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The Software Industry and India's Economic Development

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Abstract
This paper assesses the contribution of software to India's economic development, paying particular attention to the role of software in the absorption of labour and the development of human capital in the economy. India's specialization in software has been driven by two sorts of wage advantages that have reinforced each other: lower wages for software developers relative to those of their US and European counterparts makes Indian software cheaper in global markets, while the higher wages earned by these professionals relative to other industrial sectors in India have ensured a steady supply of workers. The impact of this growth, however, has been limited to a small section of the economy, and the question being asked is whether the current growth can be sustained without a significant increase in domestic demand. We believe that export-led growth is sustainable in the medium term. On the other hand, the success of the software industry has increased the relative value of professional workers, not only programmers, but also managers and analysts. The growing importance of human capital, in turn, has lead to innovative models of entrepreneurship and organization, pioneered by the software sector, and these are slowly taking root and spreading to other sectors of India's industry. A potentially important and under-appreciated contribution of the software industry is thus its exemplar of good entrepreneurship and corporate governance to the rest of India. Though less visible than the macro contributions to employment and foreign exchange, this role is a source of productivity improvement for all industries, and can have powerful long-term benefits for India's industrialization and growth.

Keywords: Indian software, software exports, software and growth, human capital and development

JEL classification: F1, I2, L8, J5, O0

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1 Introduction

In little over a decade, India has emerged as a major exporter of software in the international economy. This remarkable feat has been accomplished through the extraordinary growth of Indian software which, in the last five years, expanded at a compound annual rate of 56 per cent. More than two-thirds of this was due to exports, making the industry a major export earner for the country. The proportion of software exports to merchandise exports grew from a negligible amount in 1990 to over 6 per cent in 1998-99. Remarkably, these software exports are largely due to the efforts of domestic rather than foreign firms. Of the top twenty exporters in 1998-99, only six firms were foreign subsidiaries.

The software industry contributes 1 per cent of India's GNP, but has accounted for over 7 per cent of the growth of its GNP (Kumar 2000). In 1997, the software industry employed 160,000 of the total employed workforce of 28.245 million. Employment in the industry, although constituting only a small fraction of the total, has grown quickly and estimates for the year 2000 suggest that there will be over 410,000 IT professionals employed in India.

Can the software sector continue to contribute significantly to economic growth, and what forms are these contributions likely to take? To answer this question, we begin by examining in section 2 the factors that have contributed to India's emerging specialization in software exports. We argue that software services are intensive in human capital and the abundant supply of engineers in the country provides not only an absolute wage advantage, but also a comparative advantage. In section 3 we review the factors that constrain the current growth of the software industry on the supply side, in particular the role of underinvestment in literacy and in telecommunications infrastructure. Section 4 analyses the contribution of software growth to human capital formation. High earnings in software have resulted in considerable private investment in training, and the subsequent emergence of a successful self-financing model of tertiary education in some parts of the country. Section 5 analyses the impact of software on productivity improvements through the linkage effects of software in the domestic economy. We conclude that this mechanism of productivity improvement is of limited importance in the Indian context. Section 6 emphasizes the role of high software salaries versus the rest of India's industry in creating productivity-inducing organizational improvements in software. We also analyse the role of software firms as organizational exemplars. Section 7 summarizes our main conclusions.

2 Factors favouring the growth of software revenues in India: The role of comparative and absolute advantages

Software is not just another industry. The number of companies that produce software or employ software developers is much greater than the set of firms commonly thought of as software firms, such as Microsoft or Oracle. Indeed, large banks, insurance companies, finance companies, and virtually every organization above a certain size all develop a great deal of software. Much of this software is either developed for a particular user, or consists of a standard 'platform' such as a SAP ERP system or an Oracle accounting system, and is customized to the needs of the user organization. Once in place, these systems have to be maintained and enhanced. Some observers claim that over two-thirds of all software development efforts are spent in maintaining and enhancing existing software codes, rather than producing new software (Raymond 1999).

Despite the steady growth of software technology and tools, software development is still labour intensive and requires relatively little capital. Estimates by Lakha (1994) suggest that labour costs accounted for about 70 per cent of all software costs in the early 1990s.[1] With the information technology revolution taking hold in the 1990s, the demand for IT workers in the developed world has steadily surpassed supply. However, a fairly substantial fraction of these activities can be outsourced and are increasingly conducted away from the user organization. This outsourcing demand has formed the basis of the initial growth of the software industry in India.

The needs of software production seem particularly suited to the resource endowments of the Indian economy. Moreover, scale economies are not a significant barrier to entry. A firm can—and many do—start off as little more than one software development team. Others have started as temporary employment agencies, requiring a few rooms in which to set up a handful of PCs and a telephone. Further, the production of software is not heavily dependent on physical infrastructure such as roads and ports, although a steady supply of electrical power is critical, as is ready access to PCs, workstations and communication, airports, phones, faxes and increasingly, the Internet.

The initial growth of the software service industry was facilitated by the enlightened 'hands off' policies of the government of India. By the late 1980s and early 1990s, PC prices had fallen steadily, as had the prices of other equipment. The government allowed liberal imports of both hardware and software tools, and firms were able to provide their own electrical power through a variety of sources, including self-generation. As Table 1 shows, this growth of software revenue came disproportionately from exports,[2] and thus it is worth exploring the nature of India's advantage in software exports.

Tables 2 and 3 show the extent of the absolute (labour) cost advantage. Amongst developed countries, only Greece shows similar levels in the salaries of software professionals. If one concentrates on the availability of scientists and engineers (Table 3), India has one of the largest reserves of these professionals in the world, almost all of whom speak English.

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1 With the decrease in hardware prices and the increase in the wages of software professionals, this estimate is likely to be on the low side for the late 1990s. Furthermore, the cost of software is the dominant budgetary item in setting up computerized systems in the west. As the process of computerization accelerates in the world economy, the demand for software will continue to increase.

2 As many early observers (Heeks 1996; D'Costa 1998) have noted, this initial growth was markedly dependent on export demand; was based on relatively unsophisticated services, and often was little more than the provision of temporary workers to overseas customers. Arora *et al.* (2000) also found that for the most part, Indian software firms were generalists, specializing in terms of neither technology nor vertical industry domains, but competing largely on cost with relatively little to differentiate one from the other. One implication of this is that the firms surrender the lion's share of the rents to customers so the net benefits of the mushrooming software industry and its growing productivity are largely passed on to customers, prominently the US which accounts for over 60 per cent of India's total exports of software.

Table 1
Growth of software revenues ($ million)

Year	Export revenues	Domestic revenues
1984	22	–
1985	26	–
1986	38	–
1987	54	–
1989/90	105.4	–
1994/95	485	350
1995/96	734	490
1996/97	1,085	670
1997/98	1,750	950
1998/99	2,650	–

Source: Lakha (1994) for figures up to 1989/90; Kumar (2000) for all other years.

Table 2
International differences in salaries paid to software professionals, 1995 (US$)

	Switzer-land	USA	Canada	UK	Ireland	Greece	India
Project leader	74,000	54,000	39,000	39,000	43,000	24,000	23,000
Business analyst	74,000	38,000	36,000	37,000	36,000	28,000	21,000
Systems analyst	74,000	48,000	32,000	34,000	36,000	15,000	14,000
Systems designer	67,000	55,000	36,000	34,000	31,000	15,000	11,000
Development programmer	56,000	41,000	29,000	29,000	21,000	13,000	8,000
Support programmer	56,000	37,000	26,000	25,000	21,000	15,000	8,000
Network analyst/ designer	67,000	49,000	32,000	31,000	26,000	15,000	14,000
Quality assurance specialist	71,000	50,000	28,000	33,000	29,000	15,000	14,000
Database data analyst	67,000	50,000	32,000	22,000	29,000	24,000	17,000
Metrics/process specialist	74,000	48,000	29,000	31,000	–	15,000	17,000
Documentation/training staff	59,000	36,000	26,000	21,000	–	15,000	8,000
Test engineer	59,000	47,000	25,000	24,000	–	13,000	8,000

Source: www.man.ac.uk/idpm/isicost.htm.

Table 3 also highlights two other factors. First, India has the potential of expanding this reserve with appropriate investments in primary and secondary education. Second, countries such as China and Russia have an even greater supply of trained scientists and engineers. If they were to train a proportion of their scientists in English, these countries could participate more fully in the international software industry. But the dynamics of the software industry comes into play as well. As we argue below, the head start enjoyed by the Indian software industry will hurt the prospects of the late comers.

Table 3
Reserve of technically trained personnel, selected countries, 1995

Country	Adult illiteracy rates (%)		Scientists/engineers in R&D per million of population	Population, millions	Reserve of scientists/engineers
	Males	Females	1981-95	1995	1995
USA	-	-	3,732	263	981,516
Japan	-	-	5,677	125	709,625
Russian Fed.	-	-	4,358	148	644,984
China	10	27	537	1,200	644,400
Germany	-	-	3,016	82	247,312
France	-	-	2,537	58	147,146
UK	-	-	2,417	59	142,603
India	35	62	151	929	140,279
Israel	-	-	4,826	6	28,956
Vietnam	4	9	334	73	24,382
Turkey	8	28	209	61	12,749
Hungary	-	-	1,157	10	11,570
Greece	-	-	774	10	7,740
Ireland	-	-	1,871	4	7,484

Source: World Bank, *World Development Reports* (1997) and (1999).

The explanation of the growth of software exports from a country like India because of lower labour costs is well known. It also underlies a somewhat pessimistic outlook for the future of these exports and the software industry. Once the surplus of trained labour is depleted, the cost advantage erodes, making India less attractive in comparison to China and Russia, for instance, as the source for lower value-added services (Heeks 1996). The absence of a sizeable domestic market will compound the problem by depriving the country's software exporters of the experience needed to ultimately enable them to produce higher value-added services and products (D'Costa 1999). In this respect, the only option is for India to develop a sizeable domestic market and reduce its export dependence.

This, however, introduces a dilemma. Perhaps the main reason for the absence of a large and sophisticated domestic market is a relatively unsophisticated economy, which has, until recently, grown at 3.5 per cent per year. Thus, the development of a sizeable domestic software market is likely to be a consequence as much as it is a cause of the growth of this particular industry. Indeed, Arora *et al.* (2000) find that conditions between the domestic market and exports market are so diverse that knowledge and experience gained from domestic projects are either not applicable, or too costly for overseas customers. Arora *et al.* conclude that domestic market experience is not particularly valuable for the export market.[3,4]

Another way of looking at the growth of software exports is to determine whether India enjoys a underlying comparative advantage in software production vis-à-vis the rest of the world. If such a comparative advantage does exist, both the absolute cost advantage and favourable circumstances such as the demand caused by the millennium scare could provide the experience and scale of output needed for dynamic learning processes to kick in and positively influence the growth of the sector's productivity. In this scenario, the future of Indian software exports is not entirely bleak and increasing productivity could compensate for the erosion of the labour cost advantage.

Productivity levels measured as revenue per employee are lower in India than in other parts of the world (notably Ireland and especially Israel). More importantly, however, compared to other countries, software in India is far more productive than other sectors—the essence of a comparative advantage argument. This is clear when we compare the ratio of labour productivity in software. It is twice that of India's manufacturing and 1.3 times that of the US (Table 4).[5] The picture is similar for Israel, another country with a fast growing software industry. In an open economy, both India and its trading partners benefit from the country's specialization in software, and implicitly its imports in less productive economic sectors such as manufacturing. The distribution of these gains is a moot point, of course. Given the country's heavy reliance on the US for software exports and their undifferentiated nature, it seems likely that productivity improvements in Indian software produce greater benefits for the US rather to India.

Although the share of software production in India's industrial output, exports and employment is increasing, its share in the world market remains low. The picture changes somewhat when we look at only the share of the country's customized software in the global market: this is estimated to have gone up from 11.9 per cent in 1991 to 18.5 per cent in 1999 (Kumar 2000b).

Limited infrastructure continues to constrain the industry. The most important of these are the availability of power and the quality of the telecommunications infrastructure (bandwidth and, increasingly, limited telephone penetration). In 1996, India had 15 main telephone lines per 1,000 people, compared with 395 per 1,000 for Ireland and 446

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[3] This conclusion, however, is conditioned by the types of export projects: simple, small and not very sophisticated. In short, there may be the 'chicken and egg' problem. Given the nature of export projects, sophisticated domestic projects may be of little value, but overseas customers appear unwilling to outsource projects that would enable Indian firms to acquire the necessary experience.

[4] A more compelling argument is that the domestic market could be the source for particular types of differentiation, for example, software for multiple languages and using multiple scripts, and for mutual translation. This could be a source of competitive advantage in countries with more than one language where forms, and government and corporate publications have to be in multiple languages. Alternatively, growth in the level and sophistication of domestic demand may finally provide companies with an easy way to 'break' into foreign markets by demonstrating their capabilities. These may yet happen, as the industry matures into more differentiated and distinct segments.

[5] We use value-added as the index of labour productivity in manufacturing and revenue per employee as the index of labour productivity in software where few material inputs are needed for production.

per 1,000 for Israel. The situation is more serious when we consider the penetration of PCs in the total population: 1.5 computers per 1,000 people versus 145 for Ireland and 117.6 for Israel (WDR 1998/99). It is difficult to estimate accurately the extent to which infrastructure constraints have affected productivity. Some indirect evidence, however, is available. Costs for power are the second highest expenditure and many software firms generate their own power.[6] Low bandwidths are also a problem. While current bandwidths are adequate for simple tasks, they could become an obstacle to more complex, higher value-added projects being awarded to the same firms. For the newly emerging area of e-commerce, the lack of telephone penetration will emerge as an important problem. Here, too, the solutions point to the nature of the problem. Mobile phone penetration (which does not require land lines) experienced the most rapid growth in smaller towns. In this context, the development of mobile telephony and Internet products presents a window of opportunity and growth inasmuch as demand for these is not constrained by telephone lines, or by literacy on the part of mobile phones.

3 Can the Indian success be replicated? Implications for other developing countries

Many researchers have predicted competition from other labour-abundant countries such as China, or even Russia and Ukraine, where economic woes have resulted in large reserves of underemployed engineers and scientists. Countries, including China, are reportedly investing heavily to introduce English language skills to their engineers. Undoubtedly, the current market shares of these countries could be increased—and increased substantially—if abundant skilled labour were the sole determinant of success. But the success of the software industry also reflects a certain level of entrepreneurial and managerial capabilities, as well as the importance of strong links with major markets. In the case of India, these are expatriates working in high-level technical and managerial positions in the west, primarily in the US.

Such links helped Indian entrepreneurs to respond quickly to the growing demand for software services. At a minimum, this meant the ability to recruit programmers, and arrange for and manage outsourcing contracts. As the firms grew, so did the challenges. Successful enterprises developed capabilities that became the source of India's competitive advantage. Interviews with US managers reported in Arora *et al.* (2000) highlight the importance placed by American companies on the ability of the Indian firms to mobilize large teams of developers at short notice. This, in turn, places demands on the firms to develop substantial expertise in recruiting, screening, training and, as discussed earlier, retaining software professionals. As discovered in Russia, this is no trivial matter. Russian firms reportedly complain that getting foreign companies to overcome their hesitation of doing business with the country is a major obstacle to offshore programming. Paucity of quality control and proper management are also handicaps, despite a substantial cost advantage in wages. Russia trails behind India in the number of companies with the ISO 9000 certification (Santana 2001).

6 A manager of a leading software firm noted that spending on diesel power generators was the second largest item of the firm's capital expenditure budget. This firm claims to have generated 4 megawatts in 1997, the year in which the interview took place.

Table 4
Comparative advantage in software production across selected countries, 1995

	All manufacturing		Software	Comparative advantage	
	Output per employee (1)	Value added per employee (2)	Revenue per employee (3)	Index 1 (3)/(1)	Index 2 (3)/(2)
	($ '000)	($ '000)	($ '000)		
Israel	112.20	38.30	100.00	0.89	2.61
Ireland	242.20	117.10	142.24	0.59	1.22
India	20.80	4.10	8.93	0.43	2.18
France	205.13	77.143	161.32	0.79	2.09
Finland	231.92	76.16	83.46	0.36	1.10
USA	206.00	98.20	126.02	0.61	1.28

Sources: Authors' computations from the following data sources:

Data in columns (1) and (2) are taken from the *UN Industrial Statistics* (1998 and 1999) published by UNCTAD. Exchange rates used to convert local currencies into dollars are taken from line rf of the *International Financial Statistics* published by the International Monetary Fund.

Data in column (3) are derived from the following national and international sources:

India from NASSCOM (www.nasscom.org); Israel from Israeli Association of Software Houses (http://www.iash.org.il); Ireland from *National Software Directorate* (http://www.nsd.ie), Ireland, and France, Finland and USA from *The Software Sector: A Statistical Profile for Selected OECD Countries* (OECD) http://www.oecd.org/dsti/sti/it/infosoc/index.htm).

Figures for Israel are obtained by dividing Israeli software revenues by estimated employment. Figures for Ireland are obtained by excluding multinationals from the calculation, which may therefore, underestimate revenue per employee in software.

Table 5
India's manpower and revenues/man-year

Year	Manpower	Revenue per employee ($)
1993-94	90,000	6,198.5
1994-95	118,000	6,998
1995-96	140,000	8,924.5
1996-97	160,000	11,036
1997-98	180,000	15,000
1998-99	250,000	15,600

Source: Arora *et al.* (2000: Table 1b).

Furthermore, Indian firms are increasing productivity by improving their software development processes, by moving up the value chain, and by developing proprietary development tools (Table 5). More recent entrants in the industry have also had some success at developing products. Arora *et al.* (2000) find that larger firms (with more than 250 employees) earn $8,000–10,000 per employee more than smaller ones. The number of such large firms has increased over time. Similarly, Arora *et al.* (2000) report that Indian firms rated at CMM level 3 or higher earn about $6,000–10,000 per employee more than firms without this qualification. As many as 32 Indian software firms have received the SEI-CMM[7] certification and more than half the companies with the CMM 4 and 5 ratings are in India.

These ratings demonstrate the significant organizational capability in software development that has been built up over the last decade, making it difficult for other global companies to compete.[8] More importantly, competitors have to contend with higher market visibility and the business connections Indian firms have been able to establish. Out of *Fortune*'s 500 companies, 185 now outsource their software production to India. Indeed, onsite services have given way to more profitable offshore services with dedicated software centres, an indication of the trust US and European firms have in the quality of Indian software services. Although not insurmountable, these are formidable barriers for others to overcome, including the country's own late entrants to the industry. Thus, we are likely to see established Indian firms leverage their reputation and capability by outsourcing to China and elsewhere, as TCS, Wipro and Infosys are reported to be considering (Sengupta 2001). Similarly, a large Chinese telecom firm, Huawei Technologies, has set up an R&D centre in Bangalore where 180 Chinese programmers work alongside the locals. In other words, rather than a zero sum game, China and other nations may be able to participate in the international division of software labour through collaboration with India.

4 The growth of software and human capital formation: public and private investments in training and the rewards to an engineering education[9]

Although India has a large number of scientists and engineers, it also has one of the lowest literacy rates in the world; 52 per cent of the total working population are illiterate. As Table 3 shows, despite the vast reserve of engineers, their number per million is smaller than in several other countries. There is a corresponding over-reliance on the current reserve of trained but underemployed engineers, for whom the slowly growing and protected economy cannot generate adequate demand.

A large proportion of the employees in software firms are college graduates, as highlighted by a sample survey of nearly 60 software firms who reported that over 80 per cent of their employees had engineering degrees. Only 13 per cent were non-engineers trained in software development.[10]

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7 CMM (Capability Maturity Model) is a structured process for software development associated with the Software Engineering Institute at Carnegie Mellon University. It consists for five 'maturity' levels. Companies or units assessed at level four and five are capable of controlling, managing and improving software development practices. Though initially developed as a means of providing improved software systems for the Department of Defence in the US, the CMM is becoming popular among Indian software service firms as a means of signalling their capability to overseas clients, particularly in the US.

8 Arora *et al.* (2000) do not, however, find any difference in the productivity of younger and older firms.

9 This section draws heavily upon Arora *et al.* (2001).

10 An earlier study (NASSCOM 1999) reported that only 2 per cent of all software developers trained in private training institutes join software development firms.

This preference for engineers was unremarkable and of little consequence at the start of the industry, when demand versus annual supply was small. Currently, over 160,000 engineers from all disciplines graduate every year. The sharp and sustained growth of the software industry had increased its workforce to nearly 250,000 by 1998-99, and estimates suggest that this may reach 400,000 in the years 2000-01. If the software industry continues to grow at 50 per cent per year, then there will be a shortage of engineers, regardless of productivity improvements (see Arora *et al.* 2001 for more details).[11]

These projections are consistent with other evidence. Wages in the software industry have risen over 20 per cent per annum and attrition rates are high. In 1998-99 in a sample of over one hundred enterprises, more than half of the firms, irrespective of age, size or market orientation, reported the shortage of manpower and employee attrition (Arora *et al.* 2000) to be among the three main problems. Virtually all firms find it difficult to attract and retain talented software developers despite wages that are substantially above Indian standard.

Public policy has responded with increased investments in engineering colleges, placing greater emphasis on information technology in engineering curricula and on the creation of institutes of information technology (IIIT) similar to the better known Indian Institutes of Technology. Though superficially reasonable, this is not the answer. These investments are unlikely to have a significant effect on supply in the short run. Moreover, expansion of capacity ignores the problem that the growth of the software industry has tended to siphon off engineering masters and Ph.D students. A recent report noted that the number of engineering Ph.Ds has fallen from 675 in 1987 to 375 in 1995. Similarly, the number of engineers with postgraduate training has risen only slowly, from approximately 12,000 in 1987-89 to a little over 17,000 in 1990-92. Surveys of India's IITs (the premier technological institutions) show that a very large fraction of postgraduates (90 per cent in some cases) enter the information technology (IT) sector

Moreover, Table 6 below shows that the majority of India's engineering capacity is located in just a few states—Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh, and that the bulk of the capacity is in 'self-financed' colleges, where students receive a much smaller subsidy, if at all, than in the state-financed colleges. An interesting and hitherto unexplored question is the reason why the organizational innovation of self-financing colleges has not diffused to other parts of the country. We can only speculate that this may be related to cultural and political factors as well as the lower returns to investment in human capital in other regions of India. It is no coincident that the south and west are also economically more advanced.

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[11] Recognizing the importance of this fact, many Indian policymakers have called for an 'educational emergency' declaration to ensure that the supply of skilled software developers is increased. Several CEOs of the smaller software development firms and NASSCOM (the professional association representing the views of these firms) have begun to argue that the shortage of skilled labour is constraining their ability to grow. (See also Basic Background Report (BR-3) for the National Task Force on Information Technology (IT) and Software Development (SD) submitted to the Prime Minister of India, 18th March 1999.)

Table 6
Number and capacity of engineering colleges in India (approved up to 1998-99), by region

Region	No. of colleges	Sanctioned capacity (no. of students)	% of sanctioned capacity that is self- financed colleges
Central	50	9,470	0.52
East	25	4,812	0.26
North (incl. north-west)	140	25,449	0.42
West	140	34,165	0.74
South (incl. south-west)	308	82,597	0.79
Total	663	156,493	0.69

Source: Ramarao (1998).

Even though investments in engineering education are necessary, we believe that a more efficient use of existing human capital resources could provide at least a part of the solution. Implicit in the discussion thus far is the fact that only engineering graduates are adequately suited for the required software tasks. This assumption appears to have shaky foundations. First, the bulk of engineers working in the industry are, in fact, not trained in software engineering, computer science, or related disciplines. Further, a very significant fraction of the work involves developing and refining business applications, databases, and the like. Indeed, initially the majority of the work involved porting applications from one computing platform, typically a mainframe, to another platform such as Unix. This necessitates certain familiarity with software development tools, but does not require in-depth knowledge of computer architecture or operating systems.[12] Finally, much of the work tends to consist of small projects, with fairly low levels of technical complexity. Arora *et al.* (2000) report that the median size of the 'most important export project' of the firms in their survey was only 150 man months, with an average of 510. This suggests that the typical export project is even smaller. Moreover, about half of the work was carried out in India, the rest was onsite in the US.

When pressed, most of the managers agreed that they did not specifically require engineers. With proper training, bright graduates from any field would suffice. Thus, the preference for engineers in some cases seems to be a quality signal to customers. As one CEO put it:

> Take somebody from a good college (any of the top 20 colleges in India), give him 3 months of orientation and they are ready to take up a programming assignment. *I don't need all these engineers…. But I don't want to be branded by my customers as a guy who hires NIIT graduates* [emphasis added].
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> (from Sloan Report, Arora *et al.* 1999)

[12] The significant exception is telecommunication-related software, where telecommunication engineers are required. Similarly, companies such as Texas Instruments, Oracle and Microsoft are locating development and R&D centres to tap into the engineering talent.

This is a clear instance of a 'race to the top'. With limited market power, Indian software exporters try to distinguish themselves from competition by highlighting the quality of their processes and employees, and when possible, their experience.

Firms also have quality concerns. Some interviewed managers believe that an engineering education imparts problem-solving skills, methods of logical thinking and learning tools that would promote quick adaptation to changes in technology, domains and tasks. Since Indian firms provide services across a range of platforms and domains, this is an important asset. Another important consideration is the signalling of qualifications in the labour market. The Indian education system is such that competition for an engineering education is intense, and as a result, an engineering degree is synonymous of such qualities as intelligence and the willingness to work hard. Software firms may value these qualities more than specific substantive engineering knowledge.

If this is the case, it is certainly an inefficient allocation of resources.[13] Indeed, the software industry has expanded in part because of its ability to attract engineers from other industries. In our interviews there were a number of instances of engineers with highly specialized training (such as VLSI design or satellite systems) working on database design or the development of business application software, and quite a few senior level engineers were drawn from various public sector research and development institutions. Such a transfer of resources reflects the presumed comparative advantage in software development, but there are distortions in the economy, which warrant caution in interpreting the market signals.[14] In addition to changing the composition of economic activity, the increasingly tight market for engineers and managers is also likely to affect the organization of economic activity, such as the balance between capital and labour (or more precisely, between capital and human capital), resulting in organizational innovations.

The clearly increasing payoffs to human capital are also inducing greater investment in human capital. The middle class in India has always relied on education, particularly professional training such as engineering or medicine, as the means for economic advancement. However, with a slowly growing economy, the returns to this investment have not been very high. Precarious public finances have limited the ability of central and state governments to expand tertiary education, but the rapid growth of the software sector has created a watershed. One of the most rapidly growing sectors within the software industry is in private training, where institutions specialize in software development. Sources from NASSCOM (the National Association of Software and Service Companies) estimate that in 1998 there were 3,800 such training firms, in what was then a $300 million market, although NIIT and Aptech together are believed to

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13 A more rational allocation could be the substitution of intelligent and hardworking non-engineers trained in the use of software development tools for engineers wherever possible. Engineers could be used where their substantive knowledge or design ability was of value.

14 There might be long-run consequences as well which could damage the indigenous technology development capability. This is similar to the trend, noted earlier, of engineering graduates deserting other disciplines for the IT sector, and even more, of preferring software jobs rather than pursuing postgraduate education.

have 70 per cent of the software training market.[15] Private institutes are also important for upgrading the skills of existing software developers. This option is also used by many engineers to undertake further training in software development on their own. The growing presence of these institutes in cities across India is making it increasingly possible for software developers to obtain certificates and diplomas.

It is also noteworthy that this is a private sector response to a market opportunity, namely the demand for training in specialized skills. In the US and elsewhere, for-profit firms compete with public institutions, such as state and community colleges. In India, the rapid development of private training institutes testifies to the changed economic climate and the channelling of entrepreneurship into economically productive areas away from mere rent-seeking. This change is also at least indirectly related to the rapid growth of the software industry.

To sum up, we believe the evidence indicates that until recently the excess reserve of trained engineering talent was a significant source of competitive advantage for Indian firms. On the other hand, it provided limited incentives for firms to economize on the use of skilled engineering talent. Instead, the growth of the industry and high salaries have attracted not only new graduates but also engineers, managers and other professionals from other industrial sectors. Despite this, the explosive growth of the software industry has led to the recognition that there is a shortage of skilled engineers, software professionals and good managers. Moreover, faced with a number of attractive options, including job opportunities overseas, these trained individuals are looking for more money and a more professional and rewarding work environment. This, in turn, entails a variety of organizational changes which we discuss below.

Table 7
Growth of the information technology training sector in India

Training	1996-97 ($ million)	1997-98 ($ million)	Growth (%)
Corporate	11.67	21.43	84
Individual	145.24	182.43	26
Total	156.81	203.86	30

Source: INFAC, Mumbai.

6 The contribution of software to economy-wide productivity growth: organizational improvements and the 'demonstration effect' on other firms

The advancement of software in India has promoted some related service industries, the most notable of which is the rapid growth of the informal IT sector studied by Kumar (2000a and 2000b). Services such as the provision of IT maintenance, data entry and customization services for domestic users, all virtually non-existent a decade ago, are gaining in prominence. Kumar (2000a) estimates that software and these ancillary industries probably accounted for about 0.5 million jobs in 1998-99, a figure that is

[15] Other major vendors include Software Solutions Integrated, LCC Infotech, Tata Infotech, CMC, Indian Institute of Hardware Technology, First Computers, Pentafour Communications, Jetking, IIS Infotech, Boston Education, SQL Star, Datapro and IBM Learning Services.

likely to have increased substantially since. According to a recent survey by NASSCOM, IT-enabled services have shown the strongest upsurge (66 per cent) among all industry segments in India over the previous year and are expected to gross a revenue of US$ 880 million in 2000-01, versus US$ 530 million in the previous year.

The basic business model underlying the development of these services is similar to that of software, namely large firms outsourcing a part of their operations to take advantage of the availability of a large English speaking population at relatively low wages. Poor infrastructure in telecommunications constitutes the same impediment to the expansion of these services as it does to the growth of software services. This year the two most promising segments are customer interaction services, including call centres, and content development and animation. Table 8 shows the projections from a NASSCOM survey which forecasts opportunities for IT-enabled services.[16]

On the whole, however, software creates relatively few linkages with other sectors of the economy. But the industry is fast emerging as an exemplar of both good organizational practices and technocratic entrepreneurship. In this section we examine why this is so, and look at the mechanisms through which similar progressive practices could spread to other sectors of the economy.

While software professionals in India earn only a fraction of the salary of their international counterparts, it is still about twenty times the national average. This difference in international wages makes software firms in India vulnerable to the loss of middle-level employees to the west, and puts continuous pressure on profitability.

Table 8
Current and projected demand for software developers in IT-enabled services in India

	1998		2008 (projections)	
IT-enabled services	No. employed	Rs, millions	Can be employed	Rs, millions
Back office operations/revenue accounting/data-entry conversion	9,700	4,200	260,000	190,000
Remote maintenance and support	1,600	650	180,000	135,000
Medical transcription/insurance claim processing	3,800	1,400	160,000	110,000
Call centres	1,400	400	100,000	60,000
Database services	1,000	450	100,000	65,000
Content development	5,500	2,700	300,000	250,000
Total	23,000	9,800	1,100,000	810,000

Source: NASSCOM, 'The Software Industry in India: A Strategic Review' (1999).

16 Medical transcriptions and other forms of data entry, for instance, simply rely on high school or college graduates who know typing and language skills (for which they are trained). For instance, to transcribe the audio-taped diagnoses of physicians located in the US, Indian firms rely on software developers trained to understand English spoken with an American accent and who have the ability to type in English.

Vulnerability to employee attrition and rising wages have created different problems for the software sector. Increasing wages have caused many firms to actively introduce stock options to supplement salaries. Until recently, firms used the overvalued technology stocks to supplement wages, or as incentives to secure loyalty by offering employees stock option plans (ESOP). Private firms, such as TCS, competed similarly for talented people by offering bonuses calculated on a notional stock price of the company based on its economic value added. Kumar (2000b) estimates that as many as 41 Indian software firms offered ESOPs in addition to wages in 1998-99. More recently, Infosys and Silverline have started to offer ADR linked ESOP to their employees as part of a larger retention strategy.

While rising wages directly affect profitability, attrition creates a different kind of threat—the loss of employee-specific knowledge, the possibility that this know-how is transferred to a competitor and, at times, the loss of credibility with the client. Interviews with US-based clients of Indian software firms also indicated that many considered employee attrition a serious problem (Arora *et al.* 2000). Several clients recalled incidents of delay caused by an entire project team leaving in mid-term in response to a more lucrative offer. In addition, when attrition is at the senior level, it is possible that the firm will also lose some of its customers to the competitor.[17]

However, both of these problems have prompted software firms to explicitly introduce human capital management strategies that are comparable with their international rivals. These include:

- An increasing role by software firms for private investment in software education and training for their employees. Leading companies like TCS and Infosys spend between 4-6 per cent of their revenues on training. It is estimated that the industry as a whole spent 7,609 man-days per organization or 5.5 man-days of average training per person per organization on training (Dataqust 2000);
- Organizational practices designed to retain the interest and loyalty of employees; attention given to charting a management career path for technical personnel, perhaps the first signs of a technocracy;
- Organizational innovations designed to diffuse and combine employee-specific knowledge through different approaches, most notably through flat hierarchies, team efforts and the use of embodied forms of software knowledge such as tools or, where possible, through the use of licenses and IPRs.

The adoption of ESOPs and the charting of career paths in management for technically-qualified professionals have had at least one unintended outcome. Technically-qualified personnel view entrepreneurship itself in a new light. It has become the logical extension of managerial tasks they would have handled in any case as their careers advanced, albeit now with an added element of risk that nevertheless promises large rewards. Thus, ex-employees of HCL and Wipro have become active entrepreneurs, and TechSpan, NIIT, Pertech Computers, Global Infotech, InfoTech Enterprises, STG and Infogain were all set up by ex-Wipro employees. Similarly, product-based ventures such

[17] An early example of this was the setting up of Infosys by a group of employees who left Patni Computer systems. In recent years, as we document later in this section, this type of spin-out activity has become much more frequent.

as Jamcracker, Microland, e4e Ventures, Tarang Software, iLantus, Jumpstart, Qsupport and Mindtree Consulting have been set up by ex-Wipro employees. Other leading software firms are aware of these concerns. Satyam has sought to avoid attrition by investing in corporate venturing. Recent plans announced by TCS indicate that they, too, will start a venture capital fund to encourage start-ups by employees with innovative ideas.

In software and other service sectors, shifting into entrepreneurship is also relatively easy because of the low capital requirements and the large venture capital interest in India. Apart from individual incentives to technological personnel for greater private rewards, the social value of this changed attitude towards entrepreneurship is enormous. This is because technically trained personnel are, through entrepreneurship, directly involved in attempts to commercialize technology and this in turn results in a transfer of knowledge from universities to more applied realms in industrial manufacture.

Some of this change is already visible in the mushrooming growth of the IT-related services sector, as has been demonstrated by Kumar (2000a). This sector shows evidence of the rewards of education in entrepreneurship and the surprising step-up into entrepreneurship amongst all sections of the population.

With the advance of private training and the rush among software firms to distinguish themselves in terms of domain expertise, it is becoming relatively easy for professionals from other service sectors to migrate into IT and software through some small investments in software training. Indeed, as the salaries of technologically qualified personnel rise in India, this is one area of substitution employers will be actively looking toward. As software firms seek to build domain expertise and move up the value chain, there is an increase in the demand for marketing personnel, preferably with experience of the US markets. Salaries for software marketing executives rose 25 per cent in the last year (*Hindu Business Line* 2001), which in turn creates pressures for other service industries (banking and finance, hotels, retail trading) to offer similar rewards, be it ESOPs, or employee friendly policies. Thus, last year the hiring of managers (as opposed to technically qualified persons) in the software sector grew by an incredible 30 per cent. At the same time, firms in the banking and insurance sectors (including, in some cases, public sector firms) announced decisions to offer ESOP packages to their employees.

Even without the luring away of personnel to the software sector, the service sector is one to which the software model can, in theory, be easily transposed. The generic model underlying all service industries is the employment of personnel whose capacity to render a service can be fully utilized. Physical capital requirements of these industries are minimal. Good employees induce customer loyalty and, if undervalued, can leave the company to set out on their own. A valued employee can exert the same pressure on his employer as a capable software programmer. The software model can be almost identically replicated for services that are to be delivered globally. Thus, call centres, data entry and data transcription services operate a generic business model very similar to software service firms. Given the vastness of the Indian domestic market, in national markets similar elements also apply.

One might ask with some scepticism what are the possibilities for similar qualitative changes to evolve in the older manufacturing sectors of the economy (e.g. steel automobiles, textiles, cement, etc.), where major companies still dominate production and employment, but without the same upward pressure on wages. The surprising evidence is that older businesses are rushing to accommodate some of these changes in organizational style and employee participation. Mechanisms for the diffusion of organizational practices are, however, different from those in the services and IT-related service sectors. An increasingly large number of the big business houses (Dalmias, Birlas, Mahindras, ITC, Wipro) invested in IT divisions in the early 1990s, given the high profitability and relatively low capital needs of software services business at that time. Often these divisions enjoyed considerable autonomy to develop their own management styles, rewards and compensation to employees. The methods and practices that evolved kept pace with competition, but often also deviated from established norms of the parent companies. The struggle of the new and better practices being adopted is, in itself, an interesting story, which is beyond the scope of this paper.[18] However, once the new norms were established in one division of the company, it was rather difficult, for reasons of parity, to inure other divisions from following the same.

External borrowing has also played a big role in this process. One of the surprising outcomes of the liberalization of capital inflows in India resulted not only in large amounts of foreign investment, as policymakers had intended, but also in a huge accumulation of foreign debt due to corporate borrowing. As Indian firms tapped the foreign equity markets for their finance requirements, equity market norms were being closely followed, particularly with regard to good corporate governance. Thus, despite their relatively low investment requirements, software firms listed on US stock exchanges[19] and pioneered this fund-raising route for Indian firms. This implied the use of the American system of financial reporting (GAAP), quarterly reports and close attention to the investor community and their representatives, the equity analysts. Indian firms were anxious to comply, as these practices signalled their competence and enhanced their visibility to potential customers. Over the next two years, another 15 Indian firms will be added to the New York Stock Exchange. Reports indicate that most of these are not from the software sector, but rather from investment-heavy sectors such as pharmaceuticals and telecommunications, that will follow the same norms and transparency of procedure.

In sum, the diffusion of good management practices from the software sector to other economic areas has come through two channels. As human capital-intensive service sectors provide the software industry with much needed middle-level management, the pressures apparent in software sector will, in time, ensure that better management practices are adopted in other sectors as well. Although pressures on the manufacturing sector to adopt good management practices do not come from the rise in salaries, nevertheless the participation of old economy capital in the newly emergent software sector has ensured that old businesses are not inured against the adoption of such practices. This trend has been reinforced by the financial liberalization of the economy and its opening up to external finance.

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18 As examples we can mention recent events such as the struggle at DSQ started by external investors for professional management to have effective control; the recent attrition among executive staff at Wipro in response to a slow dilution of the firm's equity shareholding to employees; the efforts to overcome the stalemate in Mahindra-BT in 1995-96 when the company threatened to close by inducting professional management that restored profitability and credibility.

19 Infosys (Nasdaq), Satyam Infoway (Nasdaq), Silverline Technologies (NYSE) and Wipro.

7 Conclusions and some policy implications

In this paper, we have argued that the rapid advance of software exports from India is a consequence of the country's comparative advantage in the production of these services rather than the result of an absolute advantage in terms of wage differentials alone. This comparative advantage, in turn, is based on the availability of a large English-speaking and technically qualified workforce as well as the relative disadvantage in manufacturing due to poor infrastructure investments in the past. Indeed, the larger the size of this disadvantage, the greater the benefit of specializing in software. The transfer of resources from poor productivity sectors to those with greater productivity will also spur the growth process. The last decade has seen higher rates of income growth in the south and west of the country, the areas of software concentration.

These factors favouring India's software exports are further reinforced by the low domestic demand for similar types of products and services. Though there are gains from specialization, the distribution of gains from such specialization, however, remains uneven due to the structure of the Indian software industry that still remains largely undifferentiated. The latter is, however, a circumstance that will change as the industry matures.

Due to the undifferentiated and service nature of Indian software firms, however, human capital has grown in importance to levels that were hitherto reserved for the scarcer financial and physical capital in Indian industry. In an extremely competitive international software market, Indian firms emphasize the quality of their procedures and human resources to gain a competitive advantage. This microeconomic response has had both positive and negative consequences.

One benefit stems from the appreciation of training in an environment where qualified software programmers are scarce and are becoming scarcer. This, in turn, has resulted in substantial private investment in the provision and acquisition of tertiary training. The adverse consequence is the slow hiking-up of prices for the most technically-qualified workers, viz. engineers. Engineers had for years supplemented their engineering degrees with other qualifications in order to be accommodated in the better paying management cadre. Currently they are in the enviable position of being able to command large salaries for tasks for which their training is rather irrelevant.

The government has responded to this crisis in engineering education by targeting resources to the engineering colleges and institutes for information technology—the same areas favoured by private investment. Our analysis suggests that the economy as a whole can realize greater benefits by complementing private investments with public investments in basic and secondary education and in physical infrastructure, factors that had constrained the growth of the software industry in the first place. The current excess demand for engineers will, in time, be corrected by a more rational and economical strategy, viz. training science graduates in software programming.

The hiking-up of wages for Indian engineers and technically trained labour, and the increased demand for them in the international market have also forced Indian software firms to adopt organizational practices comparable to those of their strongest competitors in the US and elsewhere. This has included the charting of career paths for technical personnel and systems of rewards that share both profits and risks. Increasingly, firms are being forced to provide more congenial and satisfying work environments. We have argued that some of these measures are spilling over into other service sectors, where human capital is more important than physical capital and from where the software sector may draw employees to man middle-level management positions. In turn, this has forced various companies, which have controlled large parts of the economy, to adopt more professional and transparent practices. These changes are likely to be slow, but there are other institutional forces at work, most notably the increasing importance of equity markets, and increased competition from imports and from multinationals.

However, greater specialization in software production and exports in the domestic economy (with or without differentiation of the industry) are constrained by precisely the same factors that accounted for India's relative disadvantage in manufacturing, namely poor and inadequate investment in physical infrastructure, communications and basic education. Thus, while software development offered a window of opportunity because of the large supply of underemployed engineers, it is a narrow window. Furthermore, software has not become the leading sector in India's economic growth, at least partly because of its poor linkages with the rest of the economy. This poor linkage is itself a consequence of the 'service' rather than 'product' nature of the industry, and its external rather than inward orientation, facts lamented by previous analyses of the industry.

In this paper we have tried to show it is precisely these two facts—the (technical) labour-intensive nature of the industry and an environment of global excess demand for such labour—which have altered the attitudes towards human capital formation at the firm level and in the national economy. In the final analysis, it is in terms of this slow change in attitude towards education, entrepreneurship, and the value of human capital in the economy where the software industry has made its greatest contribution to India's economic development.

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