Origins and Growth of the Software Industry in India

By

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Abstract

The paper explains the evolution of India's software industry. Domestic entrepreneurship emerges as the key factor for origination, survival and innovation in a hostile industrial policy environment. The maturing of the industry required a shift to a supportive government policy; maturation was also critically enabled by the modularization of the programming function through new technologies. These changes favored domestic firms that provided programming services. Later policy and technological changes induced transnational entry and led to higher value-added output. The paper shows that technologically sophisticated industries can develop even when many conditions typically present elsewhere are missing. We provide conditions under which this may happen and show their effect on subsequent developments.

Key words: India, software, services, transnational corporations, software industrial policy.

1. Introduction

India's software exporting industry is one of the world's successful information technology industries. Begun in 1974, it employed 345,000 persons in 2004 and earned revenue of $12.2 bn, equal to 3.3% of global software services spending.

This paper's object is to explain the industry's origins, growth and sustainability. As we shall show, the industry originated under untypical conditions. Local markets were absent and government policy toward private enterprise was hostile.

These conditions influenced the industry's origins. The industry was begun by Bombay-based conglomerates which entered the business by supplying global IT firms located overseas with programmers. Their success owed to the innovative exploitation of a new global market opportunity and protection from transnational corporations and startups by policy. The explanation on origins is the same as used to explain industry origin in countries such as Korea and Japan (see, for example, Dicken (2003)) – with the difference that while government policy favored large domestic firms and discouraged TNCs and small firms in those countries, in India, government policy disfavored all types but was least hostile to large, domestic firms. In economic terms, the effect was the same as the more typical protectionist policy.

The protected environment restricted the growth of project management and domain skills so that, despite access to a large pool of programmers, the industry could not grow in value-addition.

A decade later, mainframe-based programming and manufacturer-specific operating systems and languages gave way to workstation-based programming and standard operating systems and high-level languages. These changes modularized the programming function, i.e., programming could henceforth be done independently of the hardware platform and from the other functions of creating software, such as system design. This, along with policy reforms that reduced costs of imported hardware and software, caused the Indian software industry to shift from supplying programmers to supplying software programs. As work moved to India, infrastructural costs increased as a proportion of total costs. This caused the industry to relocate from Bombay to Bangalore.

During the early years of the industry's third decade, beginning in the mid-1990s, the establishment of the Internet facilitated the separation of services, such as software maintenance and email management, from the site where the software was located. Following telecommunications policy reforms in 1999, this opened new opportunities for domestic firms.

In 2000, reforms in foreign ownership rules, intellectual property protection and venture capital policy induced TNC, diaspora and foreign venture capital entry. The traditional software services industry, dominated by large local firms, has subsequently competed with firms with superior domain skills and access to finance. In consequence, the industry as a whole is seeing new leadership, more product development and higher value-addition.

The paper is organized as follows. Key global events that influenced the Indian software industry are reviewed in Section 2. In Section 3, the Indian software industry's evolution is explained. Section 4 provides a concluding discussion that reviews the contribution of the paper to the literature on industrial organization and change.

Section 2. The global software services industry

2.1 Introduction

Software is usually classified by type of use and by customization.

Types of software by usage:

1. System-level software: programs that manage the internal operations of the computer, such as operating system software, driver software, virus scan software and utilities.

2. Tools software: programs that help applications to work better, such as database management software.

3. Applications: programs that deliver solutions to the end-user, such as word-processing software and financial accounting software.

Types of software by customization:

Software is either (1) written for general use and replicated in its original form across many users, or, (2) written for a specific user. The former is termed a software product or package. It may be shrink-wrapped and transported physically or over the Internet. The latter is termed custom software. Being made-to-order, custom software is more geographically constrained that products, i.e., proximity to the user is more important. Because of this, software products are more readily exportable than custom software.

System-level software is the most complex as it manages the interfaces with both hardware and higher level software; applications software is the least complex. Nowadays, all system level software are products. The more varied an end-user's needs from another end-user, the more likely is the software to be customized. Since variations in needs appear most at the stage of applications, most customized software is applications software. These attributes are summarized in the table below.

Table 1: Software types and programs used

	Product software used by:	**Custom software used by:**
Operating System	All users	None
Tools	Most users	Some users
Applications	Small and large users	Large users

Source: Author's compilation

Custom software is part of a larger category called software services. Software services are described by type and size in the table below.

Table 2: Global software services spending by categories of work, 2003, and India's market share.

	Global software services spending ($ bn)	India's global market share (%)	U.S. Wage rate ($/hour)
Consulting	41.5	< 1	80-120
Applications Development	18.4	16.4	25
System Integration: Hardware and Software Deployment and Support	91.7	< 1	18-25
System Integration: Applications, tools and O/S	62.4	< 1	40
IT education and training	18.5	0	40
Managed services	124.9	1.6	60-120
Total	357.6		

Sources: Nasscom (2004, p.19, 36, 106) for columns 2 and 3; Nasscom (2001, p.24) and author's interviews for column 4.

Definitions: Consulting refers to IT strategy, system conceptualization, architecture and design. It is comprised of Nasscom numbers for IS consulting and network consulting and integration.

Applications Development refers to creating the applications programs. It is comprised on Nasscom numbers for custom applications development.

Systems integration: Hardware and software deployment and support refers to making the software and hardware components compatible and interoperable. It is comprised of Nasscom numbers for (1) Hardware Deployment and Support and (2) Software Deployment and Support.

Systems integration: Applications, tools and O/S refers to integration of the software components (both products and custom software) in a software project.

Managed services refers to services such as managing applications either onsite or remotely over the Web, managing networks, etc. It is comprised of Nasscom numbers for applications management, IS outsourcing, network and desktop outsourcing, applications service providers and system infrastructure service providers.

Like custom software, other software services also face limits to offshoring. Some limits are physical, such as the need for proximity to provide hardware installation and support services. Other limits may also exist, especially if tacit (uncodified) knowledge is to be exchanged. Technological development may change these limits. For example, the invention of the router led to the creation of data centers, thus reducing the need for on-site storage hardware and support services. Similarly, the Internet has enabled the remote installation and maintenance of software.

2.2 Origins and growth

The independent software vendor (ISV) industry was created by IBM's decision in 1969 to unbundle its mainframe operating system, applications software and hardware by creating open standards. Subsequently, some client-firms set up inhouse software development and maintenance operations (column B below) while others outsourced the work (columns C – E). The resulting ISV businesses are shown in Table 3 below.

Table 3. Client-vendor grid during 1970-79.

Clients' options =>	External data processing and managed services (A)	Client owns hardware			
		Develop and maintain own software (B)	Buy bundled software and outsource maintenance services (C)	Buy software products from ISVs (D)	Buy custom software services (E)
ISVs' offerings =>	Managed services , EDP	No role for ISVs	Integration of hardware and software; software maintenance	System level and applications products	Applications software

Source: Author's compilation, based on Steinmuller, 1996.

Columns A to E above are not intended to describe mutually exclusive choices. For example, a firm might purchase system level software products while developing its own applications.

The columns are arranged by sequentially dominant work-types over the decade, starting with the shift from external data processing and managed services (Column A) to inhouse hardware at the start of the decade. Initially, firms developed their own software (B). As the 1970s progressed, hardware and software became more complex making inhouse software development and management more difficult. This

led to the outsourcing of system integration (C) and then to the sourcing of system level and applications products (D). The move to outsourcing customized applications (E) was due to the failure of industry specific products to meet the needs of the more sophisticated users, particularly the large banks (Steinmuller, 1996, p. 30).

In the 1980s, the PC was invented. The Wintel standard became established by the mid-1980s, leading to a decline in hardware prices and rising demand for applications. Unlike mainframes, the PC was for retail users, who were reliant on product software. The PC of the 1980s lacked both the programming capacity and performance needed by enterprises. Hence, it had no impact on the custom software business.

The workstation, introduced in the mid-1980s, had the capacity for stand-alone programming for mainframes. The widespread adoption of Unix and C as the operating system and programming language for all computers, jointly with the worstation (in short, the U-W standard), revolutionized the ISV industry. An ISV could now own a workstation made by any manufacturer, yet write programs for a client whose installed hardware might be of a different brand (even a mainframe). In other words, programming became platform independent or modularized[1] from the hardware component. In the 1990s, the success of database software packages further simplified the creation of applications software.

The workstation also had sophisticated graphics and the computational capacity needed by small enterprises. Such firms shifted from outsourcing data processing services to running their own workstations.

The platform independence that arose from the U-W standard, combined with the rise in demand for custom software by small firms, resulted in a large custom software industry (see Table 2).

In the 1990s, the rising computing power and declining cost of the PC improved its capacity to program in Unix/C. The PC, therefore, replaced the workstation as the hardware platform for programming. Later in the decade, the success of PC-based networks increased the accessibility of applications to many more users within the enterprise.

The first four columns in the table below summarize the main changes in the software services industry in the U.S. and the driving forces reviewed above.

Table 4. Software services industry new work-type and cause: US and India

	U.S. new ISV work type	**Market change**	**Technological change**	**India new ISV work type**	**India policy change**
1960-70	Software maintenance, EDP		Minicomputer	EDP	
1971-80	Custom software for applications	IBM separates software and hardware		Export of programmers	
1981-90	Software system integration	Growing complexity of IT systems	U-W standard	Custom software for applications	Lowered import tariffs
1991-2004	Managed services		Internet, database platforms	Managed services, product R&D	Reforms in VC, foreign ownership,

				and development	IP, telecom, stockmarket rules

Source: Author's compilation, based on Steinmuller (1996), Mowery (1996) and http://www.siia.net/software/resources.asp#stats for columns 1 to 4. Author's analysis for columns 5-6.

Section 3. The growth of India's IT industry

As discusssed in Section 2, managed services, time-sharing, integration and maintenance were the earliest software services to be outsourced (Table 3, columns A-C). All these required proximity to the client. Later work, such as product development and custom software (Table 3, Columns D and E) could, at least partly, be done remotely.

Custom software did not, as noted above, become important till the late 1970s. In the early 1970s, American firms looked offshore for cheaper ways to develop software products. India, Ireland and Israel were obvious choices given the widespread knowledge of English and relatively low costs of programmers.

The implantation of a technically sophisticated industry like software into a less-developed host country has typically been explained by the access of transnational corporations to local resources facilitated by policy reform (often after efforts to create industry through protectionist policies have failed). For example, Dunning(1992) argues that reform effectively enables cheap labor pools and other host country resources to be matched with the financial, managerial, technical, domain and marketing skills of TNCs.

Software might be considered a particularly difficult type of service to offshore, because the labor needs to be skilled, relative to what is required for the offshoring of, say, routine call-center work or voice transcription. Where is such skilled labor to come from if the environment lacks a home market? As Siwek and Furchgott-Roth (1993, p. 93-4) note, software development is closely linked to customer requirements and requires close coordination within the firm.

Even within software, one would expect that work to support product software, done by TNCs, would be the point of origination. The developing country's engineers could initially provide just technical support and maintenance. Indeed, as seen below, Israel and Ireland started in this fashion.

Table 5 Software exports from India, Ireland and Israel ($m)

	India	Ireland	Israel
1990	105	2132	90
2000	6200	8865	2600
2002	7500	12192	3000
2003	8600	11,819	N/A
Employment -2003	260,000	23,930	15,000
Revenue/employee – 2003	33,076	493,988	273,000

Source: Indian data from Heeks (1995), Nasscom (2003, 2004); Ireland data from http://www.nsd.ie/htm/ssii/stat.htm ; Israel data from http://www.iash.org.il/Content/SoftwareInds/SoftwareInds.asp , downloaded August 31, 2003. January 5, 2003. Irish data in Euro converted at 1 Euro = $1.043 (rate on January 5, 2003) for years prior to 2003; and then at 1.26 for 2003 (rate in January 2004). Israel's latest figures are for 2001.

Israeli policymakers offered incentives for global software firms in the early 1970s, inducing entry (Torrisi, 2002, p.18). These TNCs used local programmers initially for software product maintenance and later for R&D. Much of the labor force had earlier worked in the defence industry. In the 1980s, domestic software startups, funded by government research contracts, were established. Initially, they provided

software services to the defence industry and later developed security software products for global markets. This trend continued into the 1990s with support from global VC firms. (Teubal, 2002, p.166). Local product firms currently dominate the market accounting for 75% of employment (Torrisi, 2002, p. 9 and 18).

Irish policymakers offered incentives for global software firms only in the late 1970s following Ireland's entry into the EC in 1973 (http://www.nsd.ie/htm/ssii/back.htm and Torrisi, 2002, p. 17). Global IT firms entered in the early 1980s to localize software products for European markets (Torrisi, ibid, p. 18). These currently account for 90% of software exports (Arora et. al., 2001, p.7).

In summary, Ireland and Israel's software industries originated in software products due to policy support for TNC entry. They subsequently developed along different trajectories in product development based on differences in skills and government policies.

We now turn to the Indian case. The table below shows the software industry's growth.

Table 6. Growth of the Indian software industry

Year	Total exports ($m)	No. of firms	Average revenue per firm ($)	Average revenue per employee ($)	Exports/ Total Revenue (%)
1980	4.0	21	190,476	16,000	50
1984	25.3	35	722,857	18,741	50
1990	105.4	700	150,571	16,215	N/A
2000	5287	816	7,598,039	32,635	71.8
2004	12200	3170	7,003,154	35,362	73.9

Notes: 1. Data for 1980, 1984 and 1990 are from Heeks, (1996), pp.72, 73, 87,88.

2. Data for 2000 (financial year ended March 2001) are from Nasscom, (2002) and Nasscome (2004), p. 23, 26, 64.
3. Data for 2004 (f.y. ended March 2005) are from Nasscom (2005), p.75-6. 2004 data for number of firms and average revenue is based on software, software services and IT-enabled services because disaggregated data is not available.
4. No. of employees for 1980,1984,1990,2000 and 2004 were 250, 1350, 6500, 162,000, 260,000 and 345,000 respectively. Source: Heeks, (1996), p.93 for 1980-1990 data and Nasscom, (2004, 2005) for 2000 and 2004 data.

Indian policy in the 1970s was appropriately described as "statist, protectionist and regulatory." (Rubin, 1985) In IT, the state was the main producer of products and services. Its strategy was to create 'national champion' state-owned enterprises (Sridharan, 1996). These were granted monopolies.

The creation of national champions resulted, not surprisingly, in championship-scale failures. It created no output of any significance, crowded out the private sector and produced a labor force of dubious quality.

A key protectionist policy was the Foreign Exchange Regulation Act of 1973 (FERA-1973). Under FERA-1973, a foreign firm could operate in India only with a minority interest (foreign ownership was restricted to a maximum of 40%). Many foreign firms closed their Indian operations, including firms as diverse as Coca-Cola and IBM, citing concerns about the protection of intellectual property. FERA-1973 thus closed the door to product software development in India by TNCs.

Domestic and transnational firms jointly discovered an innovative solution. Since software development could not come to India, Indian programmers were sent to developed countries. It began in 1974 with the mainframe manufacturer, Burroughs, asking its India sales agent, Tata Consultancy Services, to export programmers for installing system software for a U.S. client (Ramadorai, 2002). Other firms followed,

including foreign IT firms that formed FERA-1973 compatible joint ventures.[2] Initially, the exported programmers worked for global IT firms. Later in the decade, as IBM grew in market share, end-users such as banks used Indian firms to convert existing applications software into IBM-compatible versions. By 1980, there were 21 firms with annual exports of $4m.

The state remained hostile to the software industry through the 1970s. Import tariffs were high (135% on hardware and 100% on software) and software was not considered an "industry", so that exporters were ineligible for bank finance. These protectionist policies favored established firms with conglomerate interests and access to finance over small firms. Bombay, the country's commercial capital, became the natural center of the business. 7 of the top 8 exporters in 1980 were headquartered in Bombay with a 90% market share (see the table below).

Table 7 Top 8 Software Exporters

Rank	1980, India HQ	1990, India HQ	2004,India HQ	Founder, education, experience
1st	TCS – Mumbai	TCS – Mumbai	TCS – Mumbai	Kanodia (MIT)
2nd	Tata Infotech – Mumbai	Tata Infotech – Mumbai	Infosys – Bangalore	Murthy (U. Mysore, IIT Kanpur)
3rd	Computronics – Mumbai	Citibank – Mumbai	Wipro – Bangalore	Premji (Stanford) and Soota (IISc)
4th	Shaw Wallace – Kolkata	Datamatics – Mumbai	Satyam – Hyderabad	Raju (Loyola College, Chennai; Ohio U)
5th	Hinditron – Mumbai	TI – Bangalore	HCL – Delhi	Nadar (PSG College, Coimbatore)
6th	Indicos Systems – Mumbai	DEIL – Mumbai	PCS – Mumbai	Patni (MIT)
7th	ORG – Mumbai	PCS – Mumbai	i-Flex – Mumbai	Hukku (BITS, Pilani) (TCS,

				Citicorp)
8th	Systime – Mumbai	Mahindra-BT – Mumbai	Mahindra-BT – Mumbai	Mahindra (Harvard)
Market share of top 8 firms (%)	90	65	38	

Sources:Heeks (1996), p.89 for columns 2 and 3; Nasscom (2005) p.76 for column 4, company websites and author's interviews for column 5.
Note: IBM is probably in the top 8 firms in 2004 (it was ranked 6th in 2002, but has withheld permission for its name to be displayed in subsequent Nasscom rankings: http://www.nasscom.org/artdisplay.asp?art_id=4413#top20, downloaded August 26, 2005)

While protection led to labor exports, it slowed the inflow of new skills into India. The industry learned global skills primarily through programmers returning from overseas assignments (Ramadorai, 2002), but this was further slowed because many chose to remain overseas. For example, in 1986, 58.5% of IIT graduates in computer science and engineering migrated (Siwek and Furchgott-Roth, 1993, p.140). An important, though thin resource, was the return of U.S.-educated engineers, who provided advanced project management and engineering skills. In summary, despite access to a large pool of programmers, the industry's value-addition measured by average revenue per employee remained low (see table 6). The activity of the industry during its first decade consisted of little other than recruitment of engineers.

We take issue with explanations that credit government policy for creating the sector (Arora and Latif (1997), Athreye (2001), Desai (2003), Sen and Frankel (2005)).[3] As a producer of IT, the government failed. Its protectionist policies were intended to benefit SOEs and crowd out the private sector. Although the private sector discovered a way out, the solution forced on domestic firms was to choose the lowest end of the business, one that reduced opportunities for learning. It was not till the mid-1980s that redemptive policies, including freer entry for TNCs, helped the sector. Education policy, moreover, has not succeeded.[4]

In retrospect, origination required bundling of the needed skills from various local resources. First, the pioneering firms chose work which required simple managerial skills and low project finance: they recruited software engineers who were exported for short periods at a time to clients that determined their use. Second, newly-trained returnees provided advanced engineering and project management skills. Third, foreign IT firms, that served Indian markets until the 1973 laws shut them down, became the first overseas clients.

In prospect, given the thinness of the more sophisticated human resources, the volatility and hostility of government policy, the unstable macroeconomic environment, the lure of protected home markets and the adverse reputational effect of the closed economy to overseas buyers, even the simple business of manpower supply was seen as a highly risky venture (Ramadorai, 2002), leading to its domination by large firms and resulting in low growth during its first decade (see Table 5).

The industry's activities changed in the mid-1980s with the global industry's adoption of the U-W standard, discussed in Section 2. Programming became a stand-alone activity that required no domain skills: once the system was fully specified by the overseas designer, the programmer did not need to know either the hardware platform or the industry for which he was writing the program.

Government policy changed to a supportive stance with the election of a new Prime Minister, Rajiv Gandhi, in 1984. His New Computer Policy (NCP-1984) consisted of a package of reduced import tariffs on hardware and software (reduced to 60%),

recognition of software exports as a "delicensed industry", i.e., henceforth eligible for bank finance but not subject to the intrusive licensing regime (Heeks, 1996, p. 44-5), permission for foreign firms to set up wholly-owned, export-dedicated units (Texas Instruments was the first to enter in 1985) and a project to set up a chain of software parks that would offer infrastructure at below-market costs. In 1985, all export revenue (including software exports) was exempted from income-tax.

The combination of the U-W standard and lower costs made writing programs in India economical. The relocation of work to India, though gradual,[5] was led by considerable new entry by TNCs and domestic firms and experimentation with different activities. Some TNCs did R&D and wrote product software using cross-country teams (such as Texas Instruments and Hewlett Packard), others wrote custom software for inhouse use (such as ANZ Bank and Citigroup) and for clients; domestic firms, such as TCS, shifted from exporting programmers to outsourced custom software and others started product development (such as Wipro). Overall, the number of software firms went from 35 in 1984 to 700 in 1990 and the share of smaller firms rose (Table 7).

Not all these efforts succeeded. In particular, product development did not succeed. The product startups failed due to the shortage of venture capital and domain skills. The TNCs doing product development created transnational teams that faced daunting communications costs and intrusive regulation (Parthasarathy, 2000). In consequence, product development accounted for less than 5% of exports by 1990 (Heeks, 1996, p. 88-89) and reached only 8% by 1999 (Nasscom, 2002, p.28).

Both domestic firms and TNCs developing custom software for export (including internal use) were successful, particularly the former. As a result, they needed more physical facilities than in the earlier recruiting business. Bangalore began to grow in importance in consequence. It had several advantages: (1) Infrastructure was cheaper: Firms were attracted by cheaper real estate than Mumbai (Premji, 2003) and the first software technology park under NCP-1984, with assured supply of electricity and telecommunications bandwidth, was located in Bangalore. (2) Labor was cheaper and in greater supply: Unlike Mumbai and Delhi, with histories of large firms and labor militancy, Bangalore had small companies that were relatively free of union troubles (Heitzman, 1999, p. 6). Further, Bangalore is located at the center of the four southern states, Karnataka (whose capital is Bangalore), Tamil Nadu, Andhra Pradesh and Kerala, which together produce 52% of India's engineering graduates. The government had earlier chosen Bangalore to locate several high technology SOEs, thus creating a trained labor force (Balasubramanyam et al, 2000, p. 351) – although the quality of the labor force was dubious and provided only a small percentage of the software industry's needs (Ramadorai, 2002). In 1909, the elite Indian Institute of Science had been established in Bangalore. Most of its graduates and research were directed towards the public sector. Some of these, if indirectly, helped Bangalore's development in software. The biggest success from IIS was Wipro Technologies, India's 3rd largest software exporter. It was founded at IIS by a group of engineers working under Ashok Soota, an academic at IIS (Parthasarathy, 2003). (3) Over time, TNCs, a key conduit for domain skills came to be largely headquartered in Bangalore, adding to its advantage as a center of learning. These included the pioneers, TI and HP, but also IBM, Accenture, Oracle, GE and Dell.

Carlsson, et al, (2002) argue that participants in an innovative system must have the "capabilities … to generate, diffuse and utilize technologies that have economic value." They identify four key capabilities: (1) selection: the ability to make innovative choices of markets, products, technologies and organizational structure; to engage in entrepreneurial activity; to select key personnel and acquire key resources including new competences. (2) organizational skills. (3) functional skills. (4) Learning: to learn from successes and failures, read market signals and to diffuse technology through the system.

In the pre-1984 period, a handful of firms competed for thin financial and entrepreneurial resources and had limited access to domain skills. Post-1984, software projects were developed within India. There was considerable experimentation on type of work done and organizational forms and there were many new entrants, leading to a rise in selective capabilities, organizational and functional skills. The location of campuses in Bangalore and proximity to TNCs facilitated learning on how to manage software projects remotely.

Several of the conditions for a competitive, innovative industry were, therefore, in place. Writing in the context of national competitive advantage, Porter notes the importance of firm strategy, structure and rivalry (Porter, 1990). Porter stresses the role of competition among actors within industries and the importance of vibrant home markets. In the post-1984 period, there was competition for programmer resources and for clients, as seen by the rising number of firms, the rising market share of new firms and overall growth (Table 6 and 7)

Rosenberg and Mowery (1978) argue that vendors become technologically sophisticated through understanding customer preferences. In the Indian software industry, the conduits to sophisticated customer demand were the TNCs. Although their activities remained small due to high coordination costs, as discussed, learning took place. For example, Indian firms became adept at remotely managing turnkey software applications development projects, a skill introduced by TI.

However, there were weaknesses as well. Domestic firms developing software products were limited by lack of venture capital and small domestic markets. TNCs developing software products and services that required cross-border coordination were hampered by the primitive telecommunications infrastructure and intrusive regulation. To that extent, the selective capabilities were limited, especially for doing sophisticated work.

Several scholars have questioned the industry's sustainability in the post-1984 period on these grounds. For example, D'Costa (2002a, p.705) criticized the industry's dependence on exports, arguing that international outsourcing of software, though commercially lucrative, discouraged firms from doing more complex projects at home because "excessive dependence on outsourcing limits the synergy between vibrant domestic and foreign markets".

Schware (1992) argued against survival on three counts. Like D'Costa, he cited the absence of a domestic market. Second, India lacks infrastructure and social networks. Third, Schware noted that the "inadequate supply of skilled personnel may well be the major constraint to the expansion of the software sector. All firms

experience difficulties recruiting qualified staff. .. the problems are rooted in low capacity… (further), faculty are not encouraged to consult."

Data from Nasscom show that only 27.12% of the workforce have an undergraduate or graduate degree in computer sciences or electrical engineering (Parthasarathi and Joseph, 2002, p.20, quoting Nasscom data for 2000). This seems to stem from India's poor education policy. The central government is the main financier of tertiary education. While it has greatly expanded the university system, quality is poor and appears to have deterred enrollment. According to a government report, "obsolescence of facilities and infrastructure are experienced in many institutions … the IT infrastructure and the use of IT in technical institutions is woefully inadequate … the barest minimum laboratory facilities are available in many of the institutions and very little research activity is undertaken … engineering institutes have not succeeded in developing strong linkages with industry … the curriculum offered is outdated and does not meet the needs of the labor market" (Ministry of HRD, 2001, Sections 2.1.2-2.1.6). There were 247 universities and 11,549 colleges in India in 1999. Still, as of 1997, only 7% of the eligible population attended university (Nasscom, 2004, p.78).

Further, the interaction between university and industry is minimal. There are few academia-industry research partnerships as well as few consultancy assignments for faculty from industry (Parthasarathi and Joseph, 2002, p.32). Very little independent research is done, partly because until recently, faculty (even at the IITs) have not been expected to do research. The average number of citations over a 5-year period for the average faculty member at the Indian Institutes of Technology is less than 3. This

compares with 45 per faculty member at MIT and 52 per faculty member at Stanford University (Nasscom, 2002, p.73). The country produces only 300 master's degree graduates and 25 Ph.D.s in computer sciences each year (despite excess capacity), compared with U.S. numbers of 10,000 and 800 respectively (Ministry of HRD, 2001, Section 2.1.12).

Correa (1996) argued that "although entry barriers are low, countries seeking to develop software businesses are constrained by the following internal factors: small domestic markets, small firm size, absence of quality standards, weak protection of property rights, low quality labor and infrastructure and poor marketing skills, and relatively low importance of labor cost savings (for packaged software) … (as well as the following) external factors: US dominance, monopolies and English language barriers".

Siwek and Furchtgott-Roth (1993, p.140) also predicted stagnation, stating that, "the cost advantages that favor Indian-based software development are dwarfed by a problem that undermines growth policies in all developing countries including India: the problem of the brain drain… We believe that certain programming activities will continue to leave the U.S. to some extent. These activities are more likely to emphasize maintenance rather than basic software design and development".

How did the industry withstand these problems? We have discussed that the solution found by domestic firms was to stay with programming for services, first by exporting programmers and later by developing custom software programs in India. This kind of work did not have to encounter threats such as small domestic markets, weak IP

protection and lack of R&D in universities and university-industry linkages. Some challenges, such as the lack of venture capital and shortage of project management skills, did not cause failure but took the industry towards a particular structure of domination by large, well-capitalized, well-managed conglomerates that diversified from existing businesses into custom software development.

Policy reforms in the 1990s and 2000 reduced import tariffs to near zero[6] and standardized foreign ownership, intellectual property protection, venture capital, stockmarket listing and telecommunications policies to global best practices. Thus, many of the weaknesses and challenges described above are likely to reduce in importance. In addition, technological changes during this period, particularly the Internet, led to a sharp decline in data storage and transmission costs. These changes induced a new round of entry of TNCs[7] and startups and opened new opportunities for existing firms in remote software services, such as email management and remote software maintenance (Table 4).

The weakness that remains is the shortage of domain skills arising from small domestic markets, limited university research and related education, and low linkages between university and commerce. There are examples of countries whose domestic firms successfully moved to high value-added software despite lacking several supposedly essential attributes. For example, Israel succeeded without a large domestic market (although it could be argued that it has done best in defence-related software, for which it has a large home market).[8] Of course, the difference with Israel was its openness to TNCs from the beginning.

Indeed, product development (including R&D) rose from 8% of software exports in 1999 (the year from which key changes in foreign ownership rules, and telecommunications, intellectual property protection and venture capital policy reforms began) to 25% in 2003 (Nasscom, 2002, p,.28 and Nasscom, 2005, p.50) and revenue per employee rose by 14% (Nasscom, 2002., p.63 and Table 6). It appears that the Indian software industry is acquiring domain skills. Some of this is undoubtedly due to the leveling of the playing field for TNCs and startups since 1999. Some has to do with a strategy of overseas alliances being pursued by the larger domestic firms. The industry, therefore, appears to have the capability to move up the value-chain. As a result, industry leadership, currently with large domestically-owned software services firms offering custom programming services, will have to be shared with startups (diaspora-linked or funded with foreign venture capital) and TNCs offering innovative products and services. The top 20 software exporters included 4 TNCs in 2004, up from just 1 in 2000 (Nasscom, 2002, p.35 and Nasscom, 2005, p.76).[9]

4. Concluding discussion.

The paper explained the evolution of India's software industry from its origins in 1974 to the present time. Domestic entrepreneurship drove the industry's origination, survival and innovation during a time when the state used policy to promote SOEs and to crowd out the private sector. The state's policies effectively prevented the private development of software in India. The private sector, in collaboration with TNCs, found an innovative solution, that of exporting programmers instead.

However, this strategy caused certain weaknesses such as the shortage of domain skills and project management skills to become embedded.

The growth of the industry, which happened in the mid-1980s, was preceded by a paradigmatic shift in government policy from hostility to the private sector to support for it; and maturation was also critically enabled by the modularization of the programming function through the establishment of Unix and the workstation in the 1980s. We showed how this led to a focus on custom programming services located in Bangalore. In the process, the industry acquired skills in managing projects remotely. Other weaknesses, particularly the shortage of domain skills and difficulties with coordinating cross-border projects, persisted.

While policy reform has put in place several of the conditions for future growth, the shortage of domain skills arising from small domestic markets, limited university research and interactions with the commercial sector remains. Some of these skills are being acquired through cross-border interactions and alliances. This, in consequence, means that established domestic firms now compete with TNCs and startups with overseas links that have superior domain skills. As a result, while the large domestic firms' leadership of the software industry is increasingly being shared with TNCs and startups, the acquisition of domain skills is likely to result in benefits for the industry as a whole, implying higher value-addition.

This paper adds to the literature on conditions for industry origination and development. The implantation of a technically sophisticated industry like software into a less-developed host country has typically been explained by the access of

transnational corporations to local resources facilitated by policy reform (often after efforts to create industry through protectionist policies have failed). Software might be considered a particularly difficult type of service to offshore, because the labor needs to be skilled, relative to what is required for the offshoring of, say, routine call-center work or voice transcription. Even within software, one would expect that work to support product software, done by TNCs, would be the point of origination. The paper's contribution to the literature is to show that it is possible to develop sophisticated industries even when many of the conditions that have typically been required elsewhere are missing. However, the absence of certain initial conditions, notably the absence of supportive policies to induce TNCs, can cause certain weaknesses to be embedded in the industry.

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[1] Modularization is the conversion of a component of the production process with one or more proprietary inputs, design or fulfilment techniques into a component with standardized inputs, design and fulfilment techniques.

[2] These included Datamatics (a joint venture between the U.S. minicomputer maker, Wang, and ex-exployees of TCS), Digital and Data General.

[3] For example, Arora and Athreye (2001, Section 2) state that "The initial growth of the software service industry in India was facilitated by the enlightened "hands off" policies of the government of India." Similarly, Sen and Frankel (2005) state that "the Indian government's policies played a greater role in the success of the IT sector than is generally recognized. The rapid growth of the IT industry over the last decade was not simply a product of benign neglect following the dismantling of centralized planning in India. Rather, it is rooted in government intervention during earlier years that favored domestic industries over foreign companies." (Executive Summary) Some scholars attribute the early success to IBM's forced departure, noting that India was lucky to be left with a cadre of over a thousand trained programmers as a result (Latif (1997), Desai (2003)). Latif notes that some started software exporting companies. These included Prakash Mehra, who left IBM and founded IDM, a leading software consulting firm (Naqvi, 2003). We think that IBM's forced exit on balance probably hurt India's software services industry. This was not immediately noticeable because it exited India when the global software services industry was in its infancy and at a low level of sophistication. Later, when the industry established itself globally and a global value chain developed, i.e., 1985-1990, IBM (had it been allowed to stay) would almost certainly have used India's low cost workforce as an integral part of its ultimately successful strategy of dominating the global software services business. Instead, it returned to India only after the 1991 reforms. True, Indian firms would have had a lower market share as a result; but the industry's size would probably have been much larger and its development more sophisticated. Further, even the impact of spinoffs from IBM are debatable. The first firm, TCS, was founded by J.R.D.Tata, the head of the Tata group, and L.S.Kanodia, a returnee from the U.S., in 1974, four years before IBM's exit. By the time IBM left, there were already 21 firms in the business. Further, apart from the Tata firms and two American ones (Citibank and TI), entrepreneurship in the top 8 firms in 1990 came from new U.S.-educated returnees rather than ex-employees of IBM.

[4] India had 0.3 scientists and technicians per 1000 people, ranking 42nd of 62 countries in the Word Bank's 1998 survey, below China at 1.3 (25th) and Ireland at 2.0 (20th). (World Development Indicators, http://wbln0018.worldbank.org/psd/compete.nsf/f14ea5988b0eec7f852564900068cbfd?OpenView&Start=1

[5] By 1988, 10% of the labor force was located in India; this had risen to 41% by 2000 and 71% by 2004 (Nasscom, 1999, Nasscom, 2002, p.28 and Nasscom, 2005, p.58).

[6] Import tariff reduction was a key feature of the 1990's reforms. These had risen to 110% by 1991 but were reduced to 85% in 1993, 20% in 1994 for applications software and 65% for systems software and, in 1995, to 10% for all software (Heeks, 1996, p.49). Duties on

hardware ranged from 40% to 55% in 1995, but by 2000 had come down to 15% for finished goods, such as computers, and 0% for components (microprocessors, storage devices, IC s and subassemblies, display screens and tubes, etc) (Ministry of Finance, 2000).

[7] The top 20 MNE software exporters employed 25,204 persons as of March 2002, or 13% of the software exporters' workforce.

[8] Similarly, as Bresnahan et al. (2001) have shown, Silicon Valley did not have several of the supposedly desirable attributes of an innovative cluster in the 1970s and yet succeeded.

[9] These were Flextronics, IBM, Perot Systems and Siemens. Of these, IBM was in the top 20 list in 2000. (http://www.nasscom.org/artdisplay.asp?art_id=4413#top20, downloaded August 26, 2005)