrysle*r. The company through its Research and Tech group in Bangalore runs alliances with 10 IT majors in the country. Besides the 100 seat center in Bangalore it also carries out dedicated research for Daimler-Chrysler's global operations. In the case of Daimler-Chrysler, an R&D center in Bangalore has been set up. Initially focused on software development, it is now also involved in other engineering design work. The Daimler-Chrysler Research center in Bangalore undertakes research in the areas of encryption, image signal processing, telematics, fuel cell modelling, CAD, CAM, CAE and PDM, for the company's global requirements. In 2006 the company announced plans to significantly expand Indian research center operations, assisting groups in design and technology upgrading. Similarly, the group's outsourcing of components like motors and crankshafts from India is also expected to grow (Vibhav Nuwal, Daimler-Chrysler to step up India R&D outsourcing Feb 13, 2006, India, News Services).

Bosch. The software division develops software solutions for Bosch units in many countries including USA, Europe and Asia-Pacific. It is developing embedded software for control units, tools and diagnostics, as well as mechanical design services and shared service center accounting for Bosch operations worldwide (Nasscom 2005).

Swedish-related engineering companies expanding operations

Examples of Swedish-related companies with Indian-based operations covering sales, production as well as R&D include: ABB, Atlas Copco, Electrolux, Sandvik, SKF and Volvo.

ABB India had 8 manufacturing units, 26 marketing offices, 8 service centers and 3 training centers as of 2005 (Domain-b.com 2006). In addition to these, the company has a channel partner network numbering approximately 500 to facilitate market penetration for its standard products and services business. ABB constitutes an example of a company in which many people of Indian origin have held top management and technical expert positions in India as well as in Sweden and other locations. These individuals have often received education in Sweden.

ABB had nine corporate centers, one each in Finland, Germany, Poland, Norway, Sweden, Switzerland, the U.S., India and China as of 2005. The company's first R&D center in Asia was established in Bangalore in 2002 and focuses on the development of software-intensive products and systems (Singh, M. 2005). In September 2005, ABB announced plans to shift high-end engineering R&D from high-cost centers, such as from Germany and Sweden, to India. These centers focus on power technologies and automation. According to the plans, ABB will nearly double the number of engineers at its R&D center in Bangalore. ABB's total number of R&D employees will reach about 500 in 2006, and is expected to increase significantly in the coming years (Global Outsourcing 2005).

SKF opened its Application Development center (ADC) in Bangalore in 2004. Company officials have said the new facility will become a fully-fledged R&D center for the company over the coming years. Initially, ADC will focus on developing competencies in application engineering, product and system design, advanced calculation and simulation, and manufacturing of prototypes, testing and validation (Domain-b.com 2004).

Volvo Trucks India has expanded into sales and production operations. It has announced plans to invest about 332 million dollars in a new production facility in India. Moreover, in 2006, the company inaugurated its engineering and software development center in Bangalore. Volvo has plans to employ more than 200 engineers to work primarily on truck design engineering. The center will also support Volvo Group activities in the areas of IT and truck product development (Volvo Truck India 2006).

4.5 Agriculture, chemicals and material sciences

Agriculture is the means of livelihood for more than two-thirds of Indians. Billions of people in developing countries also depend on agriculture for their income. In such a scenario, R&D in agriculture is critical for mankind's overall development. R&D in food and agriculture ensures numerous benefits such as economic development of rural areas, increased productivity for global food security and better nutrition for low-income groups (FICCI 2005).

The fact that agriculture in India by and large has low levels of productivity points to a major scope for improvement. India has one of the world largest agricultural sectors in terms of land under cultivation and human resources. Major problems in agriculture are weak distribution and storage and lack of diffusion of existing knowledge on cultivation and other techniques, extension and various environmental issues. In addition, current scientific advances in agro-biotech offer major promises.

India has been engaged in agricultural research since its Independence. The problem of food security, immediately after Independence, forced the government to focus on agriculture research and promote the so-called green revolution. Related initiatives cover extension and lately greater efforts to tackle environmental issues. Over the years, India has not only become self-sufficient in food-grains, but has also started exporting a variety of agricultural products to other countries. Much further efforts are however needed to raise productivity in the agricultural and to tackle problems in the rural economy as a whole.

The Indian Council of Agricultural Research (ICAR) spearheads agricultural research in the country. The council is a part of the Ministry of Agriculture and supports numerous research organizations that are carrying out R&D in various disciplines including zonal studies, fisheries, animal genetics, animal husbandry, and plant genetics (FICCI 2005).

Over the past few years, India has been carrying out critical research in this field, which has the potential of making drastic improvements in the lifestyles of billions of people. Technology intervention in production, processing, storage and distribution of agricultural products has the capability of reducing the risks involved in agriculture.

The agricultural sector is primarily based on private entrepreneurship but has been heavily regulated and including various subsidiary schemes. It is currently envisaged that the government will gradually liberalize the agricultural sector and the corporate sector will play a central role in what is envisaged to be a "second green revolution".

Furthermore, it should be noted that the Indian government has a long standing record in building R&D capacity in agriculture, chemicals and material sciences including industrial chemicals and nanotechnology. In recent years the government is increasingly pointing to the potential for the private sector to play an important role in these areas. The government is also supportive of promoting international collaboration in nanotechnology development and a wide range of other areas.

4.6 Business and knowledge processing industries

The number of large and small, foreign and Indian, companies focusing on higher-end BPO or KPO has been growing rapidly since the late 1990s. Growth areas include data search, integration and management services, financial and insurance research, biotech and pharmaceutical research, computer-aided simulation and engineering design, medical content and services, as well as remote education and publishing. According to Evalueserve's estimates, the global KPO market is expected to grow from 1.2 billion dollars in 2003 to 16 billion dollars in 2010. This corresponds to a 45 percent annual growth for KPO compared to 26 percent expected for the BPO segment (Evalueserve 2004 and 2005).

A number of benefits that be derived from offshoring and outsourcing of knowledge process services. Potentially, they can:

- enable enterprises to reduce design-to-market lead times,
- manage critical hardware efficiently,
- provide research on markets, competition, products and services,
- enhance organizational effectiveness in business administration, and
- provide help in dealing with rapidly evolving business scenarios.

Furthermore, the outsourcing solutions for high-end processes, unlike traditional BPO solutions that are commodity fixed-price solutions, are usually customized and value-based. It is often this customization that enhances the value proposition of KPO (Evalueserve 2004).

Examples of major foreign multinational companies with significant KPO operations in India are: A.T. Kearney, British Airways, Citibank, Deutsche Bank, General Electric, Goldman Sachs, Datamonitor, Fidelity, IBM, International Data Corporation (IDC), J.P. Morgan Chase, Lehman Brothers, McKinsey, Morgan Stanley, PWC, Reuters, Standard Chartered Bank, United Airlines and the Union Bank of Switzerland.

McKinsey & Company was a pioneer in setting a global R&D facility in Gurgaon (close to Delhi) in the mid 1990s. McKinsey's KPO operations in India date back to 1996 when it started a knowledge center in India. As of 2005 the firm's knowledge center in Gurgaon had 200 researchers servicing global markets. The firm plans to double this number.

Reuters largest data operation center is now in Bangalore. It had 1,100 employees in 2004 and the firm has announced plans to scale up the size of its Bangalore offshoring operations further and to move up the value added chain in BPO-KPO.

Morgan Stanley was one of the first examples of a foreign investment bank to set up a major global research center in India. Its Mumbai-based knowledge center began operating in 2003/04. As of 2005 it had 500 people working from its Mumbai center, providing high-end services for Morgan Stanley's world-wide investment banking services; including functions such as accounting, fixed income and equity market R&D. Being a first major in the niche, Morgan had significant advantages in the acquirement of high level professionals. Examples of other players who have moved in shortly after Morgan Stanley include Lehman Brothers (Mumbai) and more recently also Goldman Sachs (Bangalore).

J P Morgan Chase & Co, declared in 2005 that it plans to double its head count in India so that it will employ almost 4,500 graduates in India over the next two years. The new hires will work in the company's investment bank operations and deal with settling derivative contracts in the cities of Mumbai and Bangalore. The jobs involve ensuring derivative contracts are routed to their owners and payment is transferred.

Evalueserve constitutes an example of a new generation of India-based higher-end BPO focusing on the global provision of KPO services. The firm provides offshore-integrated global research solutions in the areas of business and market research, data analysis, investment research and intellectual property services to companies worldwide.

Evalueserve was founded in 2000 by two McKinsey partners of Indian and Swiss origin. The company has grown from 4 employees to over 850 in 2005 and plans to increase its headcount to 3,000 by 2008. The firm provides services like patent writing and evaluation and assessment of their commercialization potential for law firms and entrepreneurs. Its market research services are aimed at financial service firms, to which it provides analysis of investment opportunities and business plans. Another major offering is multilingual services. As of 2005 Evalueserve was the only firm in India that had a fully dedicated research and linguistic center capable of providing multi-lingual knowledge services in over 80 languages.

Other examples of Indian companies with major ambitions include IT majors such as Tata Consultancy Services (TCS). TCS is an example of a company with ambitions to develop not only delivery of software services but also more broadly management and strategic consultancy.

5 Networks, clustering and the diaspora

5.1 Networks and urban industrial cluster development

The Indian experience in offshoring and outsourcing of R&D by multinational and Indian companies illustrates the importance of networks and the virtual and proximity aspects of industrial clustering.

The complexity of research, coupled with the need for flexibility and constraining costs have led companies to partner with external entities to form innovation networks and clusters. Moreover, rapid R&D activity has flooded the markets with new products produced by blending different technologies. A single company typically does not have expertise in all the different technologies used in developing a particular product. Even leading companies such as IBM, Hewlett-Packard and P&G are finding it difficult and undesirable to carry out the entire spectrum of research required for their products on their own. In such cases, different entities with expertise in various technologies come together and conduct the research, with a mutual sharing of benefits. These entities, which may be companies, private and public research laboratories, universities, and even individuals, form innovation networks and clusters (FICCI 2005).

The rapid development of industrial clusters has been a central factor in the growth of the software and IT-enabled services industries in India, especially the export sectors of those industries. Early initiatives by the central governments to establish industrial parks were pivotal.

The successful development of the Santa Cruz Export Processing Zone (EPZ) outside Mumbai in the 1970s demonstrated the potential of IT services outsourcing to both foreign and Indian companies. This was followed by the central government's launch of the Software Technology Park India (STPI), which has proved successful in several major Indian cities; a prime example is the Electronic City in Bangalore which houses more than 100 Indian and foreign IT companies.

In the 2000s both the central and state governments, as well as the private sector, intensified efforts to develop industrial parks focusing on IT hardware and software, ITES, biotechnology and pharmaceuticals, including various initiatives to foster development of incubators for SMEs and research related ventures.

In the 1990s, large cities like Bangalore, Chennai, Delhi, Hyderabad, Kolkata, Mumbai, and Pune developed into significant IT industry hubs. Inspired by developments in these cities, almost all states in India are today developing software and ITES industry centers.

The success of STPs in several cities, coupled with the example of industrial clusters in other countries (China in particular), inspired the Indian government to take further steps to promote development through industrial clustering. These initiatives include reshaping the partly failing EPZ and launching a new special economic zones (SEZ) approach. In May 2005, the Indian Parliament passed legislation providing new tax and labor laws, plus other incentives for private investment in SEZs. As envisaged, the new SEZs will be larger in both scale and scope than the STPs and EPZ. These zones are intended to be engines for export-oriented growth in a wide range of goods and services industries. One of the objectives of the SEZ is to attract offshore outsourcing business, resulting in a large number of industry clusters serving global markets.[17]

Bangalore, Delhi, Mumbai, Pune, Hyderabad and Chennai have so far been the most preferred destinations for R&D in India. Factors such as the combined presence of foreign companies, research labs and educational institutes have made these locations attractive centers for R&D operations. The strength of the proposition to locate R&D activities to these cities has been demonstrated by continued, rapid corporate expansion in all of Indian's major industrial centers, despite the major local challenges of physical infrastructure bottlenecks, environmental degradation, high attrition rates, wage inflation and social problems.

5.2 The role of the Indian diaspora

The development of networks and high-tech industry clusters (in which virtual features are prominent) has been fostered by improved communication and the Internet in particular. Other central factors include the increased mobility of capital and human resources. The mobility of qualified and talented human resources within India and internationally has indeed been one of the prominent features of high-tech industry and R&D development in India.

The development of the software and BPO-KPO industry in India illustrates the importance of skills development and networks including diaspora networks. India's initial entrée into the software business has much to do with its access to a large pool of low cost human resources. Subsequently the country also developed a significant number of vendors capable of meeting high quality standards and conducting R&D. A key feature of Indian talent is that it is much more globally mobile than labor in general. Indians, (programmers especially) account in particular for more than 40 percent of the H1B visas (temporary work visas) issued by the United States to foreign talent (Khanna and Palepu 2001). Further, the Indian diaspora's, long-established success in the United States has played a central role in facilitating the flow of talent back-and-forth between India and the United States (Kapur and Ramamurti 2001).

Internationally, the "brain drain" debate has gradually been shifting towards a more prominent focus on "brain circulation", in which formal and informal cross-national networks of engineers and entrepreneurs can play a pivotal role in transferring technology, skills and capital to their country of origin. Such networks, coupled with the development of industry clusters, can promote high-technology development in the home country, sometimes more effectively than traditional forms of FDI (Saxenian 2002 and 2005).

The role of the Indian diaspora needs to be understood in a dynamic context. It is difficult to evaluate net losses or gain for India (and others), but the country is now in a position where its diaspora can be a major factor assisting in the development of knowledge-based industries and R&D activities in India by multinational companies.

[17] *The set up of large scale Special Economic Zones (SEZ's) in India, is designed to serve both domestic and export markets. They are envisaged to have world-class infrastructure with integrated real estate, power and transportation facilities, single window clearance approval and administrative processes, flexibility, internationally-competitive labor laws and transparency/clarity of governance (US CEO Forum 2005).*

While hard to measure, it can be argued that the Indian diaspora, in the past two decades, has made a larger contribution to international corporate R&D than Indians working in India itself. The Indian diaspora has played a pivotal role in attracting R&D activities to India, especially from the U.S., Canada, the U.K. and South-East Asia. The Indian diaspora's role in the U.S. R&D community is reflected by the large number of Indians in leading academic institutions and U.S. high-tech companies. In the U.S., Indians constitute 5 percent of medical doctors, 12 percent of scientists, 36 percent of the scientists in NASA, 34 percent of the employees in Microsoft, and 20 percent of the scientists at Intel (FICCI 2005).

Together with the Chinese diaspora, Indians are estimated to account for close to half of the IT industry-engineering workforce in Silicon Valley. Over the last decade, Indian engineers have started hundreds of technology businesses in Silicon Valley. These new immigrant entrepreneurs have generated jobs, exports, and wealth for the region, while simultaneously accelerating the integration of California into the global economy. About half the jobs outsourced by Silicon Valley companies are going to India, according to a 2005 survey carried out at Santa Clara University (Belotti 2005).

According to a survey that Anna Lee Saxenian made by counting surnames (for lack of a more accurate way to measure ethnic backgrounds), 3,000 of the technology firms created in the Silicon Valley since 1980 are run by Indian and Chinese entrepreneurs. Accounting for over 30 percent of the total number of technological start-ups, reaching 19 billion dollar in sales, and creating 70,000 new jobs in the local economy were companies that had at least one founder that was Indian (Saxenian 2002).

A survey by Merrill Lynch (2004) claimed that the 1.7 million-strong Indian diaspora in the U.S. included some 200,000 millionaires and the average income of the Indian diaspora was 60,993 dollars, compared to the U.S. national average of 38,885 dollars (Ministry of External Affairs 2001). Two-thirds of foreign born Indian-Americans have a university degree, i.e. three times the figure for the United States as a whole. Aproximately 44 percent of these immigrants hold managerial or professional positions. Around 80,000 Indian new students came to USA in 2005, this is more any other nationality, including Chinese (NSF 2006).

The Indian diaspora in the United Kingdom numbers more than 1.2 million and has a significant presence in healthcare, legal, accounting, financial and IT services and academia and includes several large international business leaders.

6 Growth scenario, local and global implications

6.1 Main findings on Indian-related developments

The examination of social and economic developments in India points to the fact that the country is poised to be one of the world's major powers both in terms of the size of the domestic market and in its international economic role. India also has the potential to emerge as a major power not only in terms of absorption of existing technology but also in R&D power. The country's principal strength includes its educated workforce, entrepreneurial talent and institutional infrastructure. Multiple considerations drive the expansion of multinational companies' R&D-related operations in India. Among the most important are the potentials for cost savings and access to technical competency and markets, along with a range of other factors.

India's emergence as a major economic, knowledge-based services and R&D power as discussed above will clearly have wide-ranging local and global consequences. These include direct, as well as indirect, effects on trade, investment, employment, the environment and trajectories for technological development.

The impact is poised to be significant in major sectors such as: information and communication technology; industrial manufacturing; construction and other engineering industries; agriculture and in the life sciences (covering pharmaceuticals, bioinformatics, medicine and healthcare). Furthermore, continued rapid growth is expected in IT-enabled service areas (e.g. business process outsourcing, including higher-end knowledge processing industry niches such as finance, accounting, insurance and education). This growth is spearheaded by developments in the software industry coupled with major investments in ICT hardware and telecommunications by both Indian and foreign companies. The knowledge processing outsourcing industry has considerable growth potential in a wide range of areas. It may well employ more individuals than traditional R&D operations within the next ten years.

While India is poised to continue to experience rapid economic and social development it is however essential grasp how and why this movement is constrained by a wide range of societal conditions, and that the pattern of economic development continues to be uneven. The country has traditionally scored poorly in areas such as personal income levels, R&D spending, education outcomes and ICT diffusion, if judged on a per capita basis, as large parts of the economy remain underdeveloped.

At the same time income levels are rising. The use of computers, telecommunications and the Internet, in addition to the number of people with higher levels of education, is already large in absolute terms and continues to grow rapidly. An increasingly larger share of the population is proficient in the English language and has a higher education, which makes them employable in competitive and internationally-oriented industries.

India's major cities are well ahead of the rest of the country in economic development. Their economies are growing rapidly and becoming increasingly integrated with the global knowledge economy, as demonstrated by high-technology industrial developments in Bangalore, Chennai, Delhi, Hyderabad, Mumbai and Pune.

In accordance with prevailing trends, India is highlighted as one of the world's major powers, both in terms of the size of the domestic market and in its international economic role. Furthermore, India has the potential to emerge as a major business processes, innovation and R&D power. The country's principal strengths include its educated workforce, entrepreneurial talent and institutional infrastructure. Multiple considerations drive the expansion of multinational company production and R&D operations in India. Along with a range of other factors, among the most important are the potentials for cost savings and access to technical competency and markets.

India is likely poised to continue to experience rapid economic and social development. However, it is important to note that this movement is constrained by a wide range of societal weaknesses, and that the pattern of economic development continues to be uneven. More effective and wide-ranging diffusion of existing technology coupled with improvement in management and organization in both goods and services sectors will remain key factors determining economic growth outcomes.

In many respects, India is still in an early phase of development in the areas of high-tech industries and international R&D. There exists considerable scope for building on strengths and tackling weaknesses in the national innovation system and corporate investment climate. Challenges include the critical needs of improving the physical infrastructure and the education system, laws and practices governing labor markets, taxation, land and real estate development, intellectual property rights and general functioning of government institutions at both the central and state level. Moreover, it is essential to build private-public partnerships, expand foreign investment and enhance the role of the Indian diaspora and other forms of international collaboration.

In short, from a perusal of contemporary trends, it follows that India can emerge as one of the world's principal centers for offshoring of knowledge processing, R&D and high-technology industry investment and trade within the next 10–20 years. It is, however, hard to predict the specific timing, scale and scope of these developments. Multinational companies and Indian parties are developing the capabilities of the country to undertake production-supportive and adaptive R&D and design work, as well as developing innovative means of undertaking knowledge processing work and R&D, in terms of serving both local and international market requirements. The cost of not having comprehensive strategies for developing the scope of economic and technology relations with India (and China) will prove to be significant, especially for companies with global aspirations.

Swedish industry has a long tradition of exporting to and producing goods locally in India. These activities have gradually expanded and now often include production as well as sales directed at both the Indian and other markets. Furthermore, since around 2003 there has been a significant expansion in R&D activities by Swedish companies in India. Indian private and public sector companies have a significant interest in acquiring technology from Sweden covering a wide range of areas. Indian companies are now increasingly active in seeking trade and offshoring business opportunities, including BPO and R&D.

Economic and technology relations between Sweden and India have gradually strengthened but lag when compared to ties with China and Japan. Trade and investment links however between the two countries are poised to expand substantially in the long-term. This applies to sales, production and R&D activities performed by Swedish companies in India, as well as Indian companies' operations in Sweden.

6.2 Medium and long-term outlook

Scenario for the next five years and beyond

The long-term consequences of India's (and China's) transformation from a minor to a major power in goods and services production, foreign trade and investment as well as R&D, entails the emergence of a new world economic order of which the full implications are hard to foresee (Mitra 1985a, 1985b and 2006b). Few analysts anticipated the rapid, export-oriented high-tech industry developments that have taken place in India since the 1990's. Similarly, it is difficult to predict the future with respect to corporate R&D.

The following principal scenario for development of R&D in India is based on the interviews conducted for this study and analysis of information and forecasts by various international business intelligence providers, government entities and industry associations. The emerging baseline scenario for India-based R&D in the next five to ten years entails the following[18] (Mitra 2007):

- Total R&D spending is likely to more than double in the five-year period from 2006 to 2010. Reflecting the low starting point, R&D investment (and output) levels in India are, however, not likely to match that of the G5 nations or China within the next 10 years. The number of patentable innovations of Indian origin is likely to continue to grow rapidly, albeit lagging behind that of larger industrial nations in absolute terms. Greater absorption of existing technology, improvements in industrial organisation and production processes coupled with innovation in entrepreneurship is likely to have a major impact – that is more so R&D indicators such as the increase in patents – on the growth of the Indian economy.
- Growth in R&D spending will be led by the corporate sector. Corporate R&D spending is likely to be significantly larger than government outlays.
- Foreign multinational companies will continue to be the principal driving force in high-end corporate R&D investments in India. R&D in the Indian corporate sector is

[18] The principal scenario is in line with the past five years' trends in economic growth and structural change in India as well as the country's economic and technology relations with the rest of the world. A significantly lower or higher scenario for R&D development would imply major diversions in these trends.
A higher scenario would entail a sustained high growth rates (50 percent or more) in R&D spending coupled with rapid progress in government S&T development policy, legal and regulatory environment, scale and scope of human research and institutional capabilities and external funding, including rapid growth in Indian and foreign companies R&D investments as well as venture capital funding. Large numbers of talented and qualified graduates and scientists decide to work in India.
A lower scenario would entail a significant decline in R&D spending by multinational companies in particular. This could imply that the country misses the chance to rapidly emerge as a major international R&D power. Examples of key constraining factors resulting from this outcome could be unfavorable developments in domestic political, security and geopolitical environments plus major shortcoming in efforts improve access to skilled manpower, appropriate physical infrastructure and external funding. In addition, an acceleration of the brain drain and an increased reluctance of the Indian diaspora to return to India would further support the lower scenario. As per prevailing trends, the low-end scenario is not a likely outcome (Mitra 2007).

also likely to expand, but the research intensity of both larger and smaller Indian companies is likely to continue to be low compared to leading foreign companies.

- Corporate R&D will expand rapidly in a wide range of areas, particularly in ICT, but also in biotechnology, pharmaceuticals, engineering and social sciences. The KPO sector including finance, accounting, law, and health and education services will also grow rapidly.
- Government-financed R&D will continue to focus on defense, space and nuclear power. Private-public sector partnerships are likely to become increasingly significant as government institutions become more commercially oriented.
- High-tech industry centers will be increasingly advanced in providing a wide range of services and products, and play a more substantive role in innovation. Bangalore, for example, has the potential to become an Asian version of the Silicon Valley in terms of software and IT-related industries production as well as in R&D.
- The Indian diaspora will strengthen its importance overseas as well as its links with India-based R&D activities. Its total contribution to global R&D is likely to continue to be larger than the output from India-based operations.
- Access to skilled researchers and engineers will constrain growth, resulting in higher wages and requiring more active efforts for offshoring both to and from India and greater efforts to attract skilled people to work in India. Both government and the private sector will need to make new investments in human resource development. Human resources are likely to be a principal factor constraining the prospects for continued rapid expansion of India-centric R&D.
- Both central and state governments will be exposed to increased pressure to launch and effectively implement major reforms such as improvements in the education system and research institutional infrastructure, to enable the development of world-class innovation-oriented industrial clusters, provide incentives for corporate R&D and further promotion of local and international partnership initiatives
- The interface between the corporate sector, government and non-government organizations, including the role of local and global formal and local networks, is likely to develop in scale and scope, enabling major progress in India-related R&D and in innovation.

6.3 Global and local implications

Wide-ranging global and local implications

The scale and scope of India's international economic and technology relations are likely to have an increasingly global reach, both in advanced industrial economies and in developing countries. In addition to North America and Europe, the ties between India and China (and other Asian countries) are poised to become more important, especially for India. The long-term implication of India's (and China's) transformation from minor to major power in production and trade in a wide range of goods and services as well as R&D activity will eventually entail the emergence of a new world economic order (Mitra 2007).

In the 2000s, much international attention focused on Indian exports of software and other services and the revitalization of the manufacturing sector as illustrated by the offshoring of automobile components. Exports of both goods and services are likely to continue to grow. At the same time, as the Indian domestic economy becomes larger, much of the multinational companies' efforts will focus on selling to the Indian domestic market.

Multinational companies are likely to continue expanding the scale and scope of their high-tech sourcing and India-centric R&D and KPO operations in the next five years and beyond. It is probable that U.S. and British companies will continue to play principal roles in offshoring to India. Other OECD countries are likely to catch up in this process but several European countries risk lagging behind in realizing the potential benefits of India-based corporate R&D.

There is a high probability that the Indian diaspora will continue to augment their role in R&D in major industrial countries. The U.S., Canada, U.K. and South East Asia are in strong positions to utilize their links to the Indian diaspora. Countries without a significant diaspora or countries that are non English-speaking will have a disadvantage in developing R&D and KPO ties with India.

Competition for highly skilled and talented individuals is likely to be increasingly intensive globally. Long-term projections point to continued shortages of researchers in Europe and the U.S. coupled with the rapid expansion in higher education in developing countries. This implies a major opportunity for India and its diaspora to expand its role in R&D.

According to the estimates of the European Commission, countries in the European Union will require an additional 700,000 researchers by 2010. Nearly 50 percent of the present R&D workforce in the U.S. will become eligible for retirement by 2012, according to the United States Bureau of Labor Statistics.

6.4 India-China comparisons

As in the case of China, India's principal advantages in developing R&D capabilities are its rapidly growing educated workforce, the role of the Indian diaspora, a low-cost environment for production and R&D, and access to large markets. China is ahead of India in per capita income, size of the domestic market, growth of foreign direct investment and high-tech trade. China has also been ahead in designing and implementing policies that can attract foreign direct investment and boost exports, the establishment of a large number of well-endowed science parks, large scale and generally rapidly implemented public sector investment in physical infrastructure, higher education and R&D. Also, several public sector enterprises have expanded rapidly in ICT, space and aviation and other high-technology industries. This has been coupled with a wide range of efforts to ensure that foreign companies have R&D operations in China and to attract qualified Chinese students and professionals overseas to return and to boost English language education in China. Developments towards greater integration in the international economy have concurred with an ideology of determined political, economic and technological nationalism (Mitra 2007).

India on the other hand has certain advantages, such as a long standing dynamic private sector and entrepreneurial class covering a wide range of sectors, the availability of well-educated individuals with English language competencies coupled with a long tradition of close cultural, economic and technology ties with advanced western nations. Indian individuals have proved successful working in international teams and adjusting to foreign cultures. India also has a more favourable track record in corporate-competition law, intellectual property rights legislation and systems for enforcement, maturity of financial structures, established democratic institutions and practices and a rapidly advancing export-oriented software and KPO industry (Mitra 2007).

From a corporate strategy perspective, the issue is not whether priority should be given to India or China – offer major markets, production and technology development opportunities in goods as well as services sectors. Both are poised to be major economic and technology powers. It is, however, hard to predict how the development of international corporate R&D in the two countries will unfold and which country's performance will exceed the other in the long term. The conclusion is that R&D development in China as well as in India deserves close attention, as both economies (and their diasporas) are likely to be major R&D powers within the next 10–20 years (Mitra 2007).

7 Swedish-Indian economic and S&T relations

7.1 Economic, education and S&T relations

Economic relations are becoming increasingly multidimensional

Economic and technology relations between Sweden and India have gradually strengthened, but lag behind countries like China and Japan. Trade and investment links between Sweden and India are poised to expand substantially in the long-term. This also applies to R&D activities by Swedish companies in India. In addition, Indian companies' operations in Sweden, and other European countries, are also on the verge of more substantive expansion, implying a new phase of development of economic and technology relationships.

Swedish exports of goods to India amounted to 935 million dollars in 2005 (0.7 percent of Sweden's total exports) while imports stood at close to 395 billion dollars (0.4 percent of total imports). In 2006 Swedish exports had risen to 9,887 million SEK (0.9 percent of total exports) compared to 6,983 million SEK in 2005 (Statistics Sweden 2006). While incomplete in coverage, official trade statistics point to significant expansion compared to the 1990s but the recorded trade shows significant annual fluctuations and is still small compared to the total trade volume of the two countries. This also holds true for foreign investment, license and royalty fees.

According to data published by the Central Bank of Sweden, Swedish FDI to India amounted to 57 million dollars between 1994 and 1998, and 109 million dollars between 1999 and 2003. Swedish companies employed about 7,200 people in India in 2003, according to data compiled by the Swedish Institute for Growth Policy Studies (ITPS). A broader definition including all Swedish-related companies, as well as outsourcing to Indian companies, results in a significantly larger figure. While no more comprehensive data is available, it is reasonable to assume that the total number employed in Swedish-related (broadly defined) corporate activities in India has grown significantly since the 1990s and reached almost twenty thousand around 2006.

Swedish and Indian official data do not show the full complete picture of trade, investment and employment, R&D and other forms of S&T collaboration. Typically, data on foreign trade and investment and specific R&D developments are incomplete and underestimated.[19] In short, official data does not allow for accurate analysis of economic relations

[19]*Firstly, many trade developments, particularly the trade of services, are not fully accounted for in official Swedish or Indian statistics. Many Swedish imports are not reflected in trade data since transactions occur via other EU countries.*
Secondly, according to data published by the Central Bank of Sweden, Swedish FDI to India amounted to 57 million dollars in 1994–1998 and 109 million dollars in 1999–2003. These figures are incomplete. Swedish FDI data does not include Swedish-related investment to India channeled through other countries. In addition, the expansion of Swedish companies in India is often financed locally, for example by re-investing profits and raising funds from the stock market or other local sources. It should be noted that Swedish-related companies in India have, in many cases, grown through acquisition of Indian and foreign companies operating in the country.
Thirdly, existing data on Swedish companies' employment in India (and other countries) is compiled by the ITPS on a bi-annual basis. This data has several limitations, namely that it covers only Swedish-subsidies and does not include full information on all Swedish-related companies and thus the Swedish ownership share as reported is relatively low. This implies that Sweden-related companies (e.g. ABB and AstraZeneca) are excluded from the data along with entities in India,

and R&D ties between the two countries. Therefore, an analysis of corporate R&D relations must be supplemented by company-level case studies.

The development of the ties between the two countries is reflected in a number of domains. The Swedish Trade Council has developed New Delhi operations and opened an office in Bangalore in 2006. The Sweden-India Business Council (SIBC) was established in 2003 as a result of initiatives by the Swedish government and the private sector. An agreement (MoU) was signed between the Confederation of Indian Industry (CII) and the Confederation of Swedish Enterprise. The SIBC was entrusted with the responsibility for the development of opportunities and activities between the parties. The SIBC cooperates in Sweden with the Swedish Trade Council, the Import Council and ministries, amongst others (Swedish Trade Council 2006 and SIBC 2006).

Science and technology collaboration poised to develop

The Royal Academy of Science (IVA) and Invest in Sweden Agency (ISA) have begun to give more attention to India. The Swedish International Development Cooperation Agency (SIDA) places major emphasis on S&T collaboration in the areas of the environment, ICT and biotechnology, as per SIDA's India country strategy as presented in 2005.

Potential areas for expanded commercial relations between Sweden and India, as identified by those interviewed for this study, include:

- Infrastructure: power generation and transmission, road and rail transport, airports, seaports, inland waterways, shipyards, water & sanitation systems
- ICT: telecommunications, IT and software services, software and hardware product development, E-commerce, Internet banking, E-security and E-government
- Life science related: biotechnology, bio-informatics, pharmaceuticals, healthcare products and services
- Social sciences related: financial, insurance, education, publishing, advertisement and other BPO-KPO services
- Environment technology: hazardous waste, air pollution management and others
- Mining, steel and other metal industries
- Forestry, pulp, paper and packaging industries
- Agriculture and food industries
- Automotive parts, components and design
- Urban development such as city planning, real restate and industrial parks
- Interior design products, sports goods and outdoor equipment
- Defense, aviation and the space industry.

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which de facto are controlled by Swedish interests but in which the Swedish party is a minority shareholder. Also, the data does not cover contracted or outsourced functions that are central to the software industry for example. Finally, it should be noted that it is hard to determine the sector composition of employment. For example, employment in ICT in India by a non-ICT company (as classified in Swedish statistics) is not recorded as ICT-related employment.
Fourthly, many corporate and other R&D-related operations are untraceable in official statistics, as they take place in the form of training, contracts, strategic alliance or outsourcing arrangements.

The interest in strengthening S&T collaboration between Sweden and India has gradually become more pronounced in several of the areas listed above. The Swedish and Indian governments signed a bilateral S&T agreement in December 2005 which is envisaged to result in high-level commitment to cooperate through joint-research, greater academic exchanges and to facilitate industrial R&D (Government of Sweden 2005). An Indo-Swedish steering committee is to periodically review the progress and provide policy directions for the cooperation.

According to the memorandum of understanding (MoU) for development of S&T ties between the two countries, collaboration efforts will be directed to promoting cooperation and contacts between multiple Swedish and Indian stakeholders. The MoU points to the fact that the following options should be explored: (i) to extend and strengthen the Swedish research links by particularly welcoming proposals from the fields of biotechnology, ICT and the environment and the program is generally open to all areas of research as well; (ii) to encourage cooperation and contacts between Indian and Swedish research councils and; (iii) to explore the possibilities for a wide range of research cooperation in the above-mentioned areas.

The choice of areas for scientific projects collaboration will be made in consultation with the Swedish Research Council. Research projects in the environmental field will be selected in consultation with the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning and projects in the field of research and development will be selected in cooperation with the business sector and the Swedish Agency for Innovation Systems.

Possible areas of joint research cooperation in the environmental field might include the sustainable use of renewable natural resources and ecosystems, strategies to reduce air pollution, and the development of biological pesticides to replace the use of traditional, environmentally hazardous chemicals in agriculture.

University research, education and diaspora links strengthening

While the number of Indian students and researchers in Sweden is small, it has grown. Indian nationals undertake higher education in Sweden, especially in IT and engineering. Some remain in Sweden after graduation but many reallocate to other European countries, North America, or return to India. Compared to the U.S., it appears that Swedish companies and research institutions find it hard to retain highly-qualified Indian graduate students and professionals. Reasons for this include: language and other cultural issues, weather conditions, migration barriers and tax incentives. Nevertheless, several individuals of Indian origin have made significant contribution to Swedish academic institutions, held high-level positions in Swedish companies, both in Sweden and India, and have – in some instances – been central to developing economic and technology relationships between the two countries.

All major Swedish universities have India-related R&D activity. Examples include the Royal Institute of Technology (KTH) in Stockholm which has established closer collaboration with the Indian government and universities. The Karolinska Institutet Medical University in Stockholm signed a MoU with Indian parties in 2006 to further develop collaboration in research and education. The Swedish South Asian Studies Network was launched in 2001 at Lund University (SASNET 2006). The aim is to encourage and promote an open and dynamic networking process in which Swedish researchers cooperate with researchers in South Asia and globally.

7.2 Corporate development expansion

Increasingly multi-facetted corporate operations

The Swedish manufacturing industry has a long tradition of exporting to and producing goods locally in India. The scale and scope of these activities have gradually expanded and now often include production as well as sales directed at both the Indian and other markets (Mitra 1986). Furthermore, since around 2003, there has been significant expansion of R&D activities by Swedish companies in India. Several multinational Swedish-related companies now have both adaptive R&D to serve local market requirements and innovative R&D that is mostly aimed at global markets.

The following companies have established and expanded significant R&D operations in India in the 2000s: ABB, AstraZeneca, Ericsson, Sandvik, SKF, Telelogic AB and Volvo. Alfa Laval and Atlas Copco are well-established players in the Indian market but do not conduct significant R&D in the country. Svenska Handelsbanken decided to open a representative office in India in 2006 and thereby becomes the first bank from a Nordic country to do so (Svenska Handelsbanken 2006). Swedish banks, accounting and management consulting firms and other services providers have little or no BPO-KPO operations in India. (For further information on Swedish companies Indian operations in ICT, pharmaceuticals and engineering see chapter 4 sections 4.2, 4.3 and 4.4, respectively.)

Large companies, such as Ericsson and ABB, dominate R&D activities in India. Major multinational companies are often well-placed to establish R&D operations as they already have significant sales and production operations in India. The situation is different for SMEs or newcomers. Swedish SMEs typically do not have significant production or R&D activities in the country. They tend to prefer to operate in North America or neighboring European countries, including the Nordic countries and Eastern Europe. They often lack the financial resources and local country knowledge required to set up in-house R&D centers in Asian locations. In some cases, they have encountered intellectual property rights issues associated with outsourcing arrangements. There are however, signs that SMEs are looking at India more seriously.

Indian private and public sector companies have a long history of buying technology from Sweden in a wide range of areas. In the first half of the 2000s there was a rapid expansion of these activities. Indian companies are increasingly active in seeking trade and offshoring business opportunities, including BPO and R&D.

Several Indian IT companies have established offices in Sweden in the last few years. They include large Indian IT companies such as Infosys, Tata Consultancy Services (TCS) and Wipro. In addition, several companies have established smaller operations, for example in ICT and KPO (Evalueserve and others). Several of the Indian companies with offices in Sweden or other European locations focus on drumming up business for offshoring to India and to source technology from Swedish companies. Indian biotechnology companies (including Dr. Reddy's laboratories) have begun to offshore R&D work to Swedish companies and the Indian company Biocon Ltd. is collaborating with the Royal Institute of Technology in Stockholm and the Swedish company Innate Pharmaceuticals.

Indian companies have begun manufacturing operations in Sweden and have also begun acquiring Swedish companies in recent years. An example of this is Bharat Forge's, India's largest forging company, acquisition of the Swedish Imatra Kilstra AB, a 1.3 billion dollar foundry company specializing in automobile and defense industry markets. In India Electrolux sold out most of its shares in Electrolux Kelvinator Ltd. India to the Indian firm Videocon in 2005 thereby making Videocon the largest home appliance producer in India.

In recent years, several Swedish companies have shifted their strategic perception of business opportunities in India. In the past, companies typically viewed India's market potential as limited and had little interest in Indian-based research. However, as the scale and scope for developing Indian-related business has expanded, India is increasingly seen as part of large companies' global business operations, including opportunities for offshored industrial production and service provision. Manufacturing industry trade and investment is expected to continue to grow and dominate the economic relations between the two countries but other areas, including R&D and BPO-KPO, have also attracted significant interest.

The Swedish-related companies' R&D operations in Asian economies (mainly China, India, Japan, Korea, Singapore and Taiwan) have been growing rapidly in the 2000s but are still in the nascent phase of development.

Swedish-related corporate R&D operations in India are expected to expand in software, telecommunication, engineering, pharmaceuticals and in other areas. Large companies like Ericsson plan further expansion of R&D operations in India, both in-house and outsourcing operations, as do engineering companies such as ABB and Volvo Trucks. The total number of people employed in R&D operations (broadly defined) by Swedish-related companies in India (both in-house and outsourcing) could potentially reach over 5,000 by 2010, compared to about 3,000 in 2006, and less than 100 in the early 1990s.

It is difficult to assess to what extent the expansion of Swedish corporate R&D operations in India (and other Asian economies) is occurring at the expense of activities in Sweden. In some cases, the expansion of R&D abroad might reflect the transfer of R&D activities from Sweden to India. In other cases, it is a new investment. The record of U.S. and British companies suggest that locating R&D abroad often is required to sustain competitiveness and can benefit all parties in the home and host countries (Mitra 2007).

Challenges and opportunities for companies in Sweden and India

Both Sweden and India have areas of comparative advantages in R&D, as demonstrated by well established research organizations and the existence of high-tech industry clusters and rich sets of networks. The future economic and technology development of both countries can significantly benefit from linking up these comparative advantages.

India has the potential to become one of the major centers of R&D and KPO operations for Swedish companies. Although R&D operations of Swedish companies in India are still small compared to that of their operations in Europe and North America, they can indeed be of major importance within the next 10 years.

Expansion of trade and investment (including offshored) operations can offer multiple benefits for Swedish and Indian firms, but is typically also related to management challenges. Consistent efforts, patience and pragmatic approaches are needed to tackle the opportunities and risks involved (Mitra 1986).

The "third country" effect associated with India's rise as an economic and technological power is likely to be significantly larger than a direct effect impacting on the Swedish companies (and its larger companies in particular). American and British corporations, for example, can gain advantages over Swedish firms in R&D as they can benefit globally from costing and competency advantages resulting from having R&D operations in countries such as India. Hence, it is essential for Swedish companies to explore various options to develop their international knowledge-based services and R&D operations – else they risk becoming uncompetitive and consequently marginalized in many areas.

Furthermore, it is important to distinguish between short and long-term developments. In the short term is not likely that India can be one the top economic and R&D partners for European countries such as Sweden. India's importance needs to be viewed in terms of its long term potential as a large market both for capital and consumer goods and as a center for a wide range of R&D operations. Larger Swedish-related companies need to be more involved with both India and China simultaneously -- as illustrated by Ericsson and ABB, who have R&D centers in both locations. The cost of not having comprehensive strategies for developing the scope of economic and technology relations with India (and China) will prove to be significant, especially for companies with global aspirations.

7.3 Policy implications

India needs to be viewed both in terms of its long-term potential as a large market for capital and consumer goods and as a center for a wide range of R&D-related activities. The rise of India as a more significant economic and technological power implies a need for making multiple efforts to develop the Swedish-Indian ties at a scale that is comparable to investments in other major emerging markets such as China.

India has the potential to become an increasingly important center for Swedish corporate knowledge-based services and R&D operations in the next 10 years. Sweden and India have areas of comparative advantage in R&D, and both countries can significantly benefit from connecting these environments. Patient, consistent and pragmatic approaches are needed to handle the opportunities and risks involved and to harness India's potential as one of the important centers for the R&D operations of Swedish companies.

Considerable progress has been made in developing Swedish-Indian economic and technological ties. The efforts of Swedish corporate, government and academic institutions to develop links with India have, however, been modest compared to the attention given to China and Japan for example. Moreover, many Swedish companies have no significant experience with India-related R&D operations, and Sweden is behind other industrial nations in terms of educational exchange and academic collaboration with Indian institutions.

Continued concerted effort is required to invigorate S&T links between India and Sweden. This includes the implementation of a coherent S&T development strategy involving a range of key actors. Concrete measures are required from both Swedish and Indian governments, academic and corporate stakeholders to expand S&T collaboration between the two countries. It can also be argued that Sweden needs to be more active in European Union (EU)-India related initiatives, such as the EU-India cooperation in the Seventh Framework Program, for example (see appendix).

The development of international R&D ties with India has to be understood in the broad context covering a nexus of economic, technology, education, cultural and political relations. It is essential to promote academic and private partnerships with Indian companies, universities and other R&D oriented institutions. Development of educational and scientific exchange programs and nurturing ties with the Indian diaspora are all important strategies for fostering R&D ties between the two countries.

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Based on the findings in this study, a number of initiatives can be considered to enhance economic and technological relations between Sweden and India. The efforts from the Swedish side could include the following:

1 Strengthening the monitoring, dissemination and promotional activities covering economic, cultural and S&T developments in India in order to develop Swedish-Indian relations. This would enable developing a comprehensive strategic agenda for the long-term development of economic and S&T relations and assignment of responsibilities to key actors, such as corporate stakeholders, the Swedish Embassy, the Swedish Research Council, the Swedish Governmental Agency for Innovation Systems, ITPS, ISA, the Swedish Trade Council and others.

2 Strengthening education ties and partnerships in skill development such as joint sponsorship of selected training institutes. Strengthening links in higher education by making it more attractive for Indian students and researchers to work in Sweden and vice versa. Improving the use of various exchange programs and developing alumni networks of Indians who have studied at Swedish universities.

3 Strengthening research collaboration under the official bilateral S&T agreement and supporting the development of public- and private-sector partnerships, such workshops, exchange fellowships, and joint research projects. Complementing bilateral efforts to strengthen R&D collaboration with development, as well as improved utilization of existing multinational programs including EU-India R&D related cooperation initiatives, like the Seventh Framework Program. Strengthening corporate-led commercial and R&D-related collaboration efforts between Swedish and Indian entities, which include large and small companies in both Sweden and India. Considering regular frameworks of joint Swedish-India CEO or industry association forums to identify and monitor concrete priority initiatives that can help develop economic, financial, and technological ties between the two countries.

4 Strengthening collaborations especially in critical technology areas such as software and telecommunications, biotechnology and bio-pharmaceuticals, infrastructure, including the development of high-technology industrial parks, energy, environment, governance and institutional development, legal and regulatory regimes, including IPR implementation and enforcement and building a “patents” culture.

Finally, it is important to foster in-depth understanding of the nexus of economic and technology-related developments in India and its international context. It is essential to move beyond fact-finding and general discussions, to move from words to deeds. It will indeed require persistent effort with appropriate high-level endorsement and warranted funding to make the significant expansion of economic, science and technology collaboration between foreign and Indian parties a reality.

Appendix 1. R&D institutions in India

Central Government
Department of Science and technology
Department of Scientific and Industrial Research
Council for Scientific and Agricultural Research, New Delhi
Department of Atomic Energy
Indian Space Research Organisation
Department of Biotechnology
Department of Ocean Development
Defence Research and Development Organisation
Indian Council for Agricultural Research
Indian Council of Medical Research, New Delhi

Others under Central Government
Tata Institute of Fundamental Research
Babha Atomic Research Center

Institutions working under Council for Scientific and Industrial Research (CSIR)
Central Drug Research Institute
CSIR for mathematical modeling and Computer Simulation
Central Electronic Engineering Research Institute
National Institute of Oceanography
Center for Cellular and Molecular Biology
National Aerospace Laboratories
National Institute of Ocean Technology
National Institute of Mental Health and Neuro Sciences

Public Sector
Bharat Heavy Electrical Ltd.
Oil and Natural Gas Corporation Ltd.

Private Research Centers
Raman Research Institute
Dabur Research Foundation
L V Prasad Eye Institute
Biocon
DR. Reddy's lab
Sun Pharmaceuticals Industries ltd.
Reliance Life Sciences
Sankara Nethralaya

Higher Education
Indian Institute of Science
Indian Statistical Institute
Birla Institute of Technology and Science
Indian Institute of Technology, Delhi
Indian Institute of Technology, Mumbai
Indian Institute of Technology, Khargpur
Indian Institute of Technology, Guwahati
Indian Institute of Technology, Madras
Indian Institute of Technology, Roorkee
Indian Institute of Technology, Kanpur
All India Medical Sciences

Autonomous Research Institutes
Sree Chitra Tirunal Institute of Medical Sciences and Technology
Agharkar Research Institute
Bose Institute
Indian Association for the Cultivation of Sciences
Indian Institute for Tropical Meteorology
Indian Institute of Astrophysics
Jawaharlal Nehru center for Advanced Scientific Research
Raman Research Institute
S. N. Bose National center for Basic Sciences
Birbal Sahni Institute of Palaeobotany
Indian Institute of Geomagnetism
Wadia Institute of Himalayan Geology

MNC's with R&D center in India
(Authors illustrative examples only, see further examples in main text)
ABB
ADOBE Systems
Ericsson
Ford
General Electric
General Motors
Google
HP Labs
IBM
Microsoft
Motorola
Novartis
Novell Software
Oracle
Pfizer
Philips
SAP
Sun Microsystems
Texas Instruments
Toyota Kirloskar Motor
Volvo

Source: Partly adapted from www.ficci.org. Authors note: List is illustrative only and does not claim to be complete.

Appendix 2. India's official international S&T collaborative arrangements

The central government international R&D collaboration has become increasingly ambitious in terms of bilateral, regional and multi-lateral program and new also includes emphasis on industrial R&D collaboration, the later including Japan for example.

The S&T International Cooperation Division of the Department of Science & Technology (DST) deals with the international scientific and technological affairs including the negotiations and implementation of international S&T cooperation agreements and responsibility for scientific and technological aspects of activities of international organizations. Cooperations are sought under bilateral, multilateral or regional framework modes for facilitating and strengthening interactions among governments, academia, institutions and industries in areas of mutual interest. The Division operates in cooperation with the Ministry of External Affairs, Indian missions abroad, foreign embassies in India and United Nations institutions.

The international S&T cooperation is being carried out in the following types of arrangements:

I. Bilateral Programs[20]

With developed countries

- Cooperation in the form of exchange of scientific information and scientific personnel
- Organization of joint workshops and exhibitions
- Fellowships
- Implementation of joint R&D projects
- Establishment of Centers of Excellence
- Encouragement for commercialization of scientific results leading to technology transfer and establishment of joint ventures

With developing countries

- Training for Young Scientists
- Fellowships
- Cooperation in the form of exchange of scientific information and scientific personnel
- Organization of joint workshops and exhibitions
- Implementation of joint R&D projects

[20]*As of 2006 India had bilateral S&T cooperation agreements with the following countries or regional groupings: Argentina, Armenia, ASEAN, Australia, Bangladesh, Belarus, Brazil, Bulgaria, Canada, China, Cuba, Egypt, European Union, France, Germany, Hungary, Indonesia, Iran, Israel, Italy, Japan, Korea (DPR), Kazakhstan, Laos, Malaysia, Mauritius, Mexico, Mongolia, Mozambique, Myanmar, Nepal, Oman, Peru, Philippines, Poland, Portugal, Republic of Korea, Romania, Russia, Singapore, South Africa, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Taiwan, Tajikistan, Thailand, Trinidad & Tobago, Tunisia, Ukraine, United Kingdom, United States, Uzbekistan, Venezuela, Vietnam, Yemen and Zambia.*

- Establishment of scientific infrastructure

With CIS countries

- Joint Programs of cooperation in selected areas of mutual interest
- Exchange visits
- Joint seminars/workshops/exhibitions
- Fellowships
- Transfer of advanced technologies and their adaptation to Indian Conditions with subsequent commercial exploitation

II. Regional Programs

- SAARC (South Asian Association for Regional Cooperation; members India, Nepal, Bangladesh, Pakistan, Sri Lanka, Maldives and Bhutan)
- BIMSTEC (Bay of Bengal Initiative for Multi-sectoral Technical and Economic Cooperation; members Bangladesh, India, Myanmar, Sri Lanka and Thailand)
- IBSA (India, Brazil and South Africa)

III. Multilateral Programs

- IOR - EC (INDIAN OCEAN RIM)
- TWAS
- UNESCO
- UNDP
- NAM
- STEPAN (Science & Technology Policy Asian Network)

Source: Ministry of Science & Technology, Department of Science & Technology, Government of India (2006).

Appendix 3. Trade between India and Sweden

	2001	2002	2003	2004	2005	% Change 2005/2004
SWEDISH EXPORTS (SEK 1000)	**3 711 104**	**6 247 194**	**7 111 140**	**8 296 143**	**6 983 131**	**-16**
SHARE OF TOTAL SWEDISH EXPORTS (%)	0.5	0.8	0.9	0.9	0.7	
FOOD	834	1 395	4 689	6 135	4 866	-21
RAW MATERIALS; FUELS	202 547	200 928	242 055	163 494	419 880	157
WOOD	170	196	29	176	527	199
PAPER PULP	101 977	112 341	47 876	69 498	209 500	201
ORES	93 191	86 484	187 883	86 568	203 148	135
FUELS	780	987	1 292	1 053	935	-11
CHEMICAL PRODUCTS	238 608	220 697	227 594	285 250	285 197	0
PHARMACEUTICALS	37 680	20 384	23 620	8 976	21 158	136
SEMI-MANUFACTURES	375 974	547 276	619 323	747 876	962 281	29
PAPER AND BOARD	93 946	142 647	196 387	181 629	180 999	0
WOOD MANUFACTURES	2 451	1 599	3 449	6 378	7 203	13
PREFAB BUILDINGS	0	0	0	6 358	7	-100
IRON AND STEEL	223 313	335 103	328 240	435 080	644 151	48
NON-FERROUS METALS	19 933	25 364	42 969	70 773	70 469	0
ENGINEERING PRODUCTS	2 481 815	3 519 058	4 965 055	5 542 284	4 126 049	-26
TOOLS	47 893	47 294	45 189	44 783	39 321	-12
MANUFACTURES OF METALS N.E.S	12 949	17 055	29 938	36 412	46 786	28
POWER GENERATING MACHINERY	74 540	68 279	77 349	171 162	189 015	10
AGRICULTURAL MACHINERY	2 044	3 462	4 300	7 017	3 698	-47
CONSTRUCTION AND MINING MACHINERY	127 783	105 149	60 491	72 771	73 761	1
PAPER AND PULP MILL MACHINERY	48 845	78 766	31 358	44 410	25 967	-42
MACHINES FOR SPEC INDUSTRIES N.E.S	66 889	79 991	113 021	126 793	144 178	14
METAL-WORKING MACHINERY	41 324	29 482	43 183	82 188	154 776	88
HEATING AND COOLING EQUIPMENT	53 909	62 366	63 180	74 405	124 193	67
PUMPS AND CENTRIFUGES	30 493	35 300	22 505	33 622	52 254	55
MECHANICAL HANDLING EQUIPMENT	29 996	14 702	88 695	64 119	87 771	37
PNEUMATIC ETC. HAND TOOLS	1 554	998	1 544	1 358	1 444	6
BALL OR ROLLER BEARINGS	4 553	7 268	18 650	37 673	61 010	62
NON-ELECTRICAL MACHINERY N.E.S	41 599	73 824	49 410	76 943	115 042	50
OFFICE MACHINES, ADP EQUIPMENT	28 686	47 165	30 466	35 537	82 465	132
TELECOMMUNICATIONS APPARATUS	1 417 445	2 340 741	3 469 245	3 842 990	2 193 544	-43
EQUIPMENT FOR DISTR ELECTRICITY	143 433	284 148	625 895	512 283	311 032	-39
APPARATUS FOR DOMESTIC USE	12 353	10 690	1 447	928	1 239	34
MEDICAL INSTRUMENTS, APPARATUS	52 750	37 853	18 612	27 968	56 242	101
ELECTRICAL MACHINERY N.E.S	44 897	28 384	40 005	25 284	34 789	38
PASSENGER CARS	4 088	4 640	1 803	1 593	2 965	86
LORRIES, TRUCKS AND BUSES	0	5 754	1 376	0	13 975	
PARTS FOR MOTOR VEHICLES	101 744	68 636	68 057	138 569	177 939	28
SHIPS AND BOATS	0	47	0	0	0	
TRANSPORT EQUIPMENT N.E.S	2 425	226	6 405	7 399	1 906	-74
SANITARY ETC. AND LIGHTING EQUIPMENT	135	418	207	214	531	148
SCIENTIFIC ETC. INSTRUMENTS	80 655	65 664	50 959	73 766	125 616	70
OTHER MANUFACTURED GOODS	411 327	1 757 841	1 052 424	1 551 105	1 184 858	-24
FURNITURE	422	1 491	11 406	1 656	734	-56
CLOTHING	2 217	1 893	2 629	674	553	-18
SWEDISH IMPORTS* (SEK 1000)	**2 150 086**	**2 052 742**	**2 275 578**	**2 320 239**	**2 954 918**	**27**
SHARE OF TOTAL SWEDISH IMPORT (%)	0.3	0.3	0.3	0.3	0.4	
FOOD	129 513	123 057	83 105	98 233	77 513	-21
RAW MATERIALS	6 678	31 247	30 852	19 450	11 779	-39
FUELS	0	0	0	284	57 059	
CHEMICAL PRODUCTS	88 143	44 549	39 202	45 569	61 235	34
SEMI-MANUFACTURES	857 405	758 448	786 228	820 231	1 113 397	36
ENGINEERING PRODUCTS	248 945	254 244	393 568	441 783	593 060	34
OTHER MANUFACTURED GOODS	819 402	841 197	942 622	894 689	1 040 874	16

**Import figures refer to country of origin. Figures for 2005 are preliminary.*

Source: STATISTICS SWEDEN adapted from Swedish Trade Council trade profile for India.

Appendix 4. Sweden-India Business Council members

ABB
Affärsstrategerna Capital Partners
Assa AB
AstraZeneca AB
AUTOLIV INC.
BMH Marine AB
Brim AB
CapGemini Sverige AB
Eka Chemicals AB
Electrolux AB
Evalueserve AB
Flextronics Network Services Sweden AB
GE Healthcare Bio-Sciences
HCL Technologies Sweden AB
IBS publ AB
Indiska Magasinet AB
Interkulturell Utbildning ACS
Kungsörs plast AB /KPS Petrol Pipe System
Lufthansa
MarkoTel HB
Mobitec AB
NovAseptic AB
Patni Computer System LTD
Perstorp Specialty Chemicals AB
Price, Waterhouse Coopers
Rocket Science AB
Sanson I.B.C. International AB
SCA Hygiene Products
SEB
SKANSKA
Smarttrust AB
Svensk Handel
Svenskt Näringsliv
Swede Rail AB
Swedmec AB
SWS Defence AB
Techno Transfer International Ltd
Västsvenska Industri- och Handelskammaren
Wipro Technologies
Advokatfirman Delphi & Co
Albihns Malmö AB
Assistia AB
Atlas Copco AB
Bird & Bird Advokatbyrå AB
Bombardier Transportation Sweden AB
Business Region Göteborg AB
DeLaval Holding AB
EKN
Elite Hotels of Sweden AB
Exportrådet
Foss Analytical AB
Hagströmer & Qviberg Fond i Fond
Hepp Film AB
INDCEN resor
Innate Pharmaceuticals AB
Klar Kommunikation Svenska AB
LM Ericsson
Make IT in India AB
MGgruppen
Nova Electronics Development AB
OM Technology
Personal Computer Quality Technology AB
Pointsec Mobile Technologies AB
Q-Med AB
Saft Batteries AB
SAS AB
Scania CV AB
Simplicity AB
SKF AB
Svensk Exportkredit AB
Svenska Handelsbanken
Swedbank
Swedfund International AB
Swedtel AB
Tata Consultancy Services
Telelogic AB
Volvo AB

Membership list as of November 2005. Source: SIBC 2006.

Appendix 5. India-European Community collaboration

The Sixth India-EU Summit was held in New Delhi on 7th September 2005. One of the important outcomes of this summit was the endorsement by India and the EU of a Joint Action Plan. The Joint Action Plan provides for intensified political dialogue and cooperation, with a view to meeting common threats and global challenges, starting with terrorism. India and the EU will also be intensifying their interactions in promoting effective multilateralism, strengthening UN peace keeping and peace building as well as in establishing an EU-India security dialogue on global and regional security issues, disarmament and non-proliferation. Furthermore, a major part of the Action Plan is devoted to intensifying economic dialogue and cooperation, trade and investment. It looks at specific measures to help enhanced trade and investment flows between India and the EU in various sectors. It also looks at ways and means of enhancing cooperation over several areas, including the social sector, science and technology, space, energy, clean environment development and climate change, information and communication technology and transport. The Action Plan also provides for dialogue on migration and consular issues as well as for educational cooperation through the facilitation of academic exchanges and civil society dialogue.

INCITE is funded by the European Commission under the IST (Information Society Technologies) program. On the basis of bilateral agreements between India and the EU, Indian organizations are fully eligible to participate within the funding schemes of the EU for R&D activities in the IT sector.

INCITE is a special EU program which provides impetus to R&D in the ICT sector. INCITE is the result of cooperation among 8 prestigious organizations in Europe and India. In India work is being carried out by IIIT-B (Indian Institute of Information Technology, Bangalore), IISc (Indian Institute of Science) and C-DAC (Center of Development of Advanced Computing) under the co-ordination of the ITSMA (Interactive Technology, Software and Media Association), a non profit organization established in 2002 with the objective of assisting in the development of the ICT and SMEs. To make cooperation between India and Europe easier and more beneficial to the Indian ICT sector, the project includes a large scale mapping of ICT actors in India that might be interested in co-operating in research projects with Europe. What they intend to do is to expose Indian IT excellence to a broad spectrum of cooperation opportunities and therefore enhance its potential in accessing European funds for R&D.

Furthermore, the European Commission launched a new project, the 'Academic Network for European Research related to India' (ANERI) in 2006. The project aims to strengthen the ties between the European Union and India. It also seeks to promote funding for specific types of India-focused research.

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Abbreviations, terminology and exchange rates

List of abbreviations and acronyms

AMD	Advanced Micro Devices
BCI	Business Competitiveness Index
BPO	Business process outsourcing
CAGR	Compounded annual growth rate
CII	Confederation of Indian Industries
CMIE	Centre for Monitoring Indian Economy
CSIR	Council of Scientific and Industrial Research
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DOD	Department of Ocean Development.
DoS	Department of Space
DSIT	Department of Scientific & Industrial Research
DST	Department of Science and Technology
EIU	Economist Intelligence Unit
EPZ	Export processing zone
EMRs	Exclusive marketing rights
FDI	Foreign direct investment
FICCI	Federation of Indian Chambers of Commerce and Industry
FII	Foreign Institutional Investment
FY	Financial year (starts from April 1st of one year and goes to March 31st of the next)
GE	General Electric
GCI	Growth Competitiveness Index
GDP	Gross Domestic Product
GM	General Motors
GNI	Gross National Income
GCP	Good Clinical Practices
IBM	International Business Machines
ICT	Information and communication technologies
IIM	Indian Institute of Management
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IIIT	International Institute of Information Technology
IPR	Intellectual property right
IT	Information technology
ITES	IT-enabled services
KAM	Knowledge Assessment Methodology
KEI	Knowledge Economy Index
KPO	Knowledge process outsourcing
MNC	Multinational corporations
MOU	Memorandum of understanding
NASSCOM	National Association of Software and Services Companies
NCAER	National Council of Applied Economic Research

NCST	National Center for Software Technology
NISSAT	National Information System for Science and Technology
NRI	Non-resident Indian
NSF	National Science Foundation
OECD	Organization for Economic Cooperation and Development
Offshoring	A company moves an activity abroad regardless of organizational form
Outsourcing	A company moves an activity to an external supplier
PhD	Doctorate in philosophy
PPP	Purchasing power parity
RBI	Reserve Bank of India
R&D	Research and development
S&T	Science and technology
SME	Small- and medium-sized enterprise
SEZ	Special economic zones
STPI	Software Technology Parks of India
TCS	Tata Consultancy Services
TIFAC	Technology Information, Forecasting and Assessment Council
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UGC	University Grants Commission
UNCTAD	United Nations Conference on Trade and Development
UNDP	United National Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USPTO	United States Patent and Trademark Office
USTR	United States Trade Representative
VLSI	Very large scale integration
WEF	World Economic Forum
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Exchange rates used for conversion to U.S. dollars

1 Swedish Crown (SEK) = 0.125 dollars

1 Indian Rupee (RS) = 0.023 dollars

1 U.S. dollar (USD) = 45 Indian Rupees

1 USD = 7.47 SEK