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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 the software in the absorption of labour and the development of human capital in the Indian economy. India's specialisation in software has been driven by two sorts of wage advantages that have reinforced each other: the lower wages for Indian software developers relative to that of their US and European counterparts makes Indian software cheaper in global markets, while the higher wages earned by software professionals in India relative to that in other industrial sectors has ensured a steady stream of supply of software professionals. However, the impact of this growth has been limited to a small section of the Indian economy, and there are questions whether the current growth can be sustained without a significant growth of 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 contributed to an increase in the relative value of professional workers – programmers, but also managers and analysts. In turn, the growing importance of human capital has lead to innovative models of entrepreneurship and organisation, pioneered by the software sector, which are slowly taking root and spreading to other parts of Indian industry. A potentially important and under appreciated contribution of the software industry is thus as an exemplar of good entrepreneurship and corporate governance to the rest of Indian industry. Though less visible than the macro contributions to employment and foreign exchange, this role is a source of productivity improvement for all industry, which can have powerful long- term benefits for India's industrialisation and growth.

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

The software industry and India's economic development

In a little over a decade India has emerged as a major exporter of software in the international economy. This remarkable feat has been accomplished through an extraordinary growth of Indian software: in the last five years the Indian software sales grew at a compound annual rate of 56%, of which more than two-thirds were due to export sales. The industry is emerging as a major export earner in India: the proportion of software exports to merchandise exports grew from negligible amounts in 1990 to over 6% in 1998-99. More remarkably, these software exports are largely due to the efforts of Indian firms rather than foreign firms: Of the top twenty exporters in 1998-99 only six firms were foreign subsidiaries.

The software industry contributes 1% of India's GNP, but has accounted for over 7% of the growth of that GNP (Kumar, 2000). In 1997, the software industry employed 160,000 of India's total employed workforce of 28,245 million. Though only a small fraction of the total, employment in the industry has grown quickly and estimates for 2000 suggest that over 410,000 IT professionals were employed in India.

Can the software sector continue to contribute significantly to India's economic growth, and what forms are these contributions likely to take? In answering this question, we begin by reviewing factors that have contributed to India's emerging specialisation in software exports in section 2. We argue that software services are intensive in human capital and an abundant supply of engineers in India provide not just 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 under-investment in literacy and in telecommunications infrastructure. Section 4 analyses the contribution of software growth to human capital formation. The high earnings in software have resulted in considerable private investment in such training, and consequently the 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 emphasises the role of high software salaries relative to the rest of Indian industry in inducing productivity inducing organisational improvements in software. We also analyse the role of software firms as organisational exemplars. Section 7 summarises 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: Firms that produce software or employ software developers is much larger 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 organisation above a certain size writes a great deal of software. Much of this software is either developed for a particular user, or consists of standard "platforms" such as a SAP ERP system or an Oracle accounting system and customised to the needs of the user organisation. Once in place, these software systems have to maintained and enhanced. Some observers claim that over two thirds of all the software development effort is spent in maintaining and enhancing existing software code, rather than in producing new software (Raymond, 1999).

Despite the steady growth in 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% of all software costs in the early 1990s.[1] As the information technology revolution has taken hold in the 1990s, the demand for such workers has steadily outstripped supply in the developed world. However, a fairly substantial fraction of these activities can be outsourced, and increasingly, are carried out away from the user organisation. This type of outsourcing demand has formed the basis of the initial growth of the Indian software industry.

The needs of such software production seem particularly suited to the resource endowments of the Indian economy. Moreover, scale economies are not a significant barrier to entry. Firms can, and did, start as little more than one software development team, while 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 does not depend quite so heavily on physical infrastructure such as roads and ports, although a steady supply of electrical power is critical, as is ready access to PCs, workstation and communication – airports, phones, faxes and increasingly, the Internet.

The initial growth of the software service industry in India 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. Table 1 shows this

[1] With the decrease in hardware prices and the increase in the wages of software professionals this estimate is likely to be on the lower side for the late 1990s. Furthermore the costs of software are the dominant element of costs in setting up computerised systems in the West. As the process of computerisation accelerates in the world economy, the demand for software will continue to increase.

growth of software revenues came disproportionately from export revenues.[2] Thus it is worth exploring the nature of India's advantage in software exports.

{Table 1 here}

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

{Tables 2 and 3 here}

Table 3 also shows two other things. First that India has the potential of expanding this stock by making the right investments in primary and secondary education. Second, that countries such as China and Russia have even greater stocks of trained scientists and engineers. If they were to train a proportion of their trained scientists in English, these countries too could participate more fully in the international software industry. However, the dynamics of the software industry come 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.

This story of the growth of exports of software from countries like India on account of lower labour costs is well known. It also underlies a somewhat pessimistic outlook for the future of such exports and the growth of the software industry in India, because as the stock of surplus trained labour depletes, the cost advantage erode, making India less attractive (compared to

[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 providing temporary workers to overseas customers. Arora et al (2000) also found that for the most part, Indian software firms were generalists, specialised neither in terms of technology nor in terms of vertical industry domains, 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

countries such as China and Russia) as source for lower value added services (Heeks 1996). The absence of a sizable domestic market is said to compound the problem by depriving software exporters in India of the depth of experience that will ultimately enable them to produce higher value added services and products (D'Costa, 1999). In this view, the only way out is for India to develop a sizable domestic market and reduce its export dependence.

This however begs the question. After all, perhaps the biggest 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 year. Thus, it would appear that the development of a sizable domestic market for Indian software is likely to be a consequence as much as it is a cause of the growth of the Indian software industry. Indeed, Arora et al (2000) found that domestic market conditions differ sufficiently from the export market so that learning and experience from domestic market projects is either not applicable, or if it is, overseas customers appear to be unwilling to pay for that. They 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 from India is to ask if there is an underlying comparative advantage that India enjoys in software production vis-à-vis the rest of the world? If such a comparative advantage does exist then, both the absolute cost advantage enjoyed by India, and favourable events like the excess demand caused by the millennium bug,

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growing productivity is largely passed on to its customers- most prominently the US which accounts for over 60% of all India's exports of software.

[3] This conclusion, however, is conditioned by the types of export projects – simple, small and not very sophisticated. In short, there may be a chicken and egg problem – given the nature of export projects, the 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 a source of particular types of differentiation – e.g., software for multiple languages and using multiple scripts, and for mutual translation, -- this might 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

could give Indian software exporters the experience and scale of output that is required for dynamic learning processes to kick in and start making their effect felt on the further growth of productivity in the sector. In this story the future of Indian software exports is less bleak; the erosion of the labour cost advantage could be compensated for by increasing productivity.

Productivity levels measured as revenues per employee are lower in India compared to other parts of the world (notably Ireland and especially Israel). More importantly however, software is far more productive relative to other sectors in India compared to other countries – the essence of a comparative advantage argument. This is clear when we look at the ratio of labour productivity in software to that in manufacturing and the differences in this ratio across countries in Table 4. [5] For instance, productivity in software is more than twice that in manufacturing in India, whereas it is 1.3 times in the US. A similar picture obtains for Israel, another country with a fast growing software industry. In an open economy, both India and its trading partners will benefit from India's specialisation in software, and implicitly her imports in the sectors that the economy is less productive in (e.g. manufacturing). The distribution of these gains is a moot point, of course. Given the high reliance on US exports of the Indian software sector and the undifferentiated nature of software exports from India, it seems likely that the productivity improvements in Indian software contribute more to productivity in the US rather than in India.

Though the share of software production in India's industrial output, exports and employment is growing, its share in the world market for software remains low. The Indian software industry accounts for a small proportion of her domestic employment outside

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 in manufacturing 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.

agriculture, and Indian software account for a very small fraction of the world software market. The picture changes somewhat when we look at customised software alone. India's share of the customised software market is estimated to have grown from 11.9% in 1991 to 18.5% in 1999. [6]

Infrastructure constraints continue to dog the industry. Most important of these is the availability of power and the quality of the telecommunications infrastructure –bandwidth and increasingly telephone penetration. Thus, it is estimated that in 1996, India had 15 main telephone lines per 1,000 people compared with 395 lines per 1,000 for Ireland and 446 lines per 1,000 for Israel. The picture is much worse when we consider the penetration of PCs in the total population: India boasted 1.5 computers per 1,000 people compared to 145 for Ireland and 117.6 for Israel.[7] It is difficult to estimate exactly how much infrastructure constraints have affected productivity, but some indirect evidence is available. Expenditure on power was the second largest category of expenditure among software firms and many firms generate their own power. [8] Low bandwidths are also a problem. While current bandwidths are adequate for the simple tasks required of Indian software exporters, they could potentially be keeping more complex, higher value-added tasks from coming to the same firms. For the newly emerging area of e-commerce in India, 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) saw 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, and for mobile phones, by literacy.

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[6] Estimates reported in Kumar (2000b).
[7] Estimates are from WDR, 1998/99.

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

Many commentators have pointed to future competition from other labour abundant countries such as China, or even Russia and Ukraine, whose economic woes have resulted in large pools of underemployed engineers and scientists. Countries such as China are reportedly investing heavily in imparting English language skills to their engineers. Undoubtedly, the current market shares of countries such as China can be increased, and if abundant skilled labour alone were the determinant of success, would be increased substantially. However, the success of the Indian software industry also reflects the supply of entrepreneurial and managerial capabilities, and the importance of strong links with major markets, in the form of expatriate Indians working in high level technical and managerial positions in the West, primarily in the US.

These links helped Indian entrepreneurs to respond quickly to the growing demand for software services. At a minimum, this required the ability to recruit programmers, arrange for outsourcing contracts, and manage such contracts. As Indian firms have grown, so have the challenges, and the successful Indian firms have developed capabilities that are a source of competitive advantage. Interviews with US managers reported in Arora et al (2000) highlight the importance that US firms place on the ability of Indian software firms to mobilise, at short notice, large teams of developers. In turn, this requires Indian firms to develop substantial expertise in recruiting, screening, training and, as discussed earlier, retaining software professionals. As firms in Russia have found out, this is not trivial. Russian firms reportedly complain that getting foreign companies to overcome their hesitations of doing business with

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[8] A manager at leading software firm noted that spending on diesel power generators was the second largest item of the firm's capital expenditure budget. This firm claimed to have generated 4 megawatts in 1997, the year in which

Russia is a major obstacle to offshore programming. Quality control and proper management are also handicaps, despite a substantial cost advantage for Russian firms in what they pay their labour force. Russia trails behind India in the number of companies that have achieved ISO 9000 certification.[9]

Furthermore, Indian firms are increasing productivity by improving their software development processes, by moving up the value chain, and developing proprietary development tools. More recent entrants in the industry have also had some success at developing products. Table 5 shows this growth of productivity among software firms overtime. Arora et al (2000) find that larger firms (with more than 250 employees) earn $8000 - $10,000 more than smaller firms. The number of such large firms has increased over time. Similarly, Arora et al (2000) Indian firms rated at CMM level 3 or higher earn about $6000-10,000 per employee more than firms that lack such qualification. As many as 32 Indian software firms have received the SEI-CMM[10] certification and more than half the companies with the CMM 4 and 5 ratings are located in India.

{Tables 4 & 5 here}

These ratings demonstrate the significant organisational capability in software development that Indian firms have been built up over the last decade and which other global competitors will find hard to compete against.[11] More importantly, competitors will have to contend with the higher market visibility and the established business connections that successful

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the interview took place.

[9] *Can Russia's techies mimic India?* By Rebecca Santana, Newsweek, February 20, 2001.

[10] CMM (Capability Maturity Model) is 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.

[11] Arora et al (2000) do not however find any difference in the productivity of younger and older firms.

Indian software firms have established. 185 of the Fortune 500 companies now outsource their software production to India. Indeed, onsite services have given way to more profitable offshore services with dedicated software centres for clients, indicating the greater trust that US and European firms have in the quality of Indian software services. Although not insurmountable, these are formidable barriers for others, including later entrants to the Indian software industry itself, to overcome. Thus, we are as likely to see the established Indian firms leverage their reputation and capability by outsourcing to China and elsewhere. Leading Indian firms like TCS, Wipro and Infosys are reportedly considering outsourcing deals with Chinese firms.[12] Equally a large Chinese telecom firm, Huawei Technologies, has set up an R&D centre in Banglaore where 180 Chinese programmers are employed alongside Indians. In other words, rather than a zero sum game, China and other nations may be able to participate in the international division of labour in software by co-operating with the Indian software industry.

4. The growth of software and human capital formation: public and private investments in training and the rewards to an engineering education[13]

Though India has one of the largest numbers of scientists and engineers it also has some of the lowest rates of literacy in the world with 52% of the total working population that cannot read or write. As Table 3 showed, despite the large total numbers of engineers, the numbers of engineers per million of population was smaller in India compared to several other countries. There is correspondingly an over-reliance on the existing stock of trained but underemployed engineers, for whose services a slowly growing and protected economy could not generate adequate demand.

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[12] "TCS, Infosys, Wipro to outsource from China" by Snigdha Sengupta, Economic Times, Monday Feb 05 2001.
[13] This section draws heavily upon Arora, Asundi and Fernandes (2000).

A very large fraction of the employees of Indian software firms are graduates of engineering college. Most of the Indian software firms interviewed by Arora et al. (2000) reported hiring only engineers. Data from a sample of nearly 60 software firms indicates that over 80% of their employees had an engineering degree. Only 13% were non-engineers trained in software development.[14] In interviews, many firms categorically stated that they hired only engineers.

This preference for engineers was unremarkable, and of little consequence, at the start of the industry, when its demand was small relative to the annual supply. India graduates over 160,000 engineers of all varieties. The sharp and sustained growth of the Indian industry has meant that by 1998-99, the number of employees has climbed to nearly 250,000, and estimates suggest that this may have crossed 400,000 in 2000-2001. If the industry continued to grow at 50% per year, then even allowing for increases in productivity, it appears that the software industry is going to run out of engineers to hire. (See Arora, Asundi and Fernandes, 2000 for more details.)[15]

These projections are consistent with other evidence. Wages in the software industry have grown at over 20% per annum and attrition rates are high. When asked in 1998-99 to list the top 3 problems they faced, more than half of all firms (out of a sample of over 100 firms) irrespective of age, size or market orientations (either export or import) selected manpower shortage and employee attrition as the most serious problem affecting them (Arora, et. al, 2000).

[14] An earlier study (NASSCOM, 1999) reported that only 2% of all software developers trained in private training institutes join software development firms.

[15] Recognizing the importance of this fact many Indian policy makers have called for declaring a state of "Educational emergency" to ensure that the supply of skilled software developers is increased. Several CEO's of smaller software development firms and NASSCOM-the professional association representing the views of these firms- have begun to argue that the shortage of skilled labor 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.)

Despite paying substantially above Indian standards, virtually all firms find it difficult to attract and retain talented software developers.

The public policy response has been to emphasise increased investments in engineering colleges, increased emphasis on information technology in engineering curricula and the creation of institutes of information technology (IIIT) along the lines of the better known Indian Institutes of Technology. Though superficially reasonable, this is not the answer. These investments are unlikely to have a significant affect on supply in the short run. Moreover, expanding such capacity faces the problem that the growth of the software industry has tended to siphon off engineering masters and PhD students. A recent report on graduate engineering education in India noted that the number of engineering PhDs produced has fallen from 675 in 1987 to 375 in 1995. Concurrently, the number of engineers with postgraduate training has also risen only slowly, from a little over 12,000 in 1987-89 to a little over 17,000 in 1990-92. Surveys of India's premier technological institutions-the Indian Institutes of Technology (IITs) show that a very large fraction of postgraduates from those institutions enter the Information Technology (IT) sector, in some cases as many as 90%!

Moreover, Table 6 below shows that the bulk of the Indian engineering capacity is located in just a few states – Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. Further, the table also shows that the bulk of the capacity here is accounted for by "self financed" colleges, where students receive a much smaller subsidy, if at all, compared with the state financed colleges. An interesting and hitherto unexplored question is the reason that the organizational innovation of self-financing colleges has not diffused to other parts of the country. We can only speculate that this has to do partly with cultural and political factors, and partly with the lower returns to investments in human capital in other parts of the country. Not coincidentally, the south and west are also economically more advanced.

{Table 6 here}

We believe that although investments in engineering education are necessary, a bigger part of the solution lies in a more efficient use of existing human capital resources. Implicit in the discussion thus far is that only engineering graduates are well suited to perform the tasks required. This assumption appears to have shaky foundations. First, the bulk of the engineers working in the industry are not, in fact, 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 a great of the work involved porting applications from one computing platform, typically a mainframe, to another platform such as a Unix platform. This work requires familiarity with software development tools. It does not require a deep knowledge of computer architecture or operating systems.[16] Finally, much of the work has tended 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 they surveyed 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 require engineers: Bright graduates from any field could, with proper training, do what was needed. It seems that the preference for engineers is in some cases a way of signalling quality 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*." (Emphases added.)

(from Sloan Report, Arora et al 1999)

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

Firms also have quality concerns. Some managers we interviewed believe that an engineering education imparts a set of problem solving skills, methods of thinking logically and learning tools that help 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 has to do the quality signalling in the labour market. The Indian education system is such that competition for an engineering education is intense, and as a result, graduating with an engineering degree is a signal of qualities such as intelligence and willingness to work hard. Software firms may prize these qualities more than the specific substantive knowledge of engineering.

If so, this is certainly an inefficient allocation of resources.[17] Indeed, the software industry has been growing in part by drawing away engineers from other industries. In our interviews we came across a number of instances of engineers with highly specialised training (such as VLSI design or satellite systems) working on tasks such as database design or development of business application software. Quite a few senior level engineers were drawn

[16] There is a significant exception – telecommunication related software where telecommunication engineers are required. Similarly, companies such as Texas Instruments, Oracle and Microsoft are locating development and R&D centers to tap into the engineering talent.

[17] A more rational allocation would have firms substituting intelligent and hardworking non-engineers trained in the use of software development tools for engineers where possible. Engineers would be used where their substantive knowledge or design ability was of value.

from a variety of public sector research and development institutions. Such a transfer of resources is entirely in line with the presumed comparative advantage in software development. Of course, there are a variety of distortions in the Indian economy, which imply caution in interpreting the market signals.[18] 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. As we discuss in greater detail in section 6, the increasing demand for trained engineers and managers is also affecting the balance between capital and labour (or more precisely, between capital and human capital), resulting in organisational innovations.

The clearly increasing payoffs to human capital are also inducing greater investment in human capital. The Indian middle class has always relied upon education, particularly professional education such as engineering or medicine as means of economic advance. However, with a slowly growing economy, the returns to such investments have not been very high. The precarious state of public finances has limited the ability of the central and state governments to expand tertiary education. The rapid growth of the software sector has however, marked a watershed. One of the most rapidly growing sectors within the software industry is for private training.

Private training institutions train individuals specifically for work in software development. NASSCOM sources estimated that there were 3800 such training firms in 1998, in what was then a $300 million market, although together NIIT and Aptech are believed to have 70% of the software training market.[19] Private training institutes are also important for helping existing software developers acquire new skills. Many engineers also undertake further training in software

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[18] There might be long run consequences as well, hurting the indigenous technology development capability. This is similar to the trend, noted earlier, of engineering graduates deserting other fields for the IT sector, and even more, of preferring software jobs to pursuing post graduate education.

development on their own from private training institutes. The growing presence of private training institutes in cities in India is increasingly making it possible for software developers to obtain certificates and diplomas from such institutes.

It is also noteworthy that this is a private sector response to a market opportunity, namely the demand for training in specialised skills. In the US and elsewhere, for profit firms compete with a variety of public institutions, such as state and community colleges in the US. In India, the rapid growth 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, too, owes at least indirectly to the rapid growth of the software industry.

{Table 7 here}

To sum up the foregoing, we believe the evidence indicates that until recently, an excess supply of trained engineering talent was a significant source of competitive advantage for Indian firms. By the same token, it provided few incentives for firms to economise on the use of skilled engineering talent. Instead, the growth of the industry and high salaries have attracted not only newly graduating engineers but also engineers, managers and other professionals from other industrial sectors.

Despite this, the explosive growth in the software industry has lead to a stage where firms recognise that skilled engineers, software professionals and good managers are a scarce resource. Moreover, faced with a number of attractive options including a move overseas, these talented engineers and managers are looking for more money and a more professional and rewarding work environment. In turn, this entails a variety of organisational changes we discuss below.

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[19] 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

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

Software growth has helped some related service industries in India. The most notable instance is the rapid growth of the informal IT sector studied by Kumar (2000a and 2000b). Services such as the provision of IT maintenance services to firms, data entry and customisation services for domestic users, which were virtually non-existent about a decade ago, are gaining in prominence. Kumar (2000a) estimates that software and these ancillary industries probably accounted for about half a million jobs in 1998/99, a figure that is likely to have increased substantially since. According to a recent survey done by NASSCOM (the National Association of Software and Service Companies), IT-enabled services in India have shown the highest growth (66%) over the previous year among all the industry segments and are expected to gross a revenue of $ 880 million in 2000-01, as against $ 530 million in the previous year.

The basic business model that underlies the growth of these services is similar to that of software, namely outsourcing by large firms of part of their operations to takes advantage of the availability of a large English speaking population at relatively low wages. Poor infrastructure investment in telecommunications constitutes the same impediment to the development of these services as it does to the growth of software services. The two most promising segments this year are customer interaction services including call centers and content development and animation. Table 8 shows the projections obtained by a NASSCOM survey that has forecast opportunities for IT-enabled services from India.[20].

{Table 8 here}

Star, Datapro and IBM Learning Services.

[20] 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

On the whole, however, there are relatively few linkages that software has with other sectors of the economy. However, the software industry is fast emerging as an exemplar of both good organisational practices and technocratic entrepreneurship in India. In this section we suggest why this is so, and look at the mechanisms by which such progressive practices may spread to other sectors of the economy.

While Indian software professionals earn only a fraction of the salary of their international counterparts, he or she earns an income that is about twenty times the national average. The existence of this difference in international wages makes software firms in India vulnerable to losses of some middle level employees to software firms in the West, and puts a continuous pressure on profitability.

The vulnerability to employee attrition and rising wages have created different problems for the software sector. Rising wage rates have made many firm actively seek stock options to supplement wages. Till recently overvalued technology stocks allowed software firms to supplement wages of employees and create incentives for loyalty by offering employees stock option plans (ESOP). Firms that were privately held such as TCS competed in the same way for talented people by offering bonuses (to selected employees) calculated using a notional stock price or the company based on its economic value added. Kumar (2000b) estimates that as many as 41 Indian software firms were known to have offered ESOPs in addition to pay in 1998-99. More recently some Indian firms such as Infosys and Silverline have started offering ADR linked ESOP to their employees as part of a larger retention strategy.

While rising wages eat directly into profitability, attrition creates a different kind of threat - the loss of employee specific knowledge, the possibility that this knowledge has been lost to its

diagnosis of physicians located in the U.S., Indian firms rely on software developers trained to understand English spoken with an American accent and who have the ability to type in English.

competitors, and sometimes a loss of credibility with the client. Interviews with US based clients of Indian software firms also indicated that many of them saw employee attrition as an important problem (Arora et al, 2000). Several clients commented on the delays due to entire project teams leaving in the midst of the project in response to a more lucrative offer. In addition, when attrition is at senior levels then it is also likely that a firm loses some of its customer base to a new competitor.[21]

However, both of these problems- attrition and wage increases have prompted software firms to explicitly introduce human capital management strategies comparable to their international rivals. These include:

- an increasing role for private investment by software firms in software education and training for their employees. Leading companies like TCS and Infosys spend between 4-6% of their revenues on training. It is estimated that that the industry as a whole spent 7609 man-days on training per organisation or 5.5 man-days of average training per person per organisation.[22]
- organisational practices designed to retain the interest and loyalty of employees, attention towards charting a management career path for technical personnel in firms – perhaps the first signs of a technocracy
- Organisational innovations designed to diffuse and recombine employee specific knowledge in a variety of different ways, most notably through flat hierarchies, team working and the use of embodied forms of software knowledge such as tools or where possible through the use of licenses and IPRs.

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

[22] Estimates from Dataquest, 15 July 2000: 250.

The adoption of ESOPs and the charting of career paths in management for technically qualified professionals by leading software firms have also had at least one unintended outcome. Technically qualified persons now view entrepreneurship itself quite differently. It is a logical extension of the managerial tasks that they would in any case hope to do with the growth in their careers, with an added element of risk that nevertheless promises large rewards. Thus, ex-employees of HCL and Wipro have been active entrepreneurs. Thus, TechSpan, NIIT, Pertech computers, Global Infotech, InfoTech enterprises, STG and Infogain were all set up by ex-Wipro employees. Similarly, product based ventures such 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 alive to these concerns. Satyam has sought to avoid such 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 entrepreneurship is also relatively easy because of the low capital requirements and the large venture capital interest in India. Apart from the 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 commercialise technology and this in turn results in a transfer of knowledge from universities to more applied realms in industrial manufacture.

That some of this change is already visible in the mushrooming growth of the IT related services sector has been demonstrated by Kumar (2000a). This sector shows the evidence of rewards to education in entrepreneurship and the surprising growth of entrepreneurship amongst all sections of the population.

With the growth 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 margin of substitution employers will actively looking toward. As software firms seek to build domain expertise and move up the value chain there has been an increase in the demand for marketing persons' preferably with some experience of the US market. Indeed salaries for marketing executives in software rose by 25% in the last year.[23] In turn this creates pressure on employers in other service industries (banking & finance, hotels, retail trading) to offer similar rewards (ESOPs, employee friendly policies) in their sectors or face attrition to the software sector. Thus, last year the employment of managers (as opposed to technically qualified persons) in the software sector grew by an incredible 30%. At the same time, firms in the banking and insurance sectors (including in some cases public sector firms) of the economy announced their decisions to offer ESOP packages to their employees.

Even without such luring away of personnel to the software sector, the service sector of the economy is one where 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 utilised. The physical capital requirements of such industries are minimal. Good employees command customer loyalty and in turn can leave the company to found one of their own if they perceive themselves undervalued. A valuable employee can create the same pressure as able software programmers can exert on their employers. Where services have to be delivered globally the software model can be replicated almost identically. Thus, call centres, data entry and data transcription services operate the same kind of generic business model as do software service firms. Where markets are national too similar elements apply, given the vastness of the Indian domestic market.

One might ask with some scepticism what scope there is for the same qualitative changes taking place in the older economy manufacturing sectors (e.g. steel automobiles, textiles, cement etc.), where big business houses still dominate production and employment and there is not the same upward pressure on wages. The surprising evidence here is that older business houses are rushing to accommodate some these changes in organisational style and employee participation. The mechanism through which this diffusion of organisational practices is taking place is however different from that in the services and IT related service sectors. An increasingly large number of the big business houses (Tatas, Dalmias, Birlas, Mahindras, ITC, Wipro) invested in IT arms in the early 90s, given the high profitability of the software services business at that time and its relatively low capital needs. Often these units enjoyed considerable autonomy to evolve their own management styles, rewards and compensation to employees. The methods and practices they evolved were in keeping with the competition in the industry, but often at variance with the established norm in the business houses of which they were part. The struggle it took for the new and better practices to emerge in the old business house arms is by itself an interesting and absorbing story, which we cannot narrate here.[24] However, once these new norms were

[23] *"A hard drive on the software front"* Hindu Business line, Jan 01, 2001.

[24] As examples we quote the following recent events: the struggle in DSQ started by external investors for professional management to have effective control,; the recent attrition among the executive staff at Wipro in response to the slow dilution of the firms equity share holding 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.

established in one arm of the business house it was rather difficult to inure other parts of the business from following the same for reasons of parity.

External borrowing has also played a big role in this process. One of the surprising results of liberalisation of foreign capital inflows in India is that what flowed into the economy was not large amounts of foreign investment as the policy makers intended, but a huge accumulation of foreign debt due to corporate borrowing. As Indian firms have tapped foreign equity markets for their finance requirements so the norms of such markets are being closely adhered to, in particular the norms of good corporate governance. Thus, despite their relatively low investment requirements software firms listed with some success on US stock exchanges – Infosys (Nasdaq), Satyam Infoway (Nasdaq), Silverline Technologies (NYSE) and Wipro, and pioneered this route to raising external finance for Indian firms. This required use of US system of financial reporting (GAAP), quarterly reports and close attention to the investor community and their representatives, the equity analysts, which the firms were anxious to follow as they needed to signal their quality to potential customers. In the next two years, another 15 Indian firms will be added to the NYSE: reports indicate that most these are not from the software sector, but from investment heavy sectors such as pharmaceuticals and telecommunications, yet following the same norms and transparency of procedures.

In sum, the diffusion of good management practices from the software sector to other sectors of the economy has come through two channels. The human capital intensive service sectors provide scarce middle level management to the software sector and here the same pressures that have acted upon the software sector will in time ensure that better management practices are adopted. Though the 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 the old business houses are not inured against such the adoption of such practices. This trend has been reinforced by the financial liberalisation of the economy and its opening up to external finance.

7. Conclusions and some policy implications

In this paper, we have argued that the rapid growth of software exports from India should be seen as a consequence of her comparative advantage in the production of such services rather than a result of an absolute advantage in terms of wage differentials alone. This comparative advantage, in turn hinges on the availability of a large workforce that is English speaking and technically trained, and in the relative disadvantage that the economy has in manufacturing due to poor infrastructure investments in the past. Indeed the larger the size of this disadvantage the more it will pay the country to specialise in software. The transfer of resources from poorer productivity to higher productivity sectors will also spur a growth process: the last decade has also seen higher rates of income growth of the South and West of the country where the software industry is concentrated.

These factors favouring software exports from India are further reinforced by the low domestic demand for the same types of products and services. Though there are gains from specialisation, the distribution of gains from such specialisation 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, and there are signs that firms are trying hard to do so.

The undifferentiated and service nature of Indian software firms has meant that human capital has acquired an importance that was hitherto reserved for financial and physical capital in

Indian industry. In an extremely competitive international market for software services, Indian firms have tried to emphasise the quality of procedures and human resource used by them to gain competitive advantage. This microeconomic response has had both good and bad consequences.

The good consequences stem from the appreciation of the rewards to training in an environment where trained software programmers are scarce and getting scarcer. This in turn has resulted in substantial private investment in the provision and acquisition of tertiary training. The bad consequences stem from the slow bidding up of prices for the most superior of the technically trained workers- viz. engineers. Engineers who for years had to acquire other qualifications to increase the value of their engineering degrees and be accommodated in the better paying management cadre find themselves in the enviable position of being able to command large salaries for doing tasks for which their training is rather irrelevant.

The government's response to this crisis in engineering education has been to focus resources on the same areas of tertiary education as has private investment- viz. engineering colleges and institutes for information technology. Our analysis suggests that the economy as a whole can realise even greater benefits from private investments in providing and acquiring training, by undertaking the complementary public investments, such as those in basic and secondary education and in the economy's physical infrastructure, that have constrained the growth of the software industry in the first place. The current excess demand for engineers will in time be substituted by a more rational and economical strategy, viz. training science graduates for software programming.

The bidding up of prices for engineers and technically trained labour and the excess demand for them in the international market has also made software firms adopt organisational practices that are comparable to their best competitors in the US and elsewhere. This has included charting career paths for technical personnel and rewards that share both profits and risks. Increasingly, firms are being forced to provide a more congenial and satisfying work environment for their engineers and managers. We have argued that some of these measures are spilling over to other service sectors – where again human capital is more important than physical capital and from where the software sector may draw scarce middle level management. In turn, this has forced the various business houses, which have controlled large parts of the economy to run their businesses in a more professional and transparent manner. These changes are likely to be slow, but there are other institutional forces that favour these changes, most notably the increasing breadth and depth of the equity markets, and the increased competition from imports and from multinationals.

However, greater specialisation in software production and exports in the domestic economy (with or without differentiation of the industry) are constrained by precisely those factors that probably account for India's relative disadvantage in manufacturing, viz. poor and inadequate investment in physical infrastructure, communications and basic education. Thus, while software development offered a window of opportunity provided by a large stock of underemployed engineers, it is a narrow window of opportunity. Furthermore, software has not played the traditional role of a 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 the its is precisely these two facts- the (technical) labour-intensive nature of the industry, in an environment of global excess demand for such labour - which have altered the attitudes towards human capital formation at the level of the firm and in the national economy. In the final analysis it is in terms of this slow change in attitudes towards education, entrepreneurship, and the value of human capital in the economy that the software industry has made its greatest contribution to India's economic development.

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IMF: International Financial Statistics, various volumes.

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	1085	670
1997/98	1750	950
1998/99	2650	-

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

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

	Switzerland	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: Stock of technically trained personnel, selected countries, 1995

Country	Adult illiteracy rates (%)		Scientists & Engineers in R&D	Population, Millions	Stock of scientists and engineers
	Males	*Females*	*1981-95*	*1995*	*1995*
USA	-	-	3732	263	981516
Japan	-	-	5677	125	709625
Russian Fed.	-	-	4358	148	644984
China	10	27	537	1200	644400
Germany	-	-	3016	82	247312
France	-	-	2537	58	147146
UK	-	-	2417	59	142603
India	35	62	151	929	140279
Israel	-	-	4826	6	28956
Vietnam	4	9	334	73	24382
Turkey	8	28	209	61	12749
Hungary	-	-	1157	10	11570
Greece	-	-	774	10	7740
Ireland	-	-	1871	4	7484

Source: World Development Report, 1997 and 1999

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

Country	All manufacturing		Software	Comparative advantage	
($ '000)	*Output per employee (1)*	*Value Added per employee (2)*	*Revenue per employee (3)*	*Index 1 (3)/(1)*	*Index 2 (3)/(2)*
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

Source: Authors' computations from the following data sources:

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

(b) Data in column (3) are derived from the following national and international sources
Data on India are 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 for 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).

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

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

Year	Manpower	Rev/Employee ($)
1993-94	90000	6198.5
1994-95	118000	6998
1995-96	140000	8924.5
1996-97	160000	11036
1997-98	180000	15000
1998-99	250000	15600

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

Table 6: Number and Capacity of Engineering Colleges in India {approved up to 1998-99, by region}

Region	Number of Colleges	Sanctioned Capacity (# of students)	% of sanctioned capacity that is self- financed colleges
Central	50	9470	0.52
East	25	4812	0.26
North (incl. North-West)	140	25449	0.42
West	140	34165	0.74
South (incl. South –West	308	82597	0.79
Total	663	156493	0.69

Source: Ramarao (1998).

Table 7: Growth of the Information Technology Training Sector in India

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

Source: INFAC, Mumbai

Table 8: Current and Projected Demand for Software developers in IT-enabled Services in India

IT-enabled services	1998		2008 (Projections)	
	Employed	Rs. Millions	Can be employed	Rs. Millions
Back Office operations/ Revenue accounting/data-entry conversion	9,700	4200	2,60,000	190,000
Remote maintenance and support	1,600	650	1,80,000	135,000
Medical Transcription/Insurance claim processing	3,800	1400	1,60,000	110,000
Call Centers	1,400	400	1,00,000	60,000
Database services	1,000	450	1,00,000	65,000
Content development	5,500	2700	3,00,000	250,000
Total	23,000	9800	11,00,000	810,000

Source: The Software Industry in India: A Strategic Review 1999-NASSCOM.