Information Technology Clusters in India

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Abstract. The Indian information technology (IT) industry is deeply entrenched in the key metros of India, giving rise to seven large IT clusters. The country's tier I cities Bangalore, Delhi, Chennai, Hyderabad, Pune, Mumbai, and Kolkata have all emerged as significant IT hubs. The seven IT clusters are different in their history, economic weight, activity base, anchor companies, business models, government role, and other driving forces. However, even as these cities are attracting IT investments and creating employment for thousands of citizens, the drawbacks of overstressed infrastructure, escalating real estate costs, and shortage of skilled IT professionals represent challenges for IT organizations. The paper substantiates the inevitability of the hardware and software sectors linked development at this stage. It is the first attempt to study the IT industry in India through the prism of the countrywise cluster development and combination of IT sectors – hardware design and manufacturing, IT services, software and research and development, and IT-enabled services for business process offshoring.

Keywords: cluster; software; information technology-enabled services; business process offshoring; hardware; India; innovation.

JEL classification: R12, L25, O18.

The evolution of growth in a country is traced by the Global Competitveness Index of the World Economic Forum by identification of three pillars: the quality of the macroeconomic environment, the state of the country's public institutions, and given the importance of technology and innovation, the level of its technological readiness. India was ranked 50th among 117 countries in the Growth Competitiveness Index for 2005–2006 (Lopez-Claros et al. 2005), moving up five ranks as compared with 2004–2005. The recent success in software industry in India is backed up by availability of scientists and engineers (rating number 1 among 117 coun-

tries), government prioritization of information and communication technology (ICT) (number 9), government success in ICT promotion (number 11), quality of scientific research institutions (number 17), and company spending on research and development (R&D) (number 27) (Lopez-Claros et al. 2005).

The information technology (IT) companies in clusters achieve tremendous productivity gains and cost savings that come from sharing of resources, transfer of knowledge and experiences, best practices, human resources, ready access to the specialized services, availability of infrastructure, and even the cooperative strength to build products for global markets. Research centers, universities, government officers, patentees, entrepreneurs, investors and marketers, industry associations network in these regional IT clusters in India.

The present research started with the hypothesis that IT clusters in India with their different historical backgrounds and driving forces are supposed to have different compositions of activities, economic weights, business models, value chains, and future prospects. The aim was to challenge the prevailing views limited only to software exports and crowning glory of Bangalore. Moreover, the existing literature has not reached any clear-cut conclusions on the number and localization of IT clusters in India, including their characteristics, advantages, innovation styles, and policy implications.

The paper will investigate IT clusters in India by examining various dimensions of clusters. Besides, the sectoral composition of the IT industry and the respective clusters is considered. This research is mainly conceptual with relevant theoretical and practical insights drawn from field studies conducted by the author in India in January and February 2006. The framework of cluster analysis is designed in accordance with works of Enright (2000) about dimensions of clusters and Kuchiki and Tsuji (2005) about flowchart approach to industrial cluster policy, emphasizing the importance of the ordering of policy measures. The flow of policy implementation is to establish an industrial zone, to invite an anchor company, etc.

There are four main sections following this introduction. The first section is devoted to an overview of the IT industry in India with details on the current status and sector composition. The second section provides an outline of competitive factors in the IT industry. The third section focuses on regional IT clusters in India with brief characteristic of the seven large IT clusters, namely, Bangalore, National Capital Region, Chennai, Hyderabad, Pune, Mumbai, and Kolkata. An analytical table concerning dimensions of IT clusters in India with relevant explanations is provided in the fourth section. Finally, I draw some conclusions.

IT industry in India

The history of IT the industry in India began in the 1960s with the emergence and dominance of public-sector electronic giants like Bharat Electronics Ltd (BEL), Electronic Corporation of India Ltd (ECIL), and Tata Institute of Fundamental Research. The recent software era has witnessed software exports growing from USD 22 million in 1984 to USD 12,200 million in 2003.

Therefore, the present research on IT clusters in India will be based on the recent classification of the IT industry by the National Association of Software and Service Companies (NASSCOM), which comprises IT services; engineering services and R&D, software products; IT-enabled services for business process outsourcing (ITES-BPO); and hardware (Table 1).

Software and services

The Indian companies are proactive in the following segments within IT services: project-oriented services (IT consulting, systems integration, custom application development and maintenance, network consulting and integration); IT outsourcing (IS outsourcing, application outsourcing, network infrastructure management); support and training (IT training and education, hardware support and installation, packaged software support and installation). Well-established companies like Microsoft, Cisco, Hewlett Packard,

Table 1. Composition of Indian IT industry

Industry segment	Revenues (USD billion) in:			
	2003–2004	2004–2005	2005–2006	2006–2007 [a]
IT services	10.4	13.5	17.8	23.7
Exports	7.3	10.0	13.3	18.1
Domestic	3.1	3.5	4.5	5.6
ITES-BPO	3.4	5.2	7.2	9.5
Exports	3.1	4.6	6.3	8.3
Domestic	0.3	0.6	0.9	1.2
Engineering services and R&D, software products	2.9	3.9	5.3	6.5
Exports	2.5	3.1	4.0	4.9
Domestic	0.4	0.8	1.3	1.6
Total software and services revenues	16.7	22.6	30.3	39.7
Exports	12.9	17.7	23.6	31.3
Hardware	5.0	5.9	7.0	8.2
Total IT industry (including hardware)	21.6	28.4	37.4	47.8

Source: NASSCOM 2007
[a] Estimation

Siemens, Citigroup have leveraged the India advantage for IT services through their own captive units[1] or through outsourcing.

The key opportunity areas within R&D services and software products include embedded software and systems and offshore product development. Some of the clients for embedded systems include Texas Instruments, Delphi, STMicroelectronics, Motorola, Intel, Analog Devices, and National Semiconductor. Apart from multinational corporations sourcing requirements from India, there are over 100 Indian companies operating in the embedded software solutions domain. For instance, vendors such as Infosys and I-flex Solutions[2] have successfully expanded their revenue streams by introduction of their own software products.

India is going to capitalize on the engineering skills for operation in the USD 125 billion global engineering services market. Engineering services will take IT industry beyond the functional IT services into the realm of complex, core functions from product development to product maintenance. NASSCOM already has a special forum set up to help India-based engineering service providers exploit the potential for engineering services offshoring and outsourcing. Depending on competency requirement, engineering design involves two- to three-dimensional conversion, parametric three-dimensional modeling, plant engineering, and product design.

As shown in Table 1, Indian ITES-BPO exports increased from USD 3.4 billion in 2003–2004 to USD 7.2 billion in 2005–2006, and USD 9.5 billion in 2006–2007. Three phases are distinguished in the ITES-BPO evolution in India (NASSCOM 2006a).[3] In phase 1 (1996–2000), operational cultures previously seen only in western shared-services centers were developed; large operations and high-quality infrastructure were built; delivery processes – legalizing shift work for men and women – were developed; low resistance to offshore outsourcing prevailed. In phase 2 (2000–2003), the risk profile of the business model was improved, but supply side was still perceived to be immature; early movers displayed advantage of scale; credibility of the business model was reinforced; work on process and regulatory standards was initiated: anti-offshore backlash rose. In phase 3 (2003–2008), there are a proliferation of players and service lines; further development of process and regulatory standards; changing cost economics; global acceptance of the economic imperative of offshore outsourcing.

The ITES industry may be classified into customer interaction services, transaction processing, content development, and knowledge services.

Customer interaction services is one of the largest segments within the Indian ITES industry with contribution of almost 30% to the total revenues. While the predominance of customer interaction services is gradually decreasing, the nature of services is upgrading to higher-end technical support. Several global players sourcing their customer interaction services from India are represented by Citigroup, American Express, and Hewlett Packard.

Transaction processing outsourcing is vital for the global financial institutions and airway companies. It is provided along the lines of data entry and conversion, rule set processing, problem solving, and full process outsourcing.

The Indian ITES industry offers a range of services to Walt Disney, Laserwords, and Techbooks in the area of digital content development needs of website management, production and delivery of multimedia over new media, including CDs, DVDs, and Internet.

Recent years have witnessed a spurt in sourcing of knowledge-based services: intellectual property research and writing patent applications with U.S. Patent and Trademark Office, R&D in pharmaceuticals and biotechnology, data mining, and a range of analytical services such as equity research and financial modeling.

Hence, the evolution of the IT industry in India continues with considerable expansion in product development, engineering services and R&D within the software side.

IT hardware

The Indian government has identified growth of the electronics and IT hardware manufacturing sector as a thrust area (Ministry of Communications and Information Technology 2006). Apart from meeting the country's future requirement in the converging areas of information, communication, and entertainment, India has the potential to develop and manufacture electronics and IT hardware for the global markets and gain a higher global share.

India does not have a world-class IT hardware manufacturing industry yet but performs many hardware assembly tasks internally for the domestic market. Components in such cases typically come from East or Southeast Asia. The ability to organize this aspect of production may be the basis for further development of hardware capabilities. Several East Asian countries also began as mainly assemblers of sophisticated components produced elsewhere and extended their presence in the value chain backward as they learned by doing. The manufacturing project in Hyderabad demonstrates that India is currently developing its semiconductor manufacturing industry in order to have the complete value chain of hardware manufacturing within the country.

Companies like Hewlett Packard, Dell, and Cisco have already had their operations in India. Dell is outsourcing most, if not all, of its components manufacturing and acts as an extremely sophisticated assembler. Its value creation is based on organizing this assembly as efficiently as possible with a minimum inventory. The success of Dell is based on the strong customer service, on the one hand, and management of communications and logistics at both ends of the value chain, on the other hand. These assembly operations

allow multinational corporations like Hewlett Packard, Dell, and Cisco to be the top vendors of IT hardware in India.

The PC market in India – desktops and notebooks taken together – grossed 5.04 million (50.4 lakh) units registering a growth of 32% in 2005–2006 in comparison with 2004–2005. Desktop sales crossed 4.6 million units, while the notebook shipments exceeded 0.43 million units in 2005–2006 (MAIT 2006).

The proportion of the Indian brands grew from 24% in 2004–2005 to 28% in 2005–2006, while the market share of the multinational corporations remained constant at 35% for the last two years. The proportion of assembled PCs of smaller and lesser known regional brands and unbranded systems reduced from 41% of the total PC sales in 2004–2005 to 37% in 2005–2006; however, in absolute terms they registered a growth of 14% (MAIT 2006).

The high growth in PC sales is attributed to increased consumption by industry verticals such as telecom, banking, and financial services, manufacturing, education, retail and BPO/ITES as well as major e-governance initiatives of the central and state governments. The other reason is the drop in prices, especially at the entry level, contributing to a strong household market. It is expected that increased government focus on pan-India deployment of broadband at one of the lowest costs in the world will soon lead to accelerated PC consumption in the home market (MAIT 2006).

In summary, the following factors contributed to the growth of Indian IT industry: existence of educational institutions (Indian Institutes of Technology), use of English, increase in the use of Unix and related operating systems due to the explosion of the Internet, the large number of Year 2000-related projects in the late 1990s, synergies between local e-commerce software development and export markets. All IT sectors in India have made significant progress and are well positioned for the future growth in the domestic and international markets. As to the IT industry growth potential, the outlook for corporate spending on IT and other business services over the next few years remains positive worldwide. IDC forecasts a growth of over 7% (compound annual growth rate) in global IT-ITES spends, and a growth of over 15% (compound annual growth rate) in offshore IT spending over 2005–2009 (NASSCOM 2006b).

Competitive factors in IT industry

I now attempt to highlight the factors contributing to India's leadership position in IT industry. These factors are also responsible for the emergence and future sustainability of the existing and emerging IT clusters in India.

The Porter (1998) diamond is essentially a logical structure for looking at the elements that determine the success or failure of a business or cluster of businesses. In accordance with Porter's "diamond of advantage" classification, the crucial factors for the IT industry in India include factor conditions

(specialized and highly skilled labor; creation of urban infrastructure, fostering several IT clusters); demand conditions (emergence of domestic IT market and global delivery model); firm strategy, structure, and rivalry (operational excellence that has gained cost, quality, and security leadership; global delivery model); related and support industries (value chain); government (conducive business environment including several favorable policy interventions such as the establishment of Software Technology Parks of India [STPI] and telecom reforms); chance.

At the current stage of development, the value chain represents the most challenging area of competitiveness building. In the past, although it was successful in designing chips (element 1 in the hardware value chain) for major multinational corporations, India did not have semiconductor and chip manufacturing facilities. India is a superpower in design; and total design revenues equaled USD 3.5 billion in 2005 and are expected to grow almost 15 times by 2015. This increase is attributed to the establishment of captive offshore centers and an increase in work outsourced to noncaptive companies – involving a total of about 125 companies. The aggregate cost savings from off-shoring design services to India fluctuate from 25 to 50%, while the cost reduction due to lower employee salaries ranges from 80 to 90% for many MNCs. Practically every chip company has already set up a design center in India, i.e., out of the top 25 chip companies, 18 are already in India (interview with India Semiconductor Association). There are 3 segments of the design market in India, namely, very-large-scale-integration (VLSI)[4] design, hardware and board design, embedded software.

Generally, the IT hardware value chain consists of seven links: (1) chips design, (2) semiconductor manufacture; (3) printed circuit board manufacture, (4) printed circuit board assembly, (5) product assembly, (6) testing, (7) final IT hardware assembly and manufacturing. In its turn, the semiconductor value chain (links 1 to 6) occupies the highest share of the IT hardware value chain. The semiconductor value chain, often called "food chain", in a broad sense consists of design (link 1), manufacturing (links 2 to 5), testing (link 6), embedded software (integral part of link 7).[5] Nowadays, India has design and software links and an emerging testing link[6] within the semiconductor value chain. Therefore, the current focus is in manufacturing, and the realization of an AMD-SemIndia semiconductor plant in Hyderabad, packaging and assembling in Tamil Nadu, and the like will concentrate and deploy all seven elements of the IT hardware value chain inside the country.

The Indian software skills should be leveraged in creating value-added products through development of application-specific integrated circuits (ASICs). Vinnie Mehta, executive director of the Manufacturers' Association for Information Technology feels that one advantage that India offers is a huge skill set for design: "From the standpoint of just manufacturing, China is way too formidable. So, our way forward is design-led manufacturing."

(Moritsugu 2005) The possible positioning for the Indian IT hardware industry today is the creation of combinations which comprise a fabless company[7] and a foundry.[8] Thus, India is well-positioned for the strategic completion of the semiconductor "food chain" at this stage. This becomes evident by the recent developments in the semiconductor industry, which has reached third stage. The initial paradigm was that of integrated device manufacturers such as Intel, which combined design, manufacturing, software, and marketing under one roof. At the second stage, the fabless model made its entry and design became separated from manufacturing. At the current third stage, embedded software became the third axis in this three-dimensional process, because each chip is a system containing a huge amount of software.

Both the overseas and local markets can be the drivers of demand for this model. From this perspective, there is a need to establish India as a base for volume electronics manufacturing. The prices of end user electronic products coming down cannot be linked to the volume of design work happening out of India – it is a prerogative of manufacturing. The emergence of original equipment manufacturers[9] servicing the Indian and South Asian markets with indigenous products will lead to a growth of volume electronics manufacturing at low costs. The emergence of the domestic market for consumer electronics and telecom shows opportunities for IT hardware industry in India. Semiconductor success depends heavily on having a contract electronics manufacturing capability close at hand. Thus, not only IT hardware clusters, but broader ICT and industrial clusters have been forming the landscape of the Indian economy. A volume electronics manufacturing base could then be leveraged to service other geographies as well.

In IT services, software and ITES-BPO India also moved up the value chain. India has made a noticeable progress from body shopping, or brain arbitrage to put it more polite, to providing services via companies' offices in India and abroad for customers in the United States, Europe, and the rest of the world. Later some innovative Indian companies moved up to the knowledge creation, intellectual property, product creation stage, where they are creating products in certain specific areas and getting patents, etc. Therefore, IT companies in India with specialization in IT services, software, and ITES-BPO have moved up the value chain by replacing cost with value. The evolution within the ITES-BPO value chain has been climbing through the stages of basic development (application customization), outsourcing and maintenance (custom application development), integration (IT systems integration), complete solution development and consulting (product design, business and IT consulting). This movement was spurred by the fact that clients started to look at delivery of quality through outsourcing rather than eyeing it just as a cost-saving option.

When we turn to firm strategy, structure, and rivalry in IT industry, we find that India's top 20 (especially the top 5) software companies have been

getting bigger in terms of revenues and exports by means of long-term orders,[10] added employees, acquired companies, new operations overseas, and expenditures on R&D. This stage of innovation is characterized by the ability of Indian IT companies to scale up. For example, Infosys added nearly 16,000 professionals in 2005–2006. Nowadays, Tata Consultancy Services (TCS), Infosys, and Wipro employ more than 150,000 IT professionals.

The share of India's top 20 software and services exporters was 77% (77,689 crore) of total STPI software exports (100,809 crore) in 2005–2006 (Table 2). The share of the top 5 Indian companies (TCS, Infosys, Wipro, Satyam, HCL) alone equaled 35% of total STPI software exports in 2005–2006 (calculated with data from Dataquest India [2006]).

In the ITES-BPO segment, the unique global delivery model nowadays constitutes a higher proportion of offshore in the mix of onshore, near shore, and offshore. Additionally, the previous preference for captives and co-sourcing arrangements has been changing to a preference for third-party BPO players. In essence, mature captives are gradually tending towards becoming third-party service providers. As a result, the ranking of third-party ITES-BPO providers in 2005–2006 is led by Genpact followed by WNS, Wipro BPO, HCL BPO Services, ICICI OneSource, and IBM Daksh (NASSCOM 2006c).

Both the hardware and software companies are agglomerated in a limited number of locations in India.

Regional IT clusters in India

IT industry development in many parts of the world is characterized by a strong tendency of clustering because of agglomeration economies (Saxenian 1994, 2001), related to the idea of economies of scale and network effects. Even in the case of increased competition among IT firms there are advantages, as the cluster attracts more suppliers and customers in comparison with a single firm.

In India, the software industry developed initially in Mumbai. Subsequently, especially after the entry of Texas Instruments in the mid-1980s, Bangalore emerged as a centre of software industry development. Besides Bangalore and Mumbai, the National Capital Region (NCR) – Delhi along with its suburbs Noida and Gurgaon – has been established as the third most popular concentration.

Consequently, Hyderabad and Chennai have started to provide alternative locations in the south after the saturation of Bangalore in terms of available infrastructure and scarcity of space.

The present research has revealed that clusters emerged in already industrially developed cities with the availability of IT-related infrastructure, especially in telecommunications, specialized and skilled labor force, and conducive business regime owing to central and local governments' efforts in

the creation of special economic zones (SEZ), STPI, and electronics hardware technology parks (EHTP).

The overwhelming majority of both registered companies and exports are attributed to STPI and EHTP. The software exports by STPI companies were estimated to be around Rs 74,019 crore in 2004–2005 and Rs 100,809 crore in 2005–2006 (Table 2). As reported by NASSCOM (2006b), the overall software and services exports accounted for USD 23.4 billion in 2005–2006, which was reestimated as USD 23.6 billion a year later (NASS-COM 2007) (Table 1).

At the national level, STPI units account for approximately 95% of software exports (interview with STPI). So, out of the total national figure of Rs 77,157 crore, STPI units have contributed Rs 74,019 crore to the overall export revenue from software operations in the country in 2004–2005.

The growth in exports of STPI member companies for 2005–2006 as compared to 2004–2005 is an impressive 36%. The STPI scheme, which is a 100% export-oriented scheme, has attracted many entrepreneurs in the area of software and services. More than 5,806 companies are registered under STPI umbrella out of which more than 4,379 units have exported software in 2004–2005 (interview with STPI).

Table 2. Statewise software exports under STPI scheme

State	Exports (Rs crore[a])				Growth (%) 2004–2005 to 2005–2006
	2002–2003	2003–2004	2004–2005	2005–2006	
Karnataka	12350	18100	27600	37000	34
Maharashtra	5508	8518	11542	15500	34
Tamil Nadu	6305	7621	10790	13960	29
Andhra Pradesh	3668	5025	8270	12500	51
Haryana	2734	4292	5953	8358	40
Uttar Pradesh	2541	2750	3825	5476	43
Delhi	2065	2398	2453	3520	43
West Bengal	1200	1600	2000	2500	25
Orissa	260	319	400	465	16
Kerala	165	212	270	296	10
Chandigarh	31	39	225	294	31
Rajasthan	47	130	200	271	36
Gujarat	105	141	187	247	32
Madhya Pradesh	107	102	140	189	35
Punjab	70	182	125	182	46
Pondicherry	15	22	30	40	33
Others	5	8	9	11	25
Total	37176	51459	74019	100809	36

Source: interview at STPI
[a] An Indian crore is equal to 10 million

The highest exports by STPI-registered companies were from the state of Karnataka (Rs 37,000 crore), followed by Maharashtra (Rs 15,500 crore) and Tamil Nadu (Rs 13,960 crore) in 2005–2006.

Regional industry clusters are industry clusters that are concentrated geographically, normally within a region that constitutes a metropolitan area, labour market shed, or other functional economic unit (Bergman and Freser 1999). The regional IT clusters in India have formed in and around metropolitan cities, some being the capitals of the respective states: Bangalore (Karnataka); Delhi, Noida, and Gurgaon (Union territory of Delhi, state of Uttar Pradesh, and state of Haryana, respectively); Chennai (Tamil Nadu); Hyderabad (Andhra Pradesh); Pune (Maharashtra); Mumbai (Maharashtra); and Kolkata (West Bengal). In this classification Delhi, Noida, and Gurgaon belong to different administrative units but together they form the NCR cluster, with an STPI located in Noida.

Contrary to popular perception, the Indian IT software and services industry is not exclusively clustered in Bangalore but dispersed over the south and west of the country. The number of firms in each region and their share of revenue and employment indicate this. However, foreign investment in software is concentrated in Bangalore.

For instance, Athreye (2005) reports that as of 2000–2001 the distribution of the number of software and IT services firms and share in employment (in brackets) among cities was as follows: Bangalore, 126 (24.52%); Mumbai and Pune, 149 (30.12%); Chennai, 67 (15.29%); Delhi, Noida, and Gurgaon, 156 (15.48%); Hyderabad, 63 (9.07%); Kolkata, 26 (0.48%).

Consequently, the following three elements have been considered important for IT cluster identification in India: the structure of clusters (firms and interactions among firms); competitiveness (in terms of not only scientific and technological content but also business innovation); performance rates (revenues, exports, employment, other performance measures).

The next challenge of this research has been associated with its scope, covering IT services, software and R&D, ITES-BPO, IT hardware, and emerging semiconductor manufacturing. Previous reports discussed the software industry in general or location choices for ITES-BPO companies (NASSCOM and KPMG 2004) and IT services and software companies (Iyengar 2004). They did not look inside the sector composition of IT clusters in India. Neither did they identify the total number of broad IT clusters in India.

For example, the NASSCOM–KPMG study (2004) led to the evaluation of location choice for ITES companies only. KPMG identified four key groupings of different cities. There are "business centers" like Delhi which have benefited from the availability of business infrastructure and a pool of employable people to attract ITES investments. There are "education centers" like Kolkata or Chennai that have invested in a robust education and institutional infrastructure but have traditionally seen skills migrate to other locations for ITES.

There are "tourist destinations" like Jaipur and Kochi that can leverage a global service orientation and relevant infrastructure (like hotels, transportation services) because of their tourism background. And there are "planned cities" like Chandigarh that are systematically working on attracting investments on the basis of their ability to provide telecom, power, and building infrastructure.

The analysis of secondary data, field studies in India, and following research work have led to the identification of seven big IT clusters in India: Bangalore, NCR, Chennai, Hyderabad, Pune, Mumbai, and Kolkata. A cluster's position in the group of the Big 7 IT clusters is obtained not only on the basis of its share in IT production and exports but also on the basis of its portfolio of IT sectors (IT services, software and R&D, ITES-BPO, IT hardware manufacturing, semiconductor manufacturing). Only the Big 7 IT clusters have managed to move up the value chain. Moreover, some of them are currently trying to deploy the complete value chain in IT hardware. Logically, the discussion is devoted to IT industry in a broad sense. Therefore, it reveals additional determinants of the emergence and sustainability of IT clusters beyond infrastructure development and human resources (HR) development.

The interviews have shown that hardware manufacturing and assembly is currently concentrated in the SEZ in the Chennai cluster, with Pondicherry being the IT hardware capital of India; Mumbai cluster and associated SEZ in Silvassa (PCS) and Goa (D-Link and Zenith); NCR cluster; Bangalore cluster; and Kolkata cluster. Semiconductor manufacturing is taking its roots in the Hyderabad cluster. In general, India intends to become the design and manufacturing capital of the world with the electronics hub in Chennai, chip manufacturing in Hyderabad, and design specialization in the Bangalore cluster. Probably, the Chennai cluster may even transform into an ICT cluster after the arrival of Nokia. The same possibility exists for Bangalore also.

Given the recent emphasis on engineering process outsourcing (EPO), the strong track record of Indian vendors from the Big 7 IT clusters in BPO and IT outsourcing is also likely to boost the confidence of would-be global clients in India's capabilities in this sector. Many engineering service providers will evolve from the companies that already have a great deal of experience winning and retaining BPO and IT outsourcing contracts. Being the cost-effective choices, the emerging engineering process outsourcing hubs will be built on the existing pockets of experience. Thus, Bangalore will be designated to high-tech/telecom development; Pune will focus on automotive and construction/industrial development and Chennai on utilities and automotive engineering process outsourcing (NASSCOM and Booz Allen 2006).

The concentration of the IT industry in the Big 7 IT clusters has been creating pressure on the infrastructure and increasing demand for IT specialists and government initiatives. These clusters have been exhibiting outstanding firm-level initiatives and economic initiatives. Therefore, their

experience cannot be replicated overnight. Each cluster is affected by the complex interplay of central and regional government policies influencing the trading environment, sources of innovation – private versus public –, the nature of the places where cluster resources come together and the regulation of clusters like the export obligation for STPI and EHTP units.

Bangalore IT cluster

Similarly to the country's general performance, IT services represented the largest segment of software and services exports from Bangalore cluster, i.e., enterprise applications contributed 57% of export revenues. The rest of the pie was divided between technology software (24%), ITES-BPO (16%), and other services (3%) in 2005–2006 (data provided by STPI Bangalore).

The cluster is traditionally outperforming other locations in economic terms. For instance, of the 175 product development companies in India, 38 located in Bangalore, 35 in the NCR, 25 in Pune, 25 in Mumbai, 19 in Hyderabad, and 12 in Chennai (data provided by NASSCOM). This characteristic of the Bangalore cluster gives rise to the following phenomenon, acknowledged by IT companies I interviewed in India but which has been also found in many highly competitive IT clusters elsewhere: Close proximity to competitors allows new waves of products to be launched against each other, which raises market impressions that they represent a new generation, increasing the imperative for their purchase and thus increasing the sales of the firms (for a discussion of the Cambridge ICT cluster, see Benneworth and Charles [2001]).

The Bangalore IT cluster successfully attracted FDI, and a large number of multinational corporations set up captives in Bangalore. Companies such as Microsoft, Oracle, and IBM have had a presence in India for quite some time as the region is a strategically important source of talent. The situation in high-tech manufacturing and design companies is identical to that of IT and software. Companies such as Cisco, Motorola, Dell, Applied Materials, Hewlett Packard, and Intel have a strong presence in Bangalore for over five years.

Anchor companies on the software side are represented by the indigenous Indian giants Infosys (consultancy and IT services) and Wipro.

National Capital Region

The cluster's strengths are in hardware and ITES-BPO, with the other sectors of IT being well-developed and representative of the NCR. The NCR is the number one ITES-BPO destination in India. One of the reasons for the NCR prospering in software exports is due to the entrepreneurship culture of this region.

The availabilty of technology accelerated the growth of the IT industry in the NCR, because North India had accounted for 40–55% of the hardware

contribution. Therefore, software professionals had a better chance of evaluating hardware platforms and developing software.

There are anchor companies in the hardware and software segments in the NCR cluster, with Hindustan Computers Limited (HCL) being a diversified IT company since 1976.

Chennai IT cluster

The portfolio of the Chennai cluster incorporates all IT industry sectors: IT services, software and R&D, ITES-BPO, and hardware. Application software and system software contitute the main area of specialization (73% of total software exports in 2004–2005), followed by ITES (15%), web applications like multimedia, internet, e-commerce (9%), and product packages (3%) (data provided by STPI Chennai).

STPI Chennai is responsible for the implementation of STP/EHTP schemes in the states of Tamil Nadu and Pondicherry (IT hardware capital of India) and Andaman & Nicobar Islands. Chennai is the outstanding cluster in terms of hardware among all Big 7 IT clusters. The key anchor firms are HCL Infosystems, Wipro, and the multinational Hewlett Packard.

Hyderabad IT cluster

Hyderabad is the fastest growing IT cluster with export growth (51%) above national average (36%) in 2005–2006. From the sector perspective, the Hyderabad cluster is a leading ITES-BPO destination in India. According to NASSCOM's evaluation of the top nine Indian ITES destinations (NASSCOM 2002), Hyderabad was at the top of the ranking of those cities, primarily owing to policy initiatives and manpower. The model anchor company for IT services and software is Satyam Computer Services Ltd.

Anchor companies in hardware, including semiconductor, sector are just about to establish. A USD 3 billion (Rs 13,500 crores) facility for the manufacture of semiconductors used in personal computers, television sets, mobile phones, and other digital devices will be set up by SemIndia Inc. near the Hyderabad international airport (data provided by ICT Department, Government of Andhra Pradesh).

Pune IT cluster

The emergence of the IT cluster in Pune has been driven by small, home-grown companies. The areas of specialization range from product development in the software sector to chip design and embedded software in the hardware sector. Engineering services in the traditional fields of computer-aided design, manufacture, and engineering are the other core areas for IT units in Pune.

Mumbai IT cluster

The Mumbai cluster has occupied strong positions in the following segments of IT industry: IT services (IT outsourcing for a client's entire enterprise, project-oriented services, support and training); ITES-BPO, especially knowledge process outsourcing (KPO); hardware in SEZ (except for semiconductors). Within IT services sector, the gamut of IT outsourcing extends from information system outsourcing to enterprise application services (enterprise resource planning, customer relation management, e-procurement) and network infrastructure management. Mumbai is home to the oldest and most successful IT park in the country, namely, the Santacruz Electronics Export Processing Zone. The anchor company Tata Consultancy Services (TCS) has been the leader of the Indian IT industry for the last 35 years. In its turn, originally being the spin-off of a multinational corporation's subsidiary, Citicorp Overseas Software, i-flex Solutions Limited is the largest software exporter in India.

Mumbai cluster has the second largest scope of hardware manufacturing companies, making way only to the Chennai cluster. Such companies as PCS Technology (PCs and laptops) and Kobian (motherboards and graphic boards) have proved their status as anchor companies in IT hardware. In addition, D-Link (networking devices) and Zenith (PCs and laptops) with their manufacturing facilities in the neighboring state of Goa also have been forming the Mumbai IT cluster as anchor companies.

Kolkata IT cluster

Until recently, Kolkata has witnessed a "brain drain" due to a lack of adequate, attractive employment opportunities in ITES and other sectors. The top 3 anchor companies in software as of 2005–2006 are TCS (Rs 1032.34 crore export from Kolkata), IBM India Pvt. Ltd. (Rs 351.81 crore), and Cognizant Technology Solution India Pvt. Ltd. (Rs 214.63 crore) (data provided by STPI Kolkata).

Dimensions of Big 7 IT clusters in India

The IT clusters in India can be characterized along several dimensions. On the one hand, the seven well-established IT clusters (Big 7) with combination of IT services and software, ITES-BPO, and computer hardware sectors exhibit common characteristics along the majority of dimensions. On the other hand, clusters in Tier II and Tier III cities also have similar features within the latter group. Characterization of clusters by dimensions serves the identification of key constraints and leverage points to facilitate the design of cluster policy. The following summary has applied the framework

Table 3. Dimensions of Bangalore, Chennai, and Hyderabad clusters

Dimension	Type or characteristic of cluster			
	Bangalore (Karnataka)	NCR (Delhi, Noida, Gurgaon)	Chennai and Pondicherry	Hyderabad (Andhra Pradesh)
Geographic scope	Dispersed	Dispersed	Dispersed	Dispersed
Cluster density	Dense	Dense	Dense	Dense
Software exports 2005–2006 (Rs crore)	37,000	18,301	14,000	12,500
Cluster breadth	Broad (potential for ICT, Bio-IT, EPO)	Broad	Broad (potential for ICT, e.g., Nokia)	Broad (potential for ICT)
Cluster depth	Deep	Deep	Deep	Deep
Activity base	Activity-rich along the value chain in IT services, software, ITES-BPO, R&D, hardware	Activity-rich along the value chain: BPO, IT services, software, R&D, hardware	Activity-rich, strong application and system software, strong hardware, ITES-BPO	Activity-rich along the value chain in IT services, software, ITES; strong chips
Growth potential: demand/ competitiveness	Sunrise/ competitive	Sunrise/ competitive	Sunrise/ competitive	Sunrise/ competitive
Anchor company computer hardware	Solectron, personal internet device for AMD; MRO-Tek 2, manuf. plants for network/ telecom; Flextronics, set-top boxes for Galaxis	Noida: Sahara Computers, PC and peripherals (Rs 750 crore investment); Samsung, monitors	Wipro, PC and laptops; IBM/ Lenovo, PC and laptops; TVSE, printers and peripherals	Semi-Com and AMD project for semiconductor manufacturing
Anchor company IT services, software and R&D, ITES-BPO	Infosys (HQ)[a], Wipro (HQ), Digital Global Soft (HQ)	HCL (HQ), Hughes (HQ), Genpact[b], Samsung[b]	Polaris (HQ), NIIT/training (HQ)	Satyam Computer Services Ltd (HQ)
Positioning and approach	Focus on HR[c] development	Focus on infrastructure	Focus on HR development	50/50 infrastructure/ HR focus
Government policies	Proactive	Proactive, coordination difficulty	Proactive	Proactive

Table 3. (Contd.)

Dimension	Type or characteristic of cluster			
	Bangalore (Karnataka)	NCR (Delhi, Noida, Gurgaon)	Chennai and Pondicherry	Hyderabad (Andhra Pradesh)
Innovation capacity	High	High	High	High
Industrial organization	Core with ring	Core with ring	Core with ring	Core with ring
Coordinating mechanisms	Long-term relationships, markets	Long-term relationships, markets	Long-term relationships, markets	Long-term relationships, markets
Ownership structure	Combination of foreign-owned and locally owned firms	Significant share of local small- and medium-sized enterprises, presence of multinational and Indian top companies	Combination of foreign-owned and locally owned firms	Combination of foreign-owned and locally owned firms

[a] HQ, headquarters of anchor company
[b] Multinational company
[c] HR, human resources

of Enright (2000), who specified 9 dimensions and 4 stages of development for clusters.

I performed the classification of IT clusters in India (Tables 3 and 4) and the introduction of new characteristics (like anchor company; positioning and approach; government polices) on the basis of field studies and thorough analysis.

The stages of development embrace working clusters, latent clusters, potential clusters, and wishful-thinking clusters. Working clusters are those in which a critical mass of local knowledge, expertise, personnel, and re-sources create agglomeration economies. Latent clusters have a critical mass of firms in related industries, but evince a lack of interaction and information flows necessary to truly benefit from colocation. Potential clusters suffer from important gaps in the inputs, services, or information flows that sup-port cluster development. Wishful-thinking clusters are usually "policy-driven clusters" and lack a critical mass of firms or favorable conditions for organic development (Enright 2000).

From the perspective of geographic scope, the Big 7 IT clusters in India represent dispersed clusters. The IT firms, customers, suppliers, support services, and institutions that are embedded in the ongoing relationships and interdependent activities that characterize the clusters are spread across

Table 4. Dimensions of Pune, Mumbai, Kolkata and Tier I and II city clusters

Dimension	Type or characteristic of cluster			
	Pune	Mumbai	Kolkata	Tier I and II
Geographic scope	Dispersed	Dispersed	Dispersed	Localized
Cluster density	Dense	Dense	Dense	Sparse
Software exports 2005–2006 (Rs crore)	8,300	7,200	2,500	1,008.26 (for rest of India)
Cluster breadth	Broad (potential for Bio-IT, EPO)	Broad	Broad	Narrow (consist of 1 industry)
Cluster depth	Deep	Deep	Deep	Shallow
Activity base	Very active in product development, R&D – intellectual property hub; IT services presence	Activity-rich along the value chain in IT services, software, ITES; hardware	Activity-rich along the value chain in IT services, software, ITES/BPO	Activity-poor
Growth potential: demand/ competitiveness	Sunrise/ competitive	Sunrise/ competitive	Sunrise/ competitive	Sunrise/ noncompetitive
Anchor company hardware	N/A	Kobian, motherboards and graphic boards; PCS, PC and laptops	Xenitis with Unitek of China (Rs 250 crore investment), PC	Goa: D-Link, 3 manuf. plants for networking devices; Zenith, PC and laptops
Anchor company IT services, software and R&D, ITES-BPO	Compulink Systems Pvt Ltd. (HQ)[a], also centers of Infosys, TCS, WNS, and Honeywell	TCS (HQ), Patni (HQ), Tata Infotech Ltd, SGlobal Tele-System	Operations of TCS, IBM, Cognizant	Small and medium-sized enterprises
Positioning and approach	Focus on HR[b] development	50/50 HR/ infrastructure focus	Focus on HR development	Infrastructure focus, high level skills shortage
Government policies	Improving, perfect MIDC[c]	Improving, perfect MIDC	Proactive	Emerging
Innovation capacity	High	High	High	Low
Industrial organization	Core with ring	Core with ring	Core with ring	All core, no ring
Coordinating mechanisms	Long-term relationships, markets	Long-term relationships, markets	Long-term relationships, markets	Hierarchies of branches with headquarters

Table 4. (Contd.)

Dimension	Type or characteristic of cluster			
	Pune	Mumbai	Kolkata	Tier I and II
Ownership structure	Significant share of local small- and medium-sized enterprises, small presence of multinational and Indian top companies	Combination of foreign-owned and locally owned firms	Combination of foreign-owned and locally owned firms	Locally owned firms

[a] HQ, headquarters of anchor company
[b] HR, human resources
[c] MIDC, Maharashtra Industrial Development Corporation

wider geographies in India and abroad. In contrast, the emerging clusters in Tier II and Tier III cities appear as localized clusters. The small concentrations of BPO companies found in restricted geographic areas, often a single town – like Ahmedabad, Gandhinagar, Jaipur, and Kochi –, may serve as examples of localized clusters.

Enright (2000) proposed that the density of a cluster refers to the number and economic weight (in terms of market shares of relevant industries) of the firms in the cluster. Hundreds and thousands of IT companies are inscribed in STPI registers in the dense clusters of Bangalore, the NCR, Chennai, Hyderabad, Pune, Mumbai, and Kolkata. The seven big IT clusters accounted for 98% of the software exports by STPI in 2005–2006, with the individual contribution of the Bangalore cluster being 37%. The head offices and operations of large companies like TCS, Infosys, Wipro, HCL, and multinational corporations are also concentrated in these centers. In contrast, sparse clusters in Tier II and Tier III cities do not have the same economic weight due to a limited number of companies and the absence of top IT players. However, a few clusters in Tier II cities are gaining weight gradually.

The breadth of clusters refers to the range of horizontally related industries within the cluster (Enright 2000). The Big 7 IT clusters are broad clusters which provide a variety of products in closely related industries.

For example, Bangalore, Chennai, and Hyderabad will soon transform from IT clusters to ICT clusters with a combination of IT and telecommunications products, as they have been developing semiconductor and chip design and manufacturing. Nokia has established a plant in the Chennai cluster, and Finland-based electronics manufacturing services provider Elcoteq (manufacturing handsets for top global brands such as Nokia, Motorola, and Samsung) has started assembling mobile handsets in its Bangalore manufacturing plant. The Korean major LG will be investing USD 35 million in manufacturing

of mobile phones at its Ranjangaon facility near Pune. When India becomes a design and manufacturing hardware hub, it will supply numerous products in both IT hardware and telecommunications for the domestic and international markets. These two industries are related by common technologies (chips), end users, distribution channels, and other nonvertical relationships. For this reason, new telecommunications entities choose their location close to design and manufacturing facilities of IT hardware and software companies within the Big 7 clusters.

The concentration of IT industry and biotechnology research centers in Bangalore and Pune fosters the development of the Bio-IT sector. Therefore, Bangalore and Pune are growing as hubs for IT solutions (products and services) within the health sciences sector.

The dimension of cluster depth manifests that the deep clusters in Bangalore, the NCR, Chennai, Hyderabad, Pune, Mumbai, and Kolkata contain not only IT industry and IT-related industries but complete or nearly complete supply chains. The Big 7 IT clusters leverage the local talent and university–industry partnerships for research in new technology.

It is anticipated that new agglomerations in Tier II cities are shallow clusters. They rely principally on inputs, components, equipment, technology, and support services from outside their regions. New establishments or branches of well-established companies in Tier II and Tier III cities receive technology and best practices, etc., from their respective headquarters in Bangalore, the NCR, and Chennai.

With the activity base of a cluster being charactrized by the number and nature of the activities in the value-added chain performed with the region (Enright 2000), the Big 7 clusters represent activity-rich clusters. Since its origin in 1980s, the IT industry in India has been moving up the value chain. It refers both to IT hardware as well as IT services, software R&D, and ITES-BPO in the Big 7 IT clusters. Companies in those clusters tend to organize and perform their core strategy-setting, product or service development, production, marketing strategy and sales, and strategic alliances at various stages.

Activity-poor clusters in Tier II and Tier III cities involve only one activity in IT industry or even IT industry sector (e.g., only inbound calls from the whole range of BPO operations). The current practice in Tier II and Tier III cities is concentrated around the medium-range value chain of BPO services due to a lack of highly skilled labor and networking opportunities within the cluster.

The growth potential of an individual cluster depends not only on the growth in demand for the products and services supplied by the cluster but also on the competitive position of the cluster relative to outside competitors and the availability of resources (or the ability to create or attract them) necessary to support growth. Enright (2000) distinguishes between sunrise, noonday, and sunset clusters.

The present research infers a strong domestic and foreign demand for the Indian IT industry output. However, there is a growing fierce competition among the Big 7 IT clusters. For example, four states submitted their proposals and invited a SemIndia-AMD delegation for a feasibility study concerning the location of a semiconductor facility. As a result, Andhra Pradesh attracted the investment owing to the state's government proactive policy and appropriate input conditions.

The growth potential of a cluster is also determined by the relative competitiveness of the firms in the cluster versus outside competition. Thus, the combination of demand and firm competitiveness may result in sunrise-competitive and sunrise-noncompetitive, etc., clusters. It has been revealed that each of the Big 7 IT clusters has anchor companies which are competitive at the national and international level. As a result, the Big 7 IT clusters belong to the sunrise-competitive group.

It has been assessed that resource endowment (especially human resources), infrastructure, and government policies influence the development of IT clusters. The Big 7 IT clusters benefit from the availability of highly skilled IT professionals. Though, further work is needed in infrastructure provision.

Some "high-technology" clusters are not at all innovative and some "low-technology" clusters are. A cluster's ability to sustain itself is related more to its innovative capacity than to the level of technology produced or used in the process (Enright 2000). A high innovation level is inherent in the Big 7 IT clusters and respective companies headquartered and located there. The innovative capacity refers to the ability of the cluster to generate the key innovations in products, processes, designs, marketing, logistics, and management that are relevant to competitive advantage in the industries in question. In the case of India, the examples of innovation in the Big 7 IT clusters embrace new software product development, global delivery model, knowledge process outsourcing, and strategic alliances for research and marketing, etc.

Elaborating on this issue, the managing director of Dell International Services in India stressed that the earlier slogan "Come to India for cost and stay for quality" can now be changed to "Come to India for quality and stay for innovation" (Offshoring Times, 14 June 2006).

Finally, a cluster's industrial organization refers to the governance structures and relationships among firms in the cluster, including the nature of relationships and distribution of power among firms (Enright 2000). The industrial organization in the Big 7 IT clusters shows a core with a ring. The recent hardware boom is likely to create the structure of a core with ring with a lead firm.

Coordination mechanisms involve the ways that interfirm relations are organized, through hierarchies, markets, or other forms (Enright 2000). Due

to the technological complexity of the industry, IT companies enter long-term relationships for the delivery of final products for their customers, especially in the hardware segment. As a result, the list of strategic partners for IT companies in the Big 7 IT clusters normally highlights Intel and Microsoft.

As to the ownership structure, the Big 7 IT clusters assume combinations of foreign owned firms and locally owned firms. There are well-established multinational and indigenous Indian companies. Two clusters, namely, the NCR and Pune, are distinguished by the prevalence of Indian small- and medium-sized enterprises.

Cluster research through the prism of these dimensions allows clarification of strengths, weaknesses, opportunities, and threats for the cluster in question. These data may form the basis for cluster-based policy.

Conclusion

In an array of 47 STPI centers geographically spread over India, the investigation has revealed the existence of seven big IT clusters with their specifics.

It has been shown that each of the Big 7 IT clusters in India is marked by the presence of all IT sectors: IT services; engineering services and R&D, software products; ITES-BPO; and hardware segments (including semiconductor manufacturing in Hyderabad).

Each of the Big 7 IT clusters in India has at least one large indigenous Indian firm functioning as an anchor company in the software and services sector. The anchor companies in hardware sector are represented by both Indian and international players. The anchor companies supported the development of the respective Big 7 IT clusters by acting as attractors for other major companies. They have played a catalytic role by building the critical mass of experienced managers and IT professionals and providing the customer, supplier, and alliances bases.

India is about to concentrate all stages of the value chain in both the software and hardware industries within the country. Logically, it is economically efficient to locate the design of chips and their manufacturing and testing within the same IT cluster or neighboring clusters.

The present research has scrutinized the historical and spatial evolution of the Big 7 IT clusters in India resulting in an understanding why the IT industry in India thrived in certain places and why these regions have proved so hard to replicate. These clusters are not simply high-tech regions that grown up from fortuitous combinations of excessive highly skilled engineers, STPI and entrepreneurship. They are cities of various innovation – consciously planned communities which demonstrate particular political, economical, technological, and cultural historical developments.

At the current stage of development, all IT industry stakeholders, including central and regional governments, associations, companies, and universities

should address the problems of infrastructure drawbacks (energy, water, real estate costs), especially in Bangalore, and shortage of IT specialists to gain the momentum for further growth.

Notes

1 In captive centers, activities are offshored but not outsorced to another company. They have been established by a number of players in India primarily for control over assets, intellectual property, and core business activities. In the software vertical, Microsoft, Oracle, and IBM have established their captive units in India.

2 Infosys is an indigenous Indian company. I-flex was set up by Citibank for the development of software products for the parent company. Later, I-flex was able to develop financial-sector products for clients all over the world. This approach represents a reasonable upgrading strategy for Indian software companies, i.e., natural emergence of new products from reusable components that frequently form the basis of project solutions.

3 In general, there are three types of BPO: offshore, onshore (onsite), and near-shore; and they differ in both location and function served. For a customer based in the United States and an Indian service provider, offshore outsourcing refers to the practice of outsourcing to India; near-shore, to outsourcing to an Indian company located in Mexico or Canada; onshore, to outsourcing to an Indian company located in America (Duening and Click 2005).

4 Very-large-scale integration (VLSI) is the process of creating integrated circuits by combining thousands of transistor-based circuits onto a single chip

5 Some authors structure the semiconductor value chain into design, fabrication, wafer testing, packaging and assembling, and production testing

6 For instance, testing is performed by Tessolve in the Bangalore cluster

7 A fabless semiconductor company specializes in the design and sale of hardware devices implemented on semiconductor chips. It achieves an advantage by outsourcing the fabrication of the devices to a specialized semiconductor manufacturer called a semiconductor foundry or "fab" (for "fabrication plant").

8 In the microelectronics industry, "foundry" is used to refer to a factory where devices like integrated circuits (IC) are manufactured. Foundries require many expensive devices to function. Estimates put the cost of building a new foundry over one billion U.S. dollars. The central part of a foundry is the clean room.

9 An original equipment manufacturer is a company that builds products or components which are used in products sold by another company (often called value-added reseller). An original equipment manufacturer will typically build to order on the basis of designs of the value-added reseller. For example, a hard drive in a computer system may be manufactured by a corporation separate from the company that markets and sells the computer. (Source, Wikipedia.)

10 Orders like HCL Tech's multimillion dollar deal with DSG International, which was the biggest order in the history of the Indian IT industry. (Interview with HCL.)

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