Bangalore Cluster: Evolution, Growth and Challenges

Rakesh Basant

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INDIAN INSTITUTE OF MANAGEMENT
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Abstract

The dynamism and persistence of competitiveness among industrial clusters, even in the wake of globalization and liberalization in the 1990s, has led researchers to explore the causes of dynamic efficiencies at the cluster level. Given its dynamism, the ICT cluster in Bangalore, India has attracted much research and media attention. It is often referred to as the Silicon Valley of India. While the IT sector has brought the city into limelight, it has a fairly diverse portfolio of activities with firms manufacturing machine tools, telecom equipment, electronics products and to some extent auto-components located here. In recent years, the city has also emerged as a premier bio-tech cluster in the country. This paper pools together evidence to explore reasons why Bangalore emerged as a high-tech cluster and the nature of advantages that has contributed to its growth.

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1. Introduction

The dynamism and persistence of competitiveness among industrial clusters, even in the wake of globalization and liberalization in the 1990s, has led researchers to explore the causes of dynamic efficiencies at the cluster level. The earlier explanations focused on cost/resource based advantages due to co-location of firms. Cluster studies in the 1980s argued that horizontal collaboration between small and medium sized enterprises could yield collective efficiencies in the form of reduced transaction costs, accelerated innovation through more rapid problem-solving and greater market access. Besides, positive externalities are generated by agglomerations through the availability of: (a) skilled labour and inputs; (b) certain types of infrastructure; and (c) innovation generating informal exchanges. These processes of networking and clustering contribute to the competitiveness and growth of the "participating" firms. Further, political and social institutions along with various policies can play a crucial role in supporting the emergence and development of partnering activities among firms and stimulating the transformation of such networks into broader systems of innovation and production. In fact, in most of the European success stories of networking in industrial clusters, regional and local governments played a crucial role (See Schmitz and Musyck, 1995). Recent studies have focused on dynamic efficiencies that emanate from learning at the cluster level. They emphasize the importance of knowledge flows to firms, social/relational capital and capabilities of firms as critical factors necessary for the continued success and growth of industrial clusters. It is argued that geographically bounded clusters should be viewed as systems of knowledge accumulation rather than just production systems (Bell and Albu, 1999). The focus on knowledge accumulation shifts the policy to focus to processes that convert the cluster based 'production systems' into "innovation systems' (Mytelka and Farinelli, 2000; Mytelka and Pellegrin, 2001).[1]

An application of 'innovation systems' concept to a cluster would require an analysis of capabilities internal to the cluster (or firms in a cluster) and their linkages with external knowledge sources including organizations like universities, R&D institutions, certification agencies, external firms, customers and so on. On the basis of a detailed review of the available literature it has been argued that an understanding of the dynamism of a cluster would require a systematic analysis of links between knowledge flows, cluster characteristics (including capabilities and linkages), external linkages and external policy and economic environment (Basant, 2002). Knowledge flows can take various forms but are generally embedded in products, processes and practices. These get transferred to cluster firms through a variety of mechanisms. Industrial clusters use a variety of sources for knowledge acquisition. Table 1 summarizes these sources. While the literature has highlighted the importance of inter-organizational linkages, the links between firm level resources and knowledge flows facilitated through such linkages have attracted much less attention (Bell and Albu, 1999, Basant 2002). Consequently, knowledge diffusion in clusters is often seen as passive and automatic. Related to the question of firm level learning in the context of geographically bounded clusters is the issue of the relationship among various sources of knowledge. Recent research has highlighted the increasing role of linkages external to the cluster in facilitating knowledge flows.

Various dimensions of a cluster contribute to knowledge flows. These cluster specific factors include: size of the cluster, extent of diversification, division of labour (and the associated buyer-supplier relations), nature of products (hi-tech vs. traditional), levels of competition, nature of markets, location (developing/developed economy), links with other clusters and non-cluster

[1] In simple terms, 'combinations of internally organized capabilities with external knowledge resources, and the links between them' is referred to as innovation or knowledge systems (Bell and Albu, 1999: 1718).

firms (global networks, MNCs etc) and so on. Other important factors relate to public policy and macro-economic environment. Figure 1 summarizes the variety of factors and processes that impinge on knowledge flows in a geographically bounded cluster. Table 2 provides a summary of variables that have been identified as contributors of knowledge flows in a cluster.

The ICT cluster in Bangalore, India has attracted much research and media attention. It is often referred to as the Silicon Valley of India. It currently boasts of over 1500 IT firms and many more in other sectors like electronics.[2] Further, most of the large IT firms in India like Infosys, Wipro are head-quartered in Bangalore. Wholly-owned subsidiaries of MNCs such as Motorola, Texas Instruments and Hewlett Packard have their base in Bangalore. The IT firms principally provide a range of services including customer software application development, maintenance, facility management and training. A number of firms are also moving up the value chain to provide wholly integrated packages too (Balasubramanyam & Balasubramanyam, 2000; Caniels & Romijn, 2003). While the IT sector has brought the city into limelight, it has a fairly diverse portfolio of activities with firms manufacturing machine tools, telecom equipment, electronics products and to some extent auto-components located here. In recent years, the city has emerged as a premier bio-tech cluster in the country. There is also evidence to show that diversity is on the rise even within sectors in Bangalore.[3] Recently, the Indian Institute of Management, Ahmedabad conducted a survey of electronics and IT firms in the Bangalore, Pune and the National Capital Region (NCR) clusters and in some non-cluster areas. What advantages do firms perceive of being in Bangalore, in other clusters and in non-cluster locations? Tables 3 provide some pointers. The respondent firms were asked about the perceived advantages of locating in the city where they operate. As compared to non-cluster firms, the cluster firms seem to be benefiting from proximity to customers and competitors, better access to suppliers and providers of various services. Within clusters, Bangalore seems to be better off than the two other clusters. Bangalore cluster is also a more advantageous location for availability of labour, R&D and training facilities. Obviously, all these advantages contribute to the growth of the cluster. *The rest of the paper tries to explore reasons for the existence of such advantages in Bangalore.*

A large variety of factors have contributed to the evolution and growth of the cluster in the city. In the context of the broad analytical framework enunciated in Figure 1 and the processes and factors identified as critical for the growth of the clusters (Tables 1 and 2), this paper pools together evidence on the evolution and growth of the Bangalore ICT cluster. The rest of the paper is divided into five sections. Section 2 highlights the role played by the public policy initiatives, both at the federal and the state level. This is followed in section 3 by a brief discussion of how the Indian Diaspora contributed to the growth of the cluster through a variety of linkages. The importance of linkages is emphasized further in the next three sections; while section 4 looks specifically at the role of MNCs and large firms in the city, section 5 brings out the role of industry-academia linkages in the city and the sixth section analyses the role of linkages at a generic level. The last section summarizes the main findings and identifies some policy imperatives.

2. Public Policy – Initial Capability Building and Creation of an Enabling Environment

Public policy has been one of the most important contributors to the emergence of Bangalore as a pre-eminent industrial cluster in the country. A wide variety of polices, both at the Federal and the provincial levels have played a role. Table 3 summarizes the evolution of the policy regime. This

[2] Even in the late 1980s, Bangalore included 375 large- and medium-scale industries and had 3000 companies employing 100,000 people in the electronics industry alone. The city contained up to 10,000 small industries and 8 large industrial parks (Premi, 1991).

[3] For example, Bangalore is emerging as a diverse bio-tech cluster. It covers enzymes (Biocon), bio-therapeutics (Biocon, Gangagen), bio-informatics [Strand Genomics, Bigtech, Kshema (now part of Mphasis Technologies), CDC Linux, Molecular Connections], plant genetics and genomics (Avesthagen, Monsanto, Metahelix, Advanta), contract R&D (Syngene, Aurigene, Genotypic Technology, Avesthagen, Bangalore Genei), and bio-processing and bio-instrumentation (Sartorius, WIPRO-GE, Photonics and Bio-molecules, Bangalore Genie, Millipore).

section discusses some key policy initiatives and their implications. It needs to be emphasized at the outset that macro-policy changes made after 1970s benefited the Bangalore cluster in a significant manner *because the city had the capabilities to exploit the emerging opportunities.* More on this later.

The Initial Investments

The city's emergence as a center for information technology stems from decisions taken by the federal government shortly after independence to locate strategically sensitive industries well away from borders and coastlands. Bangalore became a city of choice to locate the Indian air-force base and other public-sector institutions. This in turn promoted the establishment of a number of universities, institutions, and colleges providing engineering and scientific training (Holstrom, 1994).[4] During 1950s and 1960s the government invested heavily into large public sector units like Hindustan Machine Tools (HMT), Bharat Electronics Limited (BEL), Bharat Heavy Electricals Limited, Hindustan Aeronautics Limited (HAL) and Indian Telephone Industries (ITI). Several other defense and infrastructure industries also came up in Bangalore. In fact, the city became an important defense research center. Apart from strategic reasons, the choice of Bangalore for these investments was due to existence of educated workforce (we will see below that engineering colleges and the Indian Institute of Science contributed to this) and availability of cheap electrical power (Heitzman, 2004: 45).

A few large private sector undertakings were also given licenses. For example, Motor Industries Company better known as MICO, the automotive components manufacturer, a subsidiary of Robert Bosch GmbH of Germany and the machine tool manufacturer WIDIA came up during this period. One can partly attribute the presence of IT in Bangalore to the initial establishment of electronics firms in the city. Since software in the initial phases was more hardware centric, it was more appropriate for IT firms to locate in the vicinity of hardware units (Balasubramanyam et al., 2000; Madon, 1997).

It needs to be emphasized that the initiation of the industrialization process in Bangalore city is *not* a post-independence phenomenon. In fact, HAL was created by the British in 1940 to support the war efforts. Subsequently, two more state owned firms were set up by the British: Radio and Electric manufacturing Company was set up in 1942 to make radio receivers and components and Mysore Electrical Industries was started in 1945 to produce switchgear and motor control gear. The latter, in fact was set up in collaboration with a UK company (Heitzman, 2004: 45). The emergence of modern industry in Bangalore, therefore predated independence and along with post-independence investments created a large modern industrial workforce in the city. In fact, HAL had as many as 21,000 workers by 1960 (Heitzman, 2004: 45). Existence of such a workforce was conducive for the emergence of the IT and electronics sectors and therefore, Bangalore was able to exploit the potential in a better way than other regions.

Early Recognition of the Importance of Software Exports and Public Procurement

The potential of software exports was recognized as early as in 1972 when the *Software Export Scheme* was launched. The scheme provided a variety of concessions to software exporters including hardware imports at low tariffs. Simultaneously, computer and software education and training were emphasized and institutions that focused on training were allowed to import hardware at much lower import duties. Around the same time the Department of Electronics (DoE) began to encourage public sector projects that dealt with software development. Besides, public procurement of software gave priority to Indian companies. All this started to create some domestic demand for software.

Foreign Exchange Regulation Act and Exit of Foreign Firms

The other major policy change in the mid-1970s was Foreign Exchange Regulation Act (FERA) that sought to reduce foreign ownership of firms in India and computer firms were no exception.

[4] Key educational institutions like the Institute of Science already existed in the city at the time of independence. We will return to the role of educational institutions in a later section.

A fallout of the government's decision to reduce foreign ownership was that software development occurred in-house. Some companies like ICL (U.K) accepted this, reducing their share of the company's equity to 40 per cent, while others, such as IBM, chose to leave India in 1978. IBM's departure from India had significant implications for the computer industry in the country and in Bangalore. Some companies created 8-bit micro-processors and sold them in the local market. One of them was Wipro based in Bangalore.[5] An estimated 1,200 software personnel were released into the Indian market due to the exit of IBM. According to Heeks (1996: 70) this had an interesting impact on the software export business. Many of these people had no option but to leave India if they wanted to pursue careers in information technology. Others set up their own small companies, as there were very few companies that were dedicated to the development of software and to software services. Many of these companies were set up in Bangalore. Initially, the focus of many of the IT companies set-up during this period was on providing services for domestic clients, but as the domestic market was proving too difficult to penetrate, due to the very low level of computerization and the high level of in-house development, the focus shifted to the export market.

Trade Protection and Liberalization

For a brief period in the second half of 1970s, hardware imports were liberalized with reduction in duties,[6] especially for software exporters and a variety of incentives to export were put in place. But by early 1980s stricter controls were put on hardware imports; import duties on hardware were raised but firms were allowed to use the hardware for the development of domestic software as well as for exports. Besides, software exporters could also import "loaned" computers.[7] Moreover, the DoE's approach to the domestic software industry became more supportive than the previous restrictive and regulatory one. It also encouraged software exports and *export-oriented foreign investment*.

The policy to protect the hardware industry had an important impact on the software industry. It forced Indian computer firms to shift focus away from mainframes, which were the mainstay of the multinationals, towards producing and using micro or personal computers. This led to a generation of software engineers who gained a great deal of experience in programming for PCs, in operating systems like MS-DOS and particularly UNIX, which was an operating system for non-IBM compatible computers based on Intel and Motorola chips. This operating system was preferred and pushed by the CMC and the DoE (Heeks, 1996). Policy changes in 1986 enabled the import of the Unix source code and Unix was emerging as the de facto standard in the super micro and the mini markets. According to an IDC study, 1,400 Unix systems were shipped in 1987-88, compared to just 480 the year before—a whopping 191% growth. Meanwhile, the PC had come to India and within a couple of years, a price war triggered by Sterling Computers led to vendors slashing prices. By 1988, there were more than 70,000 microcomputers in the market. The PC and compatibles market boomed—alongside, local SW packages grew. By December 1988, more than 500 software companies were making packaged software—a major chunk of them cheap accounting packages.[8]

One of the effects of these policies was that some Indian companies, (HCL, Wipro Information Technologies Ltd, and DCM DP), became the first in the world to build computers that were based on UNIX.[9] This research and the knowledge that was created, provided Indian software engineers with a competitive edge when the computer policy was liberalized in the post-1984

[5] Others were DCM DP and HCL in Delhi.

[6] This had some interesting positive spillovers. In 1981 NIIT was started in Delhi by HCL as a training company to exploit the tax waiver on hardware imports and thus enter the hardware industry. Such training initiatives multiplied manifold in subsequent years.

[7] After a brief gap, deregulation of hardware and software imports continued in the second half of the 1980s; apart from reducing tariff rates on these imports, the policy allowed Indian firms to become distributors for foreign software. Reduction of import duties on software/hardware continued in the 1990s combined with more flexible ways of fulfilling export obligations (Table 1).

[8] This discussion is based on reports in several issues of Data Quest.

[9] Wipro located in Bangalore, is often cited as the first IT success story in the city (Heitzman, 2004: 180).

period and when the mainframe technology gave way to the personal computer technology in the global software industry in the latter half of the 1980s (Heeks, 1996, pp. 214-216). In response to the success of companies like HCL, TCS and Wipro, a new Computer Policy was introduced in 1984 which reduced many constraints on the industry (Table 3). IT industry was recognized as an industry and several measures were introduced to facilitate imports, improve foreign exchange availability and reduce tax burden for exporting firms. The New Software Policy further liberalized the regime that advocated imports. It was this regime that allowed the entry of Texas Instruments (TI) in Bangalore in 1985-86. TI was a 100 per cent export-oriented, foreign owned and operated subsidiary (its first outside the United States) with a direct satellite link to the US. The government or VSNL softened many rules to allow this connectivity. [10]

Setting-up of Electronic Parks and Infrastructure

As far back as in 1976, the Government of Karnataka attempted to encourage the electronics industry through the establishment of Karnataka State Electronics Development Corporation (KEONICS). The Corporation entered into production with its own and joint sector initiatives with domestic and foreign industrial houses. It promoted private enterprises through marketing support, created testing & development centers and also operated manpower training centers. In 1977, the Department of Electronics of Karnataka state formed an Electronics Park that also housed the Software Technology Park (STP), the first in the country. This facilitated the exploitation of emerging IT opportunities in Bangalore. In late 1980s (during 1988-91), the Software Technology Parks of India Scheme was launched by the federal government ((Heitzman, 2004: 188-89). The scheme provided many facilities (see Table 3) and helped the fledgling STP scheme that the Karnataka government had launched earlier as more resources became available from the Center for the STP in Bangalore. Around the same time VSNL commissioned a direct 64-kbps satellite link to the U.S. It was a new gateway switching system, which operated through Intelsat and was directly linked to AT&T's earth station at Coram on the US East Coast. This offered software exporters a completely new way of functioning and enhanced the facilities available through the STP scheme. These facilities got further enhanced in 1992 when an exclusive satellite international gateway for export industry was set up. The STP in Karnataka took care of a variety of infrastructural constraints, especially those related to telecom.[11]

One can argue that the timing of setting up the park in Karnataka was just right. Market forces were already inducing the creation of the cluster. This policy further facilitated this process with better infrastructure and other support. Other infrastructural facilities were also good in the city, although things have deteriorated a bit in recent years.[12] A recent survey of IT and electronics firms in Bangalore, in two other clusters (Pune and National Capital Region) and in other "non-

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[10] The DoE and the Government of India were fairly quick in the processing of the license and apparently DoE broke 26 separate rules to accommodate TI's Bangalore subsidiary and were willing to break more (Heeks, 1992, p. 7). TI played a very important role in the growth of the cluster. This will be discussed in a subsequent section.

[11] STPI Bangalore became an Internet service provider (ISP) even before VSNL, and had large number of corporate customers for its SoftNet service. In 1991-92, soon after it was set up, it "bypassed" the Department of Telecommunications and the local loop to provide a microwave link to IBM.. And in 1993, it was the only place in India with an ATM (asynchronous transmission mode) connection, providing an incubation center for nearly 60 startups. Subsequently, STPI'S communication facility at Electronics City on Bangalore's outskirts became a connectivity exchange with **7** satellite gateways and **3** metropolitan fiber networks residing at the same place, apart from the country's biggest microwave radio network for data covering more than 150 buildings in Bangalore. It has also expanded this infrastructure to Mysore and Manipal, the nearby cities. The park has three more unique features – by 2001 it provided a global gateway for **125 VSATS** (very-small-aperture terminals) across the country, including the remote areas of the northeast; it manages a Nortel hub which is one of only a dozen in the world; and it has an internal process which coordinates all communication for the other STPS with 24u7 manned consoles for network management (*Beyond Bangalore*, Business India, and July 09, 2001). In 2003, India's VSNL entered into an agreement with US-based voice and data communications major, AT&T, to offer managed data networking services to local enterprises. According to the agreement, AT&T has set up MPLS (multi protocol label switching) enabled network nodes at Mumbai and Bangalore (World IT Report, 7/9/2003). In the same year Sify Ltd. Made Bangalore city WiFi enabled with broadband connectivity from over 120 hotspots. Sify chose Bangalore for the launch of WiFi services given its lap top population, familiarity with working online, as well as international visitors needing such services while moving around the city. (*Bangalore - India's first WiFi enabled city,* World IT Report, 10/15/2003, Source: *Business Source Premier*).

[12] It is quite interesting to note that Bangalore was the first electrified city in India. The state run utility company was started in 1900 in co-operation with the US based General Electric Company (Heitzman, 2004: 33).

cluster" areas showed that a much larger proportion of Bangalore firms (55 per cent) find physical infrastructure a major constraint than firms in other areas; the proportion of firms reporting such a problem was 33 per cent in other cluster areas and only 31 per cent in non-cluster areas. It is possible that significant growth in recent years have made the available infrastructure in the city quite inadequate. Similarly, availability of power and transport facilities is increasingly becoming a constraint (See Table 5 discussed below).

Taxes, Off-shoring, Devaluation, FDI, and More

To represent the interest of the Indian Software industry, NASSCOM was formed in 1988. In the very next year, a policy decision was taken that reduced the potential profits that the Indian firms could derive through "body shopping" activities. It was decided to impose a 15 per cent tax on foreign exchange expenditure (especially on travel) (Heeks, 1996, p. 47). There may have been some effort on the part of the Indian firms around this period to reduce the "onsite" component of outsourced work. This tax was abolished in 1991 but the process of reducing the "onsite" component had begun which facilitated the growth of centers like Bangalore which were ideal for "offshore" activity given the capabilities and the infrastructure availability. The transition from "onshore" to "off-shore" continued due to another policy decision, but one taken by the U.S. government. In 1993 US Immigration and Naturalization Service proposed changes to the regulation that made it difficult to get B-1 visas. Clients had lesser incentive to hire software engineers from India. At the same time cost pressures were on the rise and a larger share of the "off-shore" component made business sense. One observed a rapid increase in the offshore segment of the Indian software and services exports.[13] Whatever may have been the underlying motivations, the transition from the onshore to the offshore model benefited locations that had a large pool of workers that had the requisite skills and Bangalore was one of them. The cost advantage of the offshore model increased with the devaluation of the Rupee in 1991, reduction in telecommunications charges for satellite links and duty-free and & obligation-free imports of telecommunications equipment in the STPs. A variety of tax and other benefits introduced in the 1990s made IT business more profitable (Table 3). As a complementary policy 100% FDI was is allowed in 1999 in the IT industry. Partly as a result of this policy many MNCs set up development centers in India as their own offshore arms, most of them doing really high-end work. In the same year the Indian Institute of Information Technology, Bangalore (IIIT, Bangalore) and the KITVEN FUND were also established. We shall come back to the impact of these developments later.

It has been argued that social and political stability within the state, absence of labour conflicts, and extensive support of the government during the initial phases of setting up of a firm (e.g., simplifying the procedures for establishment of software unit) have also contributed to the growth of the Bangalore cluster (Balasubramanyam et al., 2000; Madon, 1997). All these are broadly policy and governance linked factors. Overall, several policy measures over the years have contributed to the growth of the Bangalore cluster. While many of these policy initiatives in the 1980s and 1990s were undertaken by the federal government, they benefited the Bangalore cluster as it already had the basic capabilities – skill pool, enterprises, linkages etc. – to benefit from these policies.

3. The Diaspora – Building Networks and Reducing the Cultural Differences

Entire graduating classes from the elite Indian Institutes of Technology emigrated during the 1970s and 1980s.These émigrés often achieved impressive professional and economic successes abroad. In 1998, Indian engineers were running more than 775 technology companies in California's Silicon Valley that accounted for $3.6 b in sales and 16,600 jobs. Talented immigrants who have studied and worked abroad increasingly return to their home countries to pursue promising opportunities there. As engineers and other professionals return home—either temporarily or permanently—they transfer not only technology and capital, but also managerial and institutional know-how to formerly peripheral regions. They also link local producers more

[13] The onsite share declined from 90% in 1990-91 to about 39% in 2002-03.

directly to the market opportunities and networks of more advanced economies (Saxenian, Forthcoming, Kapur 2002, Kapur and McHale, 2005).

As mentioned, during the 1980s, Bangalore's main software-industry exports were not products, but people: high-skill, low-wage software engineers and programmers who took jobs in the United States. IT managers of Indian origin working in U.S firms have played an important role in helping their firms consider outsourcing to India. Entrepreneurs have started companies like Mastech, Syntel, CBSI and Information Management Resources (IMR) in U.S that relied on Indian programmers to provide software development services to domestic clients (Arora, Arunachalam, Asundi, & Fernandes, 2001).[14] Further, during 1960 and 1970, a number of skilled Indian professionals migrated to USA (of which many of them were from Bangalore) and returned to India in the early 1980s. These entrepreneurs set up centers in Bangalore taking advantage of large English speaking population in Bangalore.

According to one estimate, 71 of the 75 multinationals in Bangalore's software technology park were headed by Indians who had lived and worked overseas, especially in the U.S. (Ghemawat 2000). Companies like Yahoo, Hewlett Packard and General Electric opened operations in India largely because of the confidence engendered by the presence of many Indians working in their U.S. operations (Kapur, 2002). In fact, most MNC IDCs are headed by Indians who've worked in the parent multinational in the US for several years and who see this as an opportunity to come back home without jeopardizing their careers.[15] Overseas Indian presence has helped in the diffusion of knowledge through a variety of mechanisms. Given the technological frontier in the U.S. there is substantial skill up-gradation when Indian technology professionals work in the U.S., through learning by doing. To the extent that some return while others circulate between the two countries, technological diffusion occurs through imitation, mimicry being an effective way to reduce search costs (Kapur, 2002). Moreover, as Indian software professionals become knowledgeable about the U.S. economy and culture, their ability to develop software for the U.S. market is enhanced. If they return to India, this benefits both the Indian and the U.S. economy (Arora, Arunachalam, Asundi, & Fernandes, 2001). Consequently, outsourcing becomes even more cost-effective.

4. MNCs and Large Private Firms – Linkages, Capabilities and Spillovers

According to a study conducted by the Administrative Staff College of India (ASCI), 77 global firms have established R&D centers as direct subsidiaries; several others have formed R&D alliances with or have contracted research to local firms. Bangalore, with nearly 40 of the 77 centers, is clearly way ahead of the rest as the most preferred place Existing companies are expanding. Regarding new investments on an average six new MNCs per month open their centers in Bangalore (Businessline, Monday, Mar 24, 2003).

Research and development spending had increased from 2.5 per cent in 1997-98 to over 4 per cent during 2000-01, and is expected to increase further as firms try to go up the value chain (Kapur, 2002). Several studies have highlighted the role of MNCs in developing capabilities through several mechanisms (Patibandla and Peterson, 2002). The spillovers associated with the activity of MNCs in a cluster can be varied. Appendix I summarizes the activity profile of some important MNCs operating in Bangalore. It is evident that the activity profile of most of these firms has become more complex over the years with more R&D and patenting activity. The details also show that these firms contribute to the local cluster through training and collaborations with

[14] Firms such as Mastech, Information Management Resources (IMR), Syntel, Cognizant (a subsidiary of Dunn and Bradstreet), and CBSL use their India operations much in the way that Indians software export firms do. For example, tapping a large pool of relatively cheap but skilled workforce for providing software services to U.S. based clients. These firms are similar in many respects to the Indian software firms. Virtually, all are headed by entrepreneurs of Indian origin, and started their existence, as did many of the leading Indian firms, by supplying software professionals such as programmers and analysts to clients in the U.S. As Indian software exporters establish overseas subsidiaries, the distinction between the two will tend to diminish. (Ashish Arora ???)

[15] This observation is based on personal communications with IT professionals in Bangalore.

entities in the cluster. These entities include firms as well as educational institutions. Virtually everybody who has seen the evolution of the Bangalore cluster closely believes that the entry of Texas Instruments (TI) in the mid-1980s was critical for the growth of the cluster because their entry showed the potential of off-shore activities in a significant manner. Since TI persisted with their vision of having a unit in India and managed to deal with all the bureaucratic hassles of having internet connectivity etc., it inspired other firms to do the same.

One major source of capability creation in the cluster has been linkages between small IT firms and the MNCs. Some of these links are evident in the summaries provided in Appendix I. Small IT companies in India have started to offer their workforce on project basis to the large ones in an arrangement reminiscent of the old body-shopping practice. While small companies such as System Logic, Datacons Pvt Ltd, Intertec Communications and Nagaraj Technologies are lending a part of their workforce, the demand for contract professionals is mainly from the Indian arms of MNCs such as HP, Texas Instruments, Robert Bosch, Philips Software and companies such as Wipro, MindTree Consulting among others.[16]

Just as the activity profile of MNCs has enhanced the capability of the Bangalore cluster, the large domestic firms and few R&D intensive small firms have also contributed to the process. Recent evidence shows that these firms are evolving software development methods and project management skills that enable them to undertake larger and more complex projects and execute high value added parts of such projects. Studies show that firms in Bangalore make investments in training, professional development programmes, infrastructure, techniques and methods, process and people management initiatives. While more recent estimates are not available, in 2001, training constituted about 5% of revenues. Further firms like Infosys spent around 5% of their revenue on R&D. Texas Instruments in Bangalore design sophisticated chips and owned around 200 patents. Several MNC firms are also making R&D investments. Additionally, attrition of labour to the tune of 30% is common across firms in Bangalore. These help firms exchange information not only specific types of software but also generic principles and organizational methods. Despite the above the formal nature of alliances were restricted till about recently between large Indian software majors like TCS, Infosys, Wipro and the MNCs such as Nortel and HP. Apart from the above, collaborations also exist in the form of Software Productivity Improvement Network (i.e., a group of 10 large firms sharing information or benchmarks on software practices in each of the firms). All these put together contribute to the capability development of IT firms in Bangalore over the recent years (Arora, Arunachalam, Asundi, & Fernandes, 2001). Overall, while the MNCs have been active in patenting, a majority of Indian software services R&D efforts are aimed at generating other forms of IP, like reusable components. At a very simple level, IP in the IT services context can be defined as an ownership of code and the ability to sell the same piece or block of code to multiple customers (Data Quest Top 20, 2003).

Overall, the success of TI increased the interest of other US technology companies in setting up their own operations. The details in Appendix I show that only a few MNCs (While Motorola and Hewlett Packard) entered Bangalore in the 1980s; many more set up operations in the early and mid 1990s. The rate of entry of MNCs has increased significantly after the late 1990s. While the role of TI and to some extent Motorola and HP has been to put Bangalore on the horizons of the MNCs, subsequent MNC entry has facilitated the learning process and has probably also churned up the labour market. Over time the nature of activities undertaken by MNCs in Bangalore has become more diverse and complex. The externalities associated with all these activities have been

[16] For example, a few years ago Datacons had a team of professionals managing the infrastructure services at Motorola India and employees were deputed to Wipro for specific projects. The company had deputed nearly 30 of 225-strong workforce to various companies (Business, Chennai, Mar 2002, p. 1). Similarly, System Logic caters to companies such as LG Soft India, Robert Bosch, MindTree Consulting and Wipro. At any point in time, 50 of the company's 80 professionals on its rolls were on deputation to different companies.

critical for the growth of the Bangalore cluster. The linkages of firms with academia, firms and other entities may have enhanced the benefits of these externalities.

5. Academia-Industry Linkages – Providing Labour and Knowledge

Education, especially English education has a long history in Bangalore. The creation of a British military base (cantonment) in the city in 1807 unleashed a variety of processes which may have contributed to the emergence of the city as an educational center. The cantonment attracted a wide range of service providers from all over southern India, making the population very diverse. The cantonment commissioners subsequently supported the establishment of the first English medium school in 1842 (Heitzman, 2004: 29-30). Another English medium school for poor Anglo-Indians was set up in 1854. Post independence, the preference for English even among the poor has persisted and Bangalore today has more English medium schools than Kannada medium ones (Pani, 2005). Prior to independence, M Visvesvaraya contributed tremendously to the creation of the technical educational system in Bangalore. He set up an engineering college in 1917 and around the same time steered the creation of Mysore University to which many colleges in Bangalore got affiliated. The Indian Institute of Science was set-up in 1911. Visvesvaraya firmly believed in the role of the technically educated workforce in the industrialization process and his efforts made Bangalore the hub of technical education even before independence.

As a result of all these efforts, Bangalore city had high literacy rates even in the 1950s (43 per cent in 1951) and these increased rapidly to 65 per cent in 1981 and to 86 per cent in 2001 (Heitzman, 2004: 223). After independence also a large number of educational institutions were established in Bangalore including four universities, 14 colleges providing scientific and engineering education and 47 polytechnic schools. The wages were initially low due to excess availability of skilled workforce in Bangalore. By the late 1990s India was producing about 65,000 engineers and 95,000 diploma-holders annually in engineering and technology (World Bank, 2000) through a large network of public and private colleges. The system was producing nearly 100,000 IT professionals annually, many through private institutes (the figure is projected to increase to half a million by 2006). Karnataka has 132 engineering colleges with 25,000 seats, in addition to 200 diploma institutes. A further 78 colleges in engineering and science are to be permitted, with a possible addition of another 10,000 students (Kapur, 2002).

The advantages of locating in a cluster, especially Bangalore were briefly discussed in the introductory section. In the context of the role of academic institutions, it can be seen from Table 4 that firms in Bangalore cluster rate access to skilled labour as the most important advantage (with a rating of 3.99 on a five point scale) of locating in these cities. This strongly recognizes the role of academic institutions as key suppliers of labour in the market especially in the knowledge sectors of IT and Electronics. To what extent better access to training and R&D facilities in their location was an advantage? Once again, Bangalore firms found the advantage of having access to specialized services like training, R&D services and facilities etc. to be quite high. Interestingly, here on average the Bangalore firms found this advantage to be better than the other cluster firms. Another interesting result is that firms in Bangalore seem to be better placed in terms of access to skilled labour and R&D institutions than the other clusters. As expected, firms located in cities where IT and electronics cluster do not exist (non-cluster firms) are not as well placed in terms of all the three areas (access to skills, training and R&D facilities) as the cluster firms; their average score is significantly lower than those of the cluster firms. The data on constraints facing the firms located in Bangalore and elsewhere also reflect the fact that Bangalore is well endowed in terms of the availability of educational and technology development infrastructure than non-cluster areas (Table 5).

An earlier study showed that almost all the domestic and foreign firms located in the STPs have had some form of professional contact with research laboratories or institutes in Bangalore in the last five years; about one-third of the firms surveyed agreed that these institutes provided new ideas that helped to improve their existing products or design and to introduce new products (Srinivas, 1997). A more recent study has also found that the academia-industry linkages in

Bangalore are very diverse; the local academic institutions are the providers of labour as well as knowledge. Besides, institutions which were earlier essentially providing labour to the growing cluster are now making efforts to transition into knowledge based linkages. However, the number of spin-offs from academic institutions is still quite small (Basant and Chandra, 2005). In fact, the available data suggests that such activity has still not taken roots in the Indian milieu, not even in a place like Bangalore which has grown very rapidly in recent years, represents modern entrepreneurial culture and hosts many academic institutions with significant research programmes.[17]

While the role of institutions as a key source of talent is widely recognized, other linkages are formed as firms in a city cluster go up on the capability ladder or start to service complex order requirements of advanced customers. The difference in perceived benefits of linkages with academic institutions between Bangalore and other cluster firms (Table 4) could also be reflective of how the city cluster has evolved to date and may be indicative of the demand (and likely supply) for the nature of institutions and the accompanying capabilities. It may be mentioned that there is a significant difference in the mean value of responses on these linkages between firms located in a city cluster versus those that are not part of one (Table 4) implying that these locational benefits are appropriated when there are others with whom such linkages can be formed.

6. Inter and Intra-Cluster Linkages – Knowledge Flows and Capability Building

Other factors which contributed to the growth of Bangalore include social and political stability within the state, absence of labour conflicts, establishment of techno-parks, improving the physical infrastructure, high-quality residential complexes and extensive support of the government during the initial phases (i.e., simplifying the procedures for establishment of software unit) (Balasubramanyam et al., 2000; Madon, 1997).

Many firms also depended on a local network of firms (private and public sector) to carry out tests of various levels for different products. For example, a particular software company may send a test version of its product to potential client firms. Most companies located within an STP agreed that such interaction with local firms on a regular basis has helped them to adapt their products and services more quickly for global markets (Madon and Sahay, 2001: 273).

The role of these linkages gets reflected in the perception of firms regarding advantages of locating in clusters, especially Bangalore. Table 4 also shows that as compared to other clusters (and non-cluster regions) firms in the Bangalore cluster derive more benefits due to their proximity with customers and suppliers. Interestingly, advantages due to proximity with customers are not significantly higher for Bangalore firms than their counterparts in other clusters. This is presumably because a large segment of customers for the IT firms in all clusters are located in other countries. Interestingly, cluster firms derive more advantages due to proximity with customers than non-cluster firms. An unexpected result is that the Bangalore firms do not find availability of infrastructure as a major benefit as compared to firms elsewhere. This is possibly due to the fact that infrastructural facilities in the city are overstretched now and seen more as a constraint. Overall, Table 4 brings out that cluster firms derive a large variety of advantages, many of which are mentioned above. Moreover, within clusters, Bangalore continues to be a better location than others due to possibilities of local linkages, availability of R&D institutions, skilled labour and so on.

Why are linkages important? One of the many advantages could be building of capabilities through adoption of various good processes and practices. This change could be through demonstration effects due to the right location or through explicit knowledge flows built around a variety of linkages. In a recent survey undertaken by the IIM, Ahmedbad, we collected data on the good processes and practices adopted by the IT and electronics firms. The list of these processes

[17] For some details of spin-off activity, see Basant and Chandra (2005).

and practices was developed with the help of detailed interviews of experienced industry persons. Combining all types of processes and practices, Tables 6-8 provide summary information on their adoption in cluster and non-cluster firms.[18] It is evident from Table 6 that IT firms in clusters are significantly better than non-cluster IT firms in the adoption of some processes. Interestingly, Bangalore IT firms are not significantly different from other cluster firms in the adoption of any of these processes. This pattern changes when we look at adoption of practices by IT firms (Table 7), wherein Bangalore IT firms are significantly better than firms in other clusters in the adoption of coding and human resource management practices. Besides, cluster firms are significantly better than non-cluster firms in the adoption of all types of practices.

In the case of electronics, on average Bangalore firms lagged behind firms of other clusters in the adoption of some processes and practices but were ahead than non-cluster firms. Evidently, electronic firms in other clusters have not only caught up with Bangalore firms in terms of adoption of good processes and practices, they have also moved ahead. This can result in lower competitiveness of Bangalore firms in the future. The policy promoted equitable distribution of electronic firms. Consequently, NCR and Pune caught up much earlier than Bangalore in case of electronics (Joseph, 2004).

Is the adoption of good processes and practices affected by firms' linkages with outside entities within and outside the city? The IIM, Ahmedabad survey also compiled data on the variety of linkages firms have with other entities. Tables 9 and 10 provide a summary picture of linkages of electronics and IT firms respectively in Bangalore and elsewhere. It can be seen that the linkages of Bangalore firms in both the sectors is higher than that of firms in other clusters and in non-cluster areas. Bangalore firms are particularly in the advantageous situation with respect to international and national customer networks and other international networks. The variation in the number of linkages across firms is quite high (Tables 9 and 10) and the same is true of the adoption of processes and practices (data not reported here). Tables 11 and 12 show that on average, employee productivity in cluster firms is much higher in clusters than in non-cluster areas. Interestingly, on average Bangalore firms tend to be more productive than other cluster and non-cluster firms in the electronics sector; in the case of IT they are significantly better than non-cluster firms but not other cluster firms. Once again the variability across firms in productivity (not reported here) is quite high among both electronics and IT firms in clusters. Preliminary econometric estimates based on firm level equations show that these linkages facilitate capability building (through adoption of good products and processes). These capabilities in turn have a positive impact on profitability of firms.[19] Overall, therefore, there is some evidence to show that linkages, especially international linkages build capabilities, which in turn have a positive impact on the profitability of firms. Since firms in Bangalore have been able to build these linkages over the years, they are better placed in terms of opportunities and growth prospects.

7. Some Concluding Observations

Broadly then, Bangalore has been quite unique in terms of the initial conditions and benefited a great deal from policy initiatives immediately after independence. Investments in education during the pre and post-independence period paid off when the city became a focus of state sponsored industrialization process. Early emergence of a large and diversified public sector in the city created a very large pool of well trained persons who understood technology well. This in turn prepared the cluster for exploiting business opportunities that emerged during the Y2K period and subsequently as the ICT industry grew rapidly through outsourcing. Presence of Diaspora linkages and early entry of MNCs created a base for a variety of international linkages that facilitated transfer of knowledge and adoption of good processes and practices. Existence of decent educational and R&D institutions and their subsequent growth deepened the local labour

[18] For details of the processes and practices covered in the survey, see Basant, Chandra and Upadhyayula (2006) and Upadhyayula (2006).
[19] For details of these results see Basant, Chandra and Upadhyayula (2006) and Upadhyayula (2006).

market and provided good R&D and other related facilities. The state government provided good governance that facilitated the exploitation of emerging opportunities. However, survey data seems to suggest that other clusters are now catching up and Bangalore seems to be facing a variety of constraints that may hamper its growth in the near future.

Is diversity of the cluster important for technology flows and cluster growth? Although it is difficult to explore this link systematically, the available evidence suggests that diversity may have contributed to the growth and sustainability of the Bangalore cluster. The recent emergence of bio-technology firms are gradually leading to some synergies across sectors (IT, electronics and biotech) that may result in changes in the activity profile of new firms in the cluster. This issue is important from the point of view of "designing" a cluster by policy makers. Policy instruments should facilitate the exploitation of these synergies. Creation of inter-disciplinary courses and research activity in the cluster may be helpful in this regard.

The earlier literature has clearly shown that exposure to demanding markets generally enhance capability building (see Basant 2002 for a review). Bangalore is no exception with significant exposure to demanding international markets. How does one strategically maximize such learning? As many earlier studies have suggested, policies enhancing export orientation should help but the analysis above does not give us any additional insight on this issue. The paper also creates additional support for the hypothesis that presence of MNCs in the cluster can create positive spillovers through contagion and competition effects. Bangalore as a cluster seems to have benefited a great deal from their activities.

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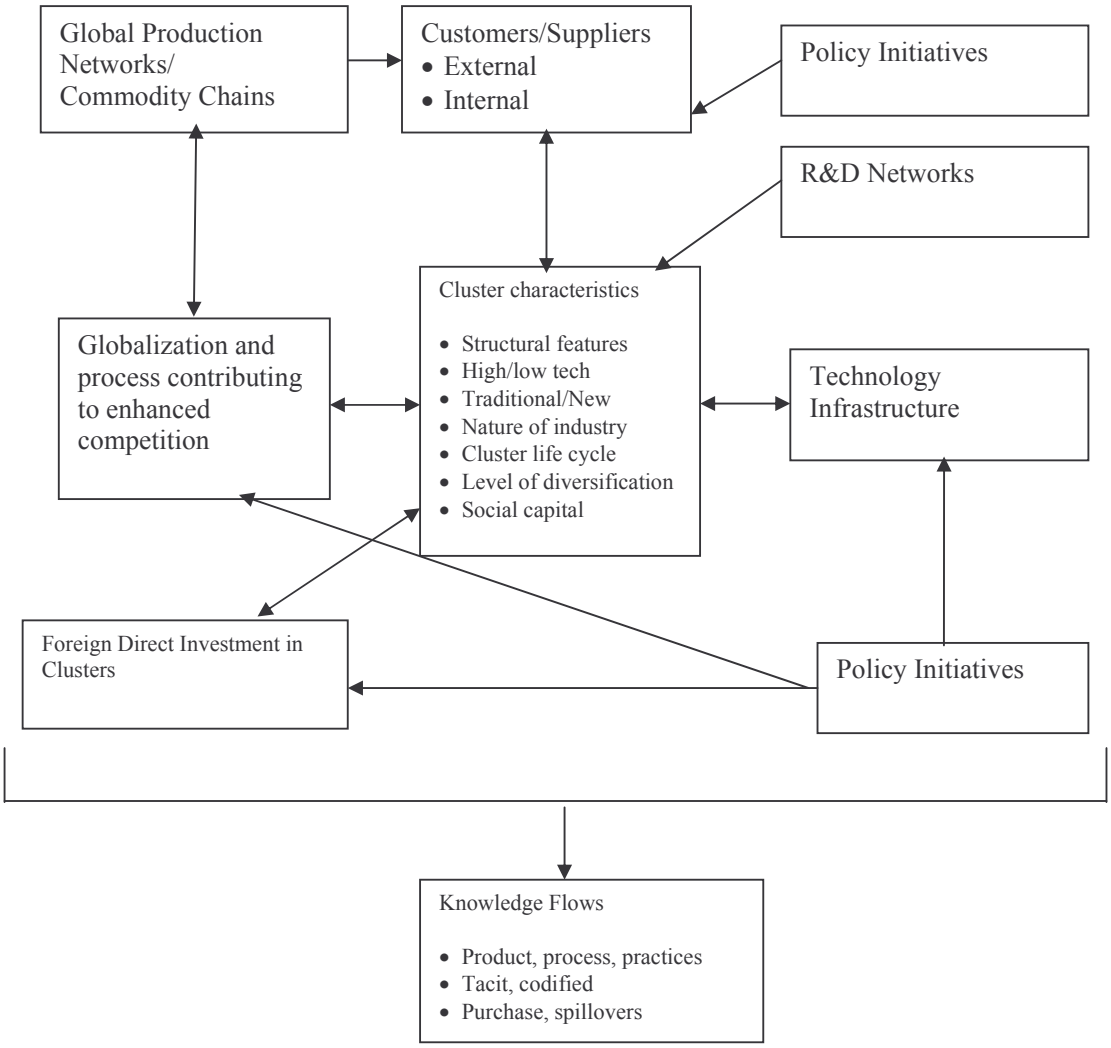

Figure 1: Cluster Characteristics, Linkages, Policies and Knowledge

Table 1: Sources of Knowledge in Industrial Cluster	
A.	Intra-firm sources • Learning by doing (Passive experience of production) • Improved process and practices derived from trial and error experimentation • Adaptation and improvement of existing technologies (reverse engineering etc) • Aligning products, processes and practices within the firm.
B.	Intra-cluster sources • Knowledge spillovers/diffusion between producers • Knowledge spillovers/diffusion between users and producers of machinery/material or production related services • Intra-cluster mobility of skilled labour • Training and skill development through cluster based/mediated initiatives • Links between enterprises and cluster based technology institutions (technology development, adaptation, testing, certification etc) • Collaboration among cluster based enterprises for adaptation and technology development (machinery, product design) • Links between enterprises and customers located in the cluster (MNC, large firms)
C.	Sources outside the cluster • Customers and traders knowledge • Machinery and other input suppliers • Collaborative testing or technology development with technology institutions and enterprises outside the cluster. • Externally sourced training • Visits to outside clusters/firms

Source: Basant (2002)
Note: Bell and Albu (1999) inspired the creation of this table.

Table 2: Determinants of Knowledge Flows in Geographically Bound Clusters – A Summary	
Factors	Likely Effect on Knowledge Flows (Empirical Evidence)
A. *Factors Internal to the Cluster*	
• Spatial proximity	Positive. Passive externalities and potential for active cooperation, flow of tacit knowledge
• Horizontal inter-firm linkages between firms producing similar products	Positive but collaboration generally weak
• Vertical inter-firm linkages (user-producer)	Positive, collaboration relatively strong
• Demanding customers	Positive
• High tech (tacit, complexity)	Generally positive but depends on production organization
• Traditional industries	Mixed results?
• Social capital	Positive, measurement difficult
• Cluster structure	
• Role of large firms	Positive? Limited evidence
• Type of clusters	Limited evidence
• Cluster life cycle	Higher during early phases
• Existence of facilitating institutional framework	(Tacit knowledge) critical
• Universities/R&D institutions	Critical for high-tech and some traditional
• Associations (standards, testing etc.)	Important for all types
• Nature of industry	Limited evidence, knowledge flows seem to be more important for science based industries
• Diversified/industry specific	Limited evidence Nature of knowledge flows may differ
B. *External Links of the Customers/Suppliers*	
• External customers	Positive if customer demanding and has less market power
• Links with equipment suppliers/R&D institutes	Generally positive
• Links with global production network or commodity chain	Important location in the network/chain matters
• Foreign direct investment	Depends on technology gap and objectives of FDI
C. *Policy Initiatives, Environment*	
• Enhancing competition (trade liberalization)	Encourage efforts to access knowledge Optimal levels of competition?
• FDI policies	Local manufacturing?

Source: Basant (2002)

Table 3: Summary of Policy Changes Contributing to the Emergence and Growth of the Bangalore Industrial Cluster	
Period	*Policies*
1947-60 *Public Sector Policies and Creation of Large Firms*	• State monopoly in several defense and infrastructure industries and most of them located in Bangalore • Setting up of large public enterprises like Hindustan Machine Tools (HMT), Bharat Electronics Limited (BHEL) and Indian Telephone Industries (ITI) • Licenses for large private firms like Motor Industries Company better known as MICO (the automotive components manufacturer, a subsidiary of Robert Bosch GmbH of Germany) and the machine tool manufacturer WIDIA
Early 1970s *Export Focus Training and Procurement Policies*	• The **Software Export Scheme** included imports of hardware for exporting firms with duty concessions • Emphasis on computer and software education and training. Institutions that focused on training were allowed to import hardware at much lower import duties • Department of Electronics (DOE) began to encourage public sector projects that dealt with software development. Public procurement of software gave priority to Indian companies.
Mid 1970s	• Restrictions on foreign ownership (FERA)
1976-77 *Export-Import Liberalization*	• Hardware import duties reduced from over 100 per cent to 40 per cent • Faster clearance of software export applications • Software exporters could take advantage of export incentives including locating in EPZs • Non-resident Indians allowed to import hardware for the purposes of software export with a 100 per cent export obligation.
Early 1980s *Foreign Investment Export-Import Liberalization*	• DoE more supportive of the domestic software industry, encouraged software exports and export-oriented foreign investment • Import duties on hardware were raised • Firms allowed to use the hardware for the development of domestic software as well as for exports • Software exporters could also import "loaned" computers
1984 *New Computer and Software Policy*	• Import procedures for hardware and software simplified • Import duties for hardware and software reduced from 135 per cent to 60 per cent for hardware and 100 per cent to 60 per cent for software • Software recognized as an industry and licensing procedures simplified • Improved access to foreign exchange for software firms • Income tax exemption on net export earnings reduced from 100 per cent to 50 per cent
1985	• DoE of Karnataka formed an Electronics Park - KEONICS- that housed the Software Technology Park
1986 *Computer Software Export, Software Development and Training Policy*	• Imports of hardware and software further deregulated; anyone could import software at 60 per cent duty • 100 per cent export oriented software production units permitted to import hardware duty free • Indian firms allowed to sell foreign software, i.e. they could become distributors • Export obligations for hardware importers increased by 50 per cent and the time in which to meet the obligations reduced to 4 years
1989 *Tax on Travel*	• Imposition of a 15 per cent tax on foreign exchange expenditure on travel

1989 *Telecom Infrastructure*	• VSNL commissioned a direct 64-kbps satellite link to the US - a new gateway switching system, which operated through Intelsat and was directly linked to AT&Ts earth station at Coram on the US East Coast
1988-1991 *Software Technology Parks of India (STPI) Scheme*	• Software Technology Parks of India Scheme - Creation of software technology parks for the production of software for export o Government provided office space and computer equipment, access to high-speed satellite links and an uninterrupted supply of electricity. o DoE installed appropriate telecommunications equipment to provide easy access to the clients of software firms that expedited delivery of software exports o 100 percent export-oriented firms a tax-free status for five years within the first eight years of operation o Single window clearance for projects (for the smaller projects, i.e. less than Rs. 30 million only STP clearance required) o 100 per cent foreign equity permitted, and no restrictions on location (1) o Provision of video-conferencing services between Bangalore and the rest of the world
1991 *Forex policies and Trade Liberalization*	• Devaluation and partial convertibility of the Rupee • Abolition of tax on foreign exchange for travel • Reduction in telecommunications charges for satellite links • Duty-free and obligation-free imports of telecommunications equipment in the STPs
1992 *Telecom*	• Exclusive satellite international gateway for export industry is set up.
1992 *Tax Policies*	• Software exports brought under the Income Tax Act exempting exporters from income tax (2) • Income tax exemption offered to EPZs and 100 per cent export oriented units extended to software exports from companies taking part in these schemes which were established in or after 1993
1994-95 *Trade Liberalized Further*	• Reduction of import duties on software to 20 per cent for applications software and 65 per cent for systems software and in 1995 to 10 per cent for both • Liberalization of hardware import duties and loans for importing hardware given certain export obligations (export obligations could be met from earnings from on-site services)
1997 *State IT Policy*	• Govt. of Karnataka announces IT Policy and Karnataka becomes the first state in India to do so
1999 -2001 *FDI Policy*	• DoE allowed 100% FDI in the IT industry • Government favors foreign investment in infrastructure and high technology over consumer products
2001-2005 *Deregulation*	• Deregulation continues, albeit at a slow pace

1. STPs are connected by an integrated network, SoftNET, whereby subscribers can lease a point to point digital 64 kbps channel, and have access to the Internet with their own TCP/IP number, which would give them e-mail, remote log in, and file-transfer services as well as access to the World Wide Web.
2. Confirmation of this status occurred on an annual basis until 1995 when confirmation became open-ended. Because software exports were brought under the same chapter of the tax code as merchandise exports, some of the benefits were eroded due to the different characteristics between merchandise and software exports. (Current status?)

Table 4 : Perceived Advantages of Locating in a City Cluster – Summary of Responses from Cluster and Non-Cluster Firms in IT and Electronics Industry (1)					
Advantages of Location	**Bangalore**	**Other Clusters (Pune & NCR)**	**Non-Clusters**	**Significant difference**	
				Bangalore & Other clusters	**Bangalore & non-clusters**
Proximity to customers	3.46	3.04	3.29	Y	N
Access to information from competitors	3.08	3.00	2.68	N	Y
Access to information about competitors	3.17	3.12	2.63	N	Y
Availability of skilled labour from competitors	3.16	3.17	2.78	N	Y
Access to skilled labour	3.99	3.74	3.29	Y	Y
Presence of hardware & software suppliers	3.95	3.60	3.22	Y	Y
Better access to support services	3.89	3.60	3.08	Y	Y
Better access to training facilities	3.94	3.48	2.91	Y	Y
Better access to R&D institutions	3.61	3.25	2.56	Y	Y
Better access to information on fairs & exhibitions	3.74	3.55	2.53	N	Y
Availability of maintenance/repair services	3.85	3.70	3.38	N	Y
Availability of better infrastructure	3.30	3.79	3.68	Y	Y
Source: IIMA Survey of IT and Electronic firms					

Notes: 1. The Sample for Bangalore is 166, other clusters is 141 and non-clusters is 105
2. The perceived advantage was measured on a five point scale, advantage being higher if the score was closer to five.
3. The significant of the difference in the mean responses for cluster and non-cluster have been tested at 5 percent.

Table 5: Percentage of Firms Facing Constraints due to Infrastructure					
Infrastructure Constraints	**Bangalore**	**Other Clusters**	**Non-clusters**	**Significant Difference**	
				Bangalore & other clusters	**Bangalore & non-clusters**
Availability of Power	49.10	65.97	45.10	**Y**	N
Telecom Services	28.74	26.39	22.55	N	N
Transportation facilities	50.30	45.14	36.27	N	**Y**
Industrial safety & security	12.57	11.11	18.63	N	N
Centers for better technical education	6.59	5.56	29.41	N	**Y**
Basic education facilities	9.58	4.17	16.83	**Y**	N
Consultancy & support services	5.39	6.94	22.55	N	**Y**
Credit line availability	11.98	6.94	18.63	N	N
Technology development centers	10.18	7.64	41.18	N	**Y**
Presence of Industry Associations	5.39	7.64	22.55	N	**Y**
Livability of the city	22.75	20.83	5.88	N	**Y**
Entertainment Services	12.12	7.64	7.84	N	N

Source: IIMA IT and Electronics Survey

Notes: 1. The sample for Bangalore is 167, Other clusters is 144 and non-clusters is 102
2. The significant of difference between proportion of firms facing constraints is tested at 5 percent

Table 6: Percentage of IT Firms Adopting Various Processes					
Process	**Bangalore**	**Other Clusters (Pune & NCR)**	**Non-Clusters**	**Significant difference**	
				Bangalore & Other clusters	**Bangalore & non-clusters**
High End Application Development Process	88.60	88.13	76.67	N	**Y**
Low End Application Development Process	90.99	92.97	91.67	N	N
Package Implementation Process	56.51	50.42	53.00	N	N
Quality Process	34.30	31.77	10.83	N	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 86, other clusters is 96 and non-clusters is 60
2. The significant differences in proportions have been tested at 5 percent

Table 7: Percentage of IT Firms Adopting Various Practices					
Practices	**Bangalore**	**Other Clusters (Pune & NCR)**	**Non-Clusters**	**Significant difference**	
				Bangalore & Other clusters	**Bangalore & non-clusters**
Coding Practices	76.74	82.50	66.33	**Y**	**Y**
Knowledge Management Practices	70.93	72.71	57.00	N	**Y**
Security (data & physical) Practices	71.40	75.83	57.67	N	**Y**
Human Resources Practices	70.64	78.13	57.50	**Y**	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 86, other clusters is 96 and non-clusters is 60

2. The significant differences in proportions have been tested at 5 percent

Table 8: Percentage of Electronic Firms Adopting Various Processes & Practices					
Capabilities	**Bangalore**	**Other Clusters (Pune & NCR)**	**Non-Clusters**	**Significant difference**	
				Bangalore & Other clusters	**Bangalore & non-clusters**
Process capability	28.40	37.08	25.56	**Y**	N
Design capability	53.50	43.75	51.11	N	N
Practice capability					
Planning	47.69	57.29	40.41	**Y**	**Y**
Quality	53.54	55.68	46.72	N	**Y**
Training	62.35	71.88	69.19	**Y**	N

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 81, other clusters is 48 and non-clusters is 43

2. The significant differences in proportions have been tested at 5 percent

Table 9: Number of Networks for Electronic Firms (Weighted Means and Standard Deviations)								
	Bangalore		Other Clusters (Pune & NCR)		Non-Clusters		Significant difference	
Networks	Mean	σ	Mean	σ	Mean	σ	Bangalore & Other clusters	Bangalore & non-clusters
Internal (within the city) customer networks	2577	22496	15436	102434	1215	7357	N	N
National customer networks	25085	223597	696	3199	2059	10508	N	N
International customer networks	1424	11214	211	1442	1	2	N	N
Internal other networks	1277	11119	15	19	20	23	N	N
National other networks	40	138	8	17	34	91	N	**Y**
International other networks	37	178	1	4	13	76	N	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 81, other clusters is 48 and non-clusters is 46

2. The significant differences in proportions have been tested at 5 percent

Table 10: Number of Networks for IT firms (Weighted Means and Standard Deviations)								
	Bangalore		Other Clusters (Pune & NCR)		Non-Clusters		Significant difference	
Networks	Mean	σ	Mean	σ	Mean	σ	Bangalore & Other clusters	Bangalore & non-clusters
Internal (within the city) customer networks	38.22	155.83	15.49	44.52	95.10	309.42	**Y**	N
National customer networks	121.17	766.74	17.34	48.99	203.15	1094.04	N	N
International customer networks	125.24	686.82	103.56	567.44	7.40	18.25	**Y***	N
Internal other networks	18.72	28.54	14.91	30.01	12.97	15.29	N	N
National other networks	14.23	23.18	30.39	160.22	29.62	130.67	N	N
International other networks	11.36	19.40	11.94	39.04	0.52	1.68	**Y**	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 86, other clusters is 97 and non-clusters is 60

2. The significant differences in proportions have been tested at 5 percent

* denotes significance at 10%

Table 11: Performance of Electronic firms					
				Significant difference	
Performance	Bangalore	Other Clusters (Pune & NCR)	Non-Clusters	Bangalore & Other clusters	Bangalore & non-clusters
Sales (Rs. in Lakhs)	9454.71	6006.42	813.81	N	**Y**
Number of employees	73.84	85.73	37.14	N	**Y***
Employee Productivity (Rs. In Lakhs)	93.35	42.98	20.93	N	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 58, other clusters is 40 and non-clusters is 44
2. The significant differences in proportions have been tested at 5 percent.
*- indicates significance at 10%

Table 12: Performance of IT firms					
				Significant difference	
Performance	Bangalore	Other Clusters (Pune & NCR)	Non-Clusters	Bangalore & Other clusters	Bangalore & non-clusters
Sales (Rs. in Lakhs)	3533.37	15141.88	522.53	N	**Y**
Number of employees	126.38	159.98	49.35	N	**Y**
Employee Productivity (Rs. In Lakhs)	53.86	54.23	9.80	N	**Y**

Source: Survey of IT and Electronic firms

Notes: 1. The Sample for Bangalore is 69, other clusters is 71 and non-clusters is 50
2. The significant differences in proportions have been tested at 5 percent.

Appendix I
Role of Major MNCs Operating in Bangalore Cluster

A large number of MNCs operate in the Bangalore cluster and have contributed to the growth of cluster in a variety of ways. These include training and knowledge spillovers through direct and indirect linkages with other entities in the cluster. The appendix summarizes the activity profile of a few major MNCs to indicate their likely impact on the cluster.

1. Texas Instruments

Area of work/Activity: In 1985 TI (India) was incorporated in Bangalore. TI India started with just 20 people, now has over 1000 engineers and around 200 business associates. The center started with the production of CAD software in Bangalore. The center has two divisions: VSLI design and embedded software. The VSLI team designs chips for DSP, ASIC, broadband and wireless. Two-third of engineers are involved in it. The embedded team designs software applications for DSP, broadband and wireless.

It has developed chips for mobile and 3G communications TI (India) collaborates with other TI design centers. There is a huge talent gap in VLSI design. To bridge the talent gap in VSLI design TI (India) started masters' programs in VLSI design and signal processing with 15 universities. TI's roadmap is to set up DSP labs in several hundred universities across India. It has already sponsored DSP labs in 29 leading institutions, including the Indian Institute of Science at Bangalore, the five Indian Institutes of Technology and leading regional engineering colleges. (http://neasia.nikkeibp.com/nea/200308/intvw_259901.html)

Size (employees/sales): 1000 engineers

Market: 100% exports company. TI designs chips for the wireless handset, wireless LAN, digital still cameras, Internet audio players and IP telephony market. Every design that is shipped out of TI worldwide has components designed by an Indian team.

R&D: Over the last 15 years, around $20 millions had been invested in the Bangalore outfit, which was TI's biggest facility in the Asia- Pacific. (Businessline, Islamabad, Jan8 2000) It will invest 3 million on its R&D unit in Bangalore in the next two years.

Patents & New Products: **225** patents granted and the world's first single chip on mobile phones developed by Indian center at TI. And also the world's fastest fixed point DSP for emerging video and imaging applications. TI has also designed a single combined chip for high-speed modems. By 2003 - TI released a slew of 'Made in India' products (around 20 products) - including the Ankur Digital Signal Processor; Sangam, a bridge router for the DSL; and Zeno, which runs multimedia applications. (Dataquest)

Training: It has partnership for 4 off campus development centers and more that 400 partner engineers are working closely with TI**.**

Local collaboration: TI sees third party software developers as a key part of their growth plans. (ToI, 2nd December 2003). It is working in partnership with several Indian software firms like Wipro, Sasken and Tata Elxsi for designing and developing embedded software. (BBC News, Thursday, 3 October, 2002).

Impact: TI has helped many highly skilled Indian professionals in the US return to their homeland.

2. Intel

Area of work/ Activity: The first Intel R&D Center was started an R&D center in Bangalore in 1998 with 20 engineers. Today it has around 1400 engineers. It is mainly involved in e-business applications. In the second R&D center around $41 million are to be invested and it will employ over 1000 employees more. The new center will focus on microprocessor chip designing, large-scale integration (VLSI) and embedded software applications for mobiles. (Rediff.com). The development center is already doing work on Xeon processors, and will be involved in developing the next generation of Intel's mobile Centrino platform A group of engineer's is working on a microprocessor chip scheduled for introduction in 2006. The 32-bit processor, designed entirely in Bangalore, is to have one billion transistors (Intel's Pentium 4, its most advanced 32-bit chip for desktop computers has 55 million transistors) (rediff.com).

Size: 1,400 engineers

Training: Intel has also started a computer literacy program in line with its corporate social responsibility. It has already made 2,40,000 teachers computer literate in the country.

Local collaboration: Intel and Nokia tie up with the Indian Institute of Science, accelerating work in many domain areas. Intel has also set up an R&D lab in IIIT, Bangalore. The Technology Centre at Bangalore also oversees the company's multimedia labs in various IITs (Computers Today, April 1998). Intel started a capital fund, which invested in 15 companies' within 18 months. Among the companies Intel invested in were Rediff, Network Solutions, Eastern Software, Ritechoice, Bharati, Indus Software and Silicon Automation Systems. It has sold its 5 per cent Rediff.com stake to Warburg Pincus for $ 3.5 million. It is also selling its 15 % Bharti Telespatiale [ISP] and 10% Bharti Telesoft since SingTel invested $ 650 million. Intel's acquisition of Bangalore-based Thinkit technologies would supplement design capability sourcing from India. Pramati Technologies in Hyderabad also got investment from Intel in the Java technologies area. Intel India announced plans to acquire the 120-person consulting group of systems integrator Network Solutions, located in Bangalore, India.

Patents & Products: More than 14 Patents have been granted to the two centers. The first center has developed a network switch product (Dataquest).

Impact: As Intel India was expanding its R&D operations, and Intel USA embarked on downsizing, it relocated personnel from the US to its Indian operations. (ZDNet, August 04, 2001). Of the 1,400 engineers who work in Intel Technology India, nearly 10 percent are repatriated Indians who have spent significant time working abroad. Most who move of their own volition, may take significant cuts in pay, bringing their compensation closer to Indian salaries. Evidently, the opportunity to return home, and the lower cost of living, makes the tradeoff acceptable (New York Times, Sunday, December 14, 2003).

3. General Electric (GE)

Areas of Work/Activity: The GE R&D Centre in Bangalore was inaugurated in year 2000. In 2001, it expanded by building the phase II of the center that could accommodate additional 700 scientists, researchers, and engineers taking the total to 1,800. It worked in 11 multi-disciplinary labs supporting various GE businesses. They are part of a global G.E. research team that also has centers in Schenectady, N.Y., Munich and Shanghai - all of which are able to collaborate via computer networks.

Size: 1,800 engineers with more than 20% having global experience and 31% are PhDs.

Local Collaboration: GE started by contracting with four companies, including Infosys and Wipro (Wall Street Journal (eastern edition), New York: Sep 27, 1999 pg. A.1). John Welch

forged a JV with Wipro for medical systems and also became one of the largest outsourcers to the Indian software industry. GE accounts for more than two percent of the software outsourced to India. Wipro benchmarked GE's 'six sigma' process and became what Welch describes as "the poster child of the Indian hi-tech industry". Since then, Indian software firms —essentially services firms—have not only benchmarked the best practices, but have also started competing with the IBMs of the world (Express Computer).

Patents and Products: General Electric's research engineers in Bangalore have already filed for 95 patents in the four years since the research facility was set up in 2000.

Market: GE plans to invest $800 million in IT and expects software exports from India to rise to $3 billion by 2004 with software outsourcing expected to account for a third of the export targets. (http://www.offshoredev.com/jsp/features_detail.jsp?fid=41)

4. IBM

Area of Work/Activity: IBM had left India in the late 1970s when severe restrictions on MNCs were put in place. It re-entered India in 1992 through a joint venture with Tata Consultancy Services (TCS). In 1997, it started IBM Global Services India. In Bangalore it runs a SEI- CMM level 5-accreditation Software Testing Center. Currently, the Center is working on IBM's Blue Gene Project and the verification aspect of IBM's Giga Processor for the next generation of IBM systems. In 2000, IBM launched a new facility in its Solution Partnership Centre (SPC) in Bangalore to support Web-based application development in the country, one among only 10 IBM facilities worldwide. IBM's new initiative is aimed at partnering with Independent Software Vendors (ISVs) to provide Web-based solutions to end-users (Business Lline, Islamabad, April 3, 2000, p 1). Subsequently, it was involved in the development of WebSphere's application server and commerce suite. In 2003, IBM Global Services India (IGSI) set up a call center in Bangalore, which could accommodate close to 1,000 people. The new center will provide technology support to global customers of IBM worldwide.[20]

Size: 3100 engineers. 400 professionals work at Software Testing Center.

Patents and Products: 85 patents have been filed.

Local Collaboration: In 2002, IBM and Wipro signed a non-exclusive alliance. In the agreement, Wipro Infotech will market, integrate and offer solutions and services around IBM's wide range of server and storage products in India, APAC and Japan. While on the other hand, IBM gets a foot into Wipro Infotech's large domestic market.

Training: IBM set up Centre for Advanced Studies at its Bangalore facility to promote co-operation between its employees and key engineering institutes in India. The Bangalore center, one of the eight such centers opened worldwide, will offer M.Tech, MS and Ph.D students from premier engineering institutes in India access to IBM research areas, technical staff and other resources, with the goal of solving research problems of the utmost importance to software developers. (Business Line, Wednesday, June 18, 2003). Moreover, NIIT Limited and IBM India Limited have entered into an alliance to expand the pool of technical manpower skilled in IBM software technologies. Besides, IBM India has announced the National Entrance Test (NET) for the IBM Advanced Certificate course in Software Engineering (IBM ACSE), a structured short-term software development course offered at 44 IBM Authorized Centers for Education (IBM-ACE) in India. The entrance test was held in 29 cities in India.

[20] IBM Global Service's Indian operation has bagged a 10-year project from AT&T. More than 5,000 people could be working on this project.

5. Oracle

Area of Work/Activity: Oracle entered India in 1987 through a distribution tie-up with TCS. It formed its Indian subsidiary in 1993 in Bangalore with just three people. Initially engineers worked for the company on a project-by-project basis. Later they hired regular employees. IDC Bangalore works on Oracle's database, development tools, application servers and e-business applications. This includes components of the Oracle 9i Database Server and the 9iAS Application Server. It is also working on grid computing tools. The Center is Oracle's largest development center outside the U.S.The Center introduced consultancy and also provides tech support to the company's global customers for a range of Oracle products including databases, tools and applications. It has deployed a pilot project for the National Stock Exchange and e-Governance. Oracle is in the process of establishing its second center in Bangalore. Oracle has also decided to bring the Asia-Pacific region under the purview of its venture capital fund.

Size: Over 3,200 staff working in the country. A large share in Bangalore

Market: About 60 percent of Oracle's sales come from outside the United States, and India is the company's fifth-largest market in Asia, with more than 6,000 customers (siliconvalley.com, Posted on Sun, Nov. 09, 2003).

Training: Oracle employees have enrolled for MS programs at the Illinois Institute of Technology. Up to 75 per cent of the cost of this course is subsidized by the company (Businessline, Chennai, 2003). Oracle India keeps hosting Oracle Developer Days, a series of one-day workshops in Bangalore and New Delhi. Software developers from various organizations across industries such as manufacturing, financial services, government departments and developers from IT companies, independent software vendors and systems integrators participate. These workshops are specifically designed to teach developers the latest in emerging technologies while showing them how to take advantage of their existing skills and technology investments (Businessline, Chennai, Nov. 2003).

Local Collaboration: Oracle started an e-Governance center in partnership with Hewlett-Packard. NIC and several other companies are part of this initiative. This center will promote packaged software through a partnership model.

Patents and Products: 10 Patents have been filed.

6. Analog Devices

Area of work: Analog's liaison office was started in 1990 in Bangalore and the software subsidiary was launched in Bangalore in the year 1996. The software subsidiary is now known as the India Product Development Center (IPDC). The focus of the development center is on digital signal processing (DSP), both DSP IC Design and DSP software development. The Massachusetts based ADI's products have been sold in India since the mid-1970s. Its channel partners include BBS Electronics and Capricorn the Group. IPDC develops software tools capability for real world signal processing applications. Tools developed here are used to program DSP for different applications. In 2002, Analog opened an analog and mixed signal design center at its India product development center in Bangalore.

Size: About 70 engineers (35-40 in chip design and about 30 Analog and Mix Signal Design Center).

Patents and Products: A landmark achievement by the IPDC was the indigenous designing of a 32-bit digital signal processor, ADP-21065L, codenamed 'Shark', which Analogue claims is the world's highest performance 32-bit general purpose DSP today.

Training: In 2001, Analog Devices entered into an agreement with the Indian Institute of Technology, Madras, to fund a DSP learning center for training 500 engineers every year. The center, funded by Analog Devices with about Rs 4 crore investment caters to the growing need for digital signal processing skills.

Local Collaborations: **T**he Company has tie-ups with several Indian companies for which it will design and develop solutions to be incorporated in products that will be sold worldwide. A decade ago ADI launched a series of initiatives with local companies that included development of DSPs for electronic meters and work on a low-cost wireless local loop using ADI's chips. It is planning to make the IPDC home to its application engineering support group to provide technical training, support and advice to customers in South-East Asia.

Market: The chip used in manufacturing electronic metering systems is supplied by Analog in India. Analog had about 80 per cent market share for these chips in India especially from mid-to-late 2000.

7. Philips Innovation Campus

Area of Work/Activity: Established in 1996, the Center develops software for Philips products. Drawing on an investment of $2.5 million, is focusing on television, telephony, and video-communication products. Almost all Philips products that use software have some contribution from this center. It is the largest software center for Philips outside Holland. The center's primary expertise is in embedded and information system engineering, architecture design, programming and testing. It specializes in logic and circuit design for integrated chips. The center has six product divisions that include Philips' Mainstream Consumer Electronics, Philips Semiconductors, Philips Medical Systems, Philips Research and Center for Industrial Technology. These product divisions work on technologies ranging from speech procession and video telecommunication to embedded memories, systems-on-silicon design flow, digital rights management and wireless—802.11. Software for digital entertainment and advanced medical diagnostics, and design for some enabling microelectronic circuits are some areas of research focus.

Size: About 2000 employees.

Market: Philips India contributes nearly 20% of software to Philips operation globally. (http://www.iiitb.ac.in/ss/Publications/TOI/Philips%20Software%20Centre.htm)

Training: The center, which has the ownership of complete software stack for DVD, has a tie-up with IIT, Delhi for M.Tech in VLSI technology and collaboration with IISc, Bangalore for research activities. Since 1996 Philips participates in a Master's Program at the Indian Institute of Technology in Delhi in the area of VLSI: Design, Tools, and Technology. Philips Research also has an embedded-systems architecture laboratory at the Indian Institute of Science in Bangalore.

8. Hewlett Packard (HP)

Area of Work and Activity: The HP operation in India (known as HP ISO-India Software Operations) started in the year 1989 in Bangalore but he major expansion happened post 2000. It set up two labs in Bangalore - one at its software development facility and another at the Indian Institute of Science (IIS) campus. The third one was set up at the Electrical Engineering Department of the Indian Institute of Technology (IIT), Chennai. The Centers in Bangalore play strategic role in developing and enhancing many of HP products by partnering with many HP divisions and businesses. HP ISO also acts as a back-end for HP India in supporting its customers with consultancy and technology services. In 2003 Hewlett Packard decided to invest $20 million in its Bangalore software unit, even as the services division of that unit was merged with subsidiary Digital GlobalSoft Ltd. Digital Globalsoft, was started in 1988 in Bangalore. Digital is into application management, enterprise package implementation and Infrastructure services. It

recently acquired two products from erstwhile Compaq – Digital Infolife (a suite of storage management products) and EDI. Company's Advance Technology Center/Group is involved in enterprise mobility solutions and has significant .NET capability. Intellectual property includes work in speech technology, 3G Protocol Stack, a unified messaging platform called mFortis and several initiatives in VoIP. The R&D facility also work on key R&D programs areas like operating systems, embedded systems, network management, CoolTown - HP's Web centric vision of the future, mobile services among others.

In 2000 Hewlett-Packard Co. established a worldwide e-speak support center at its India software operations (HP-ISO) facility in Bangalore. The new set-up brought in a total investment value of HP-ISO to $30 million. In 2001 HP said that it would invest $1 million in setting up a Partner Technology Access Centre (PTAC) in India, which will help uses port and test their applications on Itanium (Intel). HP is working with industry partners such as Oracle, SAP, and Microsoft to make more applications available on the new family.

HP India supplies components to white box assemblers for the unbranded PC market in the country. It provides basic PC configuration and certain optional components to these assemblers through the distributors like Redington. HP assembles the ML Proliant 150 servers at its facility in Bangalore, which has an installed capacity of 3,000 servers per month. In 2004 it became the first time that HP set up a wholly owned contact center for post-sales support of its consumer products sold in the U.S.

Size: About 1,000 engineers work on product development at Bangalore, spread across eight different centers. It has an equal number of engineers split between partners such as TCS, Wipro and Digital Globalsoft, who are focused on maintenance, implementation and support services. (Businessline, Jul4, 2003). GlobalSoft itself has about 1500 engineers.

Patents and Products: Then 6-8 patents were under review.

Training: HP set up a joint lab with IIT Madras, focusing on technologies for developing markets. The objective of the joint lab is to provide an environment for HP employees to work with faculty, research staff and students in the creation of communication technologies.

Market: Limited information is available on this issue. HP ISO (India Software Operations)'s key projects last year included a mobile e-services solution for customers in Europe and Korea and a project to help Amazon.com move to Linux.

9. Sun Microsystems

Area of Work/Activity: It entered India through a sales and support agreement with Wipro in 1987 and set up its own office in Bangalore only in 1995 and opened an engineering center in 1998. Initially established 20 people, iIt does work mainly on Sun's software, which includes Solaris and Sun One. Sun Microsystems, considers India as a high growth area, and has committed to invest close to $50 million, mainly in ramping up its infrastructure and setting up more offices. Sun gives top priority to R&D, is considering a mandate to the Indian operations to develop a complete stack of servers. About 25% of the company's workforce on SunONE—its Web services platform—is based out of India.

Size: Around 850.

Patents and Products: 10 patents filed. Large chunks of SunOne—Version 6 of its application serrver, meta directory products, mail and calendar service—were developed in India. Part of the SunMC—the management console for Solaris—was designed in Bangalore. (Dataquest)

Impact: Many of the employees worked earlier in the San Francisco Bay Area. First-rate talent is moving back and helping bridge cultures, bootstrap new work and build skill sets in organizations at the Sun Microsystems' India Engineering Center, in Bangalore. This has given Indian

developers and engineers the kind of work and living conditions that they would normally have had to go to the US for. They get to work on the technology they want, at the salaries they want.

10. CISCO

Area of Work/Activity: Entered the Indian market in 1995. Cisco Systems India Private Limited (CSIPL) in Bangalore is the largest research and development (R&D) center established later by Cisco outside of the US. Cisco Systems Inc is increasingly looking at Bangalore as its core product and IP development center. *Cisco sells and supports its networking products and services through systems integrators, such as Datacraft RPG, Compaq India Ltd, HCL Infosystems, Microland, CMC, Wipro Infotech and Tata Infotech; and distributors such as D-Link and Godrej Pacific Technology Ltd. (http://www.ipan.com/press, June 1999).* Since 2002, the company started looking into VC funding of Indian start-ups, particularly those that operate in the Internet software segment.

Size: About 1500 engineers. In addition to their own engineers, Cisco India operates through a network of ecosystem partners across India. The engineering partners in the ecosystem consist of three leading Indian IT companies- Infosys Technologies and Wipro and HCL Technologies. In 2002, more than 1,600 engineers work for Cisco through these partners. (*http://newsroom.cisco.com/dlls/ts_123002.html, December 30, 2002)*

Patents and Products: An entire gigabit switch fabric ASIC uses in a gig-ethernet switching product has been designed by Cisco India (Businessline, May 2003).

Local Collaborations: In 2001, Cisco decided to invest $ 200 million in India. The investment was to promote **five** development centers, which Cisco had set up with Indian IT companies (January 18, 2001, ZDnetindia.com). Cisco formally ties up with Wipro, HCL, Infosys and two tother companies and the joint research centers contribute to a growing pool of knowledge in all three Indian companies. Subsequently, IBM India Limited and Cisco India decided to offer comprehensive and integrated solutions for contact centers in India.

Training: Cisco provides various levels of certification for IT professionals with several different tracks to meet individual needs.

Market: India contributes about 10 percent of Cisco's revenues. Punjab National Bank (PNB) was one of Cisco's largest clients as they helped them network 3,870 branches as part of its Rs 150 crore plan.

11. Other MNCs in Bangalore

There are a few MNCs which are quite active in Bangalore but for which detailed information was not readily available.

Motorola

A 100 per cent-owned subsidiary of Motorola Inc, it started the Bangalore operations in the year 1987. It has been assessed at SEI Level 5, the only software company in the world to achieve this status (Computers Today, April, 1998). Motorola Global Software Corp subsequently integrated its two centers in Bangalore under a single roof. Since the setting up of the subsidiary, India has been a major hub for Motorola's R&D efforts—the company set up the internal software development division or global software group (GSG) as Motorola India Electronics Limited (MIEL) in 1991 and has centers in Bangalore and Hyderabad. Besides, Motorola also established its chip development operations in the country in 1998 and has chip design labs at Noida and Gurgaon as part of Motorola's semiconductor products sector (SPS) division. MIEL focuses on software process engineering and building large software systems. Products developed here include libraries for Motorola's DSPs, parallel compilers, software for cellular phone systems and pagers, and subscriber data maintenance. The development center in Bangalore focuses on

software development for all Motorola handsets as well as cutting edge research on wireless technologies. The software used in the Motorola Accompli PDA-cum-GSM Phone that was launched globally in mid 2001 was developed entirely in India (DQ). About 30% of all software for Motorola's latest phones is written in India. (www.nri-worldwide.com)

Motorola is donating its cutting-edge networking processor technology to design labs in 14 top engineering institutes across the country under the IMPACT-SSS program of the Ministry of *Information Technology* and the Bangalore-based Indian Institute of Science. The grant of tools and software of the Asia Pacific Region's Semiconductors' Power PC family is valued at Rs. 5 million ($111,000) (*Bangalore,* Silicon India, 10919503, Sep 2000, Vol. 4, Issue 9).

Nortel

Nortel has carried out significant offshore software development through agreements with TCS, Infosys, Wipro and SAS (now Sasken). It regards them as strategic partners for the long-term success of its R&D activity in India (Businessline, Wednesday, Aug 06, 2003). BPL Innovision Business Group and Nortel Networks have announced a partnership to develop software and sell Internet and GSM cellular services in India. As part of the partnership Nortel would set up an offshore software development center at *Bangalore's* Electronics City for offering technology solutions to Nortel's global customers. It would also provide consulting and technology support for BPL Group's domain expertise and access to the huge domestic market. The alliance will also allow Nortel to offer its infrastructure expertise to Innovision's Internet and cellular service companies. Nortel, which has already invested about $30 millions in its development partners in India, will continue to pump in at least $2-3 millions per year. The bulk of the investment has gone into installation of about eight captive offices and in associated tools for mainstream product development. Nortel has also invested heavily in IISc, Bangalore, for advanced research, in a network management centre at IIT, Kharagpur, and in a telecom policy research centre at IIM, Ahmedabad.

Nokia

Nokia has two global software development teams in India. The Intelligent Edge products group based in Bangalore is involved in the development of ASR routers and recently released the ASRO 2020, an IP aggregation router. And the other is based in Hyderabad. Nokia sponsors PhD students in IIT Delhi and sets up a fellowship in high-speed networking, driving research in that area. Intel and Nokia tie up with the Indian Institute of Science, accelerating work in many domain areas. (Dataquest, September 10, 2002)