Supply and Demand for Software Developers in India

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Abstract

India's success and worldwide reputation in software development and services has naturally led to questions about the fundamental factors influencing this success. In this paper, we focus on one very critical factor – human capital. We analyze the aspects related to the supply and demand for skilled human capital-software developers to the Indian software development industry. We then look at two empirical studies to understand the ground realities of the challenges facing the industry vis-à-vis the acquisition and retention of skilled human capital as it exists right now and prospects for the future. Our general finding is that a situation of excess demand currently exists for skilled software development professionals. The large loss of experienced professionals due to relocation to the U.S. under the H-1 B visa program has exacerbated the problem. We find that although there are some interesting differences in the types of skills used by the two major categories of software professionals: engineers and non-engineers with a certificate from private training institutes, these differences are not very large at the outset of their job experiences. This indicates that unobserved differences in the *perceived* abilities of the individuals rather than educational experience or training could play a primary role in the skill sets acquired by experienced software professionals. However, the differences in skills sets acquired with experience do not indicate many critical differences in the software development capabilities of professionals from these two categories other than a specialization of skill sets acquired. Given the slow pace at which engineering education capacity can be expanded, we recommend expanding the potential pool of recruits beyond its current reliance on engineers and computer science graduates to include graduates with training from private institutes in order to sustain the growth rate of the industry.

1. Introduction

The rapid growth of the Indian software industry owes much to lowered barriers to the international movement of capital, goods and services. Indeed, the Indian software got its start because of the excess demand for software programmers in the U.S. – many Indian software exporters began by supplying programmers to U.S. firms. Since then the business models have evolved but the essential source of competitive advantage for the Indian software industry remains its access to a large source of low cost software developers (Arora et al 2000).

Despite the large pool of talent available in India, there are concerns that the rapid growth of demand worldwide and in India itself in particular, will soon lead to a situation of excess demand. Responding to the demands of the information technology industry in the U.S., the passage of the U.S. Workplace Competitiveness Act of 1998 permitted an increase in the supply of skilled software developers to the U.S. economy for a limited period. A large proportion of this supply is skilled software developers from India. In India, government policy looking to encourage the continuing spectacular growth of the industry perceived that future shortfall in the supply of skilled labor was a serious threat.

Recognizing the importance of this fact many Indian policy makers have called for declaring a state of "Educational emergency[1]" 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.

[1] 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

Larger firms are concerned mainly with a mismatch in the skills of software developers available, especially for experienced software developers.

Concerns about an impending shortage are not new. For instance, in a study of the Indian software industry published in 1994, Lakha (1994: 394-396) notes that although India had 2.5 million scientists and engineers, with 160,000 new ones produced each year, and despite the many new computer courses introduced by the government in various institutes, "personnel requirements are exceeding the current supply, making it more difficult to attain the government's software export target." (p 394). Similar concerns about an actual or impending shortage have been voiced by a number of others, such as Barr and Tessler (1996).

The basic issue is that the software industry in India has relied heavily upon a large pool of engineers. However, the growth of the industry and the relatively inelastic supply of engineering graduates are rapidly exhausting the available pool of engineers. Therefore, whether the Indian software industry can maintain a high rate of growth in the future depends critically upon whether it can substitute bright, English speaking graduates without engineering degrees to make up for the shortfall (relative to growing demand) in the supply of engineering graduates. The bulk of these new recruits will be trained in software development and related skills by private training institutes. The ability to sustain growth also depends on how Indian firms mature and acquire domain expertise that can offset the diminished labor cost advantage. However, to do so they must deal with the steady drain of experienced and talented software developers to the U.S. and other countries.

In this paper, we focus on the overall demand supply situation facing the Indian software industry. Section 1 discusses how important the labor cost advantage is for Indian software exporters. Sections 2 & 3 discuss respectively the sources of supply and demand, concluding with a rough estimate of the projected excess demand if current hiring patterns hold. Section 4 describes an analysis of a sample of newspaper advertisements for software developers, substantiating the strong bias in favor of engineers. Section 5 draws on the analysis of a questionnaire survey administered to 61 software developers to address the differences in the on-the-job skills used by engineers and non-engineers, and how these differences evolve over time. Section 6 summarizes our findings and concludes.

1. The importance of Human Capital for the Software Development Industry[2]

The key to the success of Indian software development firms is the supply of trained, low cost software developers. Estimated wage costs for software developers in India are about 1/3rd to 1/5th the corresponding U.S. levels for comparable work (INFAC: Indian Software Market Status Report, 1998). Other estimates suggest that the difference is smaller, and that once all costs are factored in, the human capital costs of software development are around ½ of U.S. levels. A variant on the labor cost argument is the large pool of suitable workers.

In a companion study, we interviewed U.S. firms that had outsourced software development to India (Arora et al 2000). The most frequently cited reasons for

[2] This section draws heavily upon Arora et al. (2000).

outsourcing have to do with the shortage of software developers in the U.S. - Firms claim that they simply cannot find enough software developers fast enough. In some cases, U.S. firms outsource to Indian firms to get access to more specialized engineering talent, particularly in the area of telecommunications. Other reasons include the option of round the clock operations and the ability of Indian vendors to assemble "functional" teams of engineers at a very short notice.

Most of the U.S. managers we interviewed commented on the excellent programming and coding skills available in India. They also noted that their Indian vendors were good and willing learners, receptive to new ideas, and flexible in terms of the software and hardware platforms for which they provide services. Many of the respondents downplayed the cost difference, insisting that cost was a relatively minor consideration. This appears to be a response to the prevailing concern in the U.S. about the possible harm to U.S. engineers from software outsourcing and inflow of foreign software developers. The apparent lack of concern with cost is inconsistent with the extensive price competition that prevails in the Indian software industry, and with the actual behavior of some of the firms that outsource to India.[3]

In recent years, a new category of software services, called IT-enabled services, has shown strong growth. This category includes customer interaction services including call centers and help desks, data entry, medical transcription, travel reservations, content development and animation and financial transactions for banks and other financial

[3] For instance, one of the telecom firm we interviewed had, in addition to a couple of prominent Indian firms, a firm largely in the business of “bodyshopping” among its list of preferred vendors. Our interview suggested that this was a way of promoting competition and keeping prices down. This firm’s policy was to ensure that its business accounted for a substantial (but less than 50%) share of the vendor’s revenues and that no single vendor had more than 25% of its business. These policies ensured that it had considerable bargaining power in the pricing negotiations with its Indian vendors.

institutions. Table 4 (Appendix 1) shows the projections obtained by a NASSCOM survey that has forecast opportunities for IT-enabled services from India. Currently around 23,000 software developers are employed in this category, which is anticipated to show phenomenal growth[4] in the next decade. If this anticipated growth occurs, it would put further pressure on the ability of software development firms to meet their staffing needs, although some portion of this demand would draw on a different pool of software developers whose primary skills are related to the use of software rather than software development[5].

Despite the apparently large stock of human capital in India, the National Association for Software and Service Companies (NASSCOM 1999) claims that by the year 2000 demand will outstrip supply. The NASSCOM study projects an annual demand of about 75,000 by the year 2000. In fact, our research leads U.S. to conjecture that, within segments of skills and experience in software development firms, demand already far exceeds supply. The growth of the software development industry in India is being severely constrained due to the shortage in supply of skilled software developers with

[4] 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 (Rs 4000 crores) in 2000-01, as against $ 530 million (Rs 2,400 crore) in the previous year. The two most promising segments this year are customer interaction services including call centers and content development and animation. The survey indicates that customer interaction services are expected to generate $ 160 million (Rs 750 crores) in this year, compared to $90 million (Rs 400 crore) during the last year. Revenues from content development and animation are expected to almost double from $ 180 million (Rs 820 crore) in 1999-00 to $ 355 million (Rs 1,600 crore) in 2000-01. The survey indicates that the following cities: Gurgaon, Mumbai, Hyderabad, Bangalore, Chennai, Pune, Ahmedabad and Thiruvananthapuram are emerging as major hubs of IT-enabled services.

[5] 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 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.

experience, caused largely due to the loss (immigration) of experienced software developers with 4-6 years of work experience to the U.S through the H-1B visa route[6].

In an earlier study (Arora et al 2000), we surveyed over a 100 software firms on various attributes of managing software development firms in India. When asked in 1998-99 to list the top 3 problems they faced, more than half of all 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.

Overall, software export firms appear to view both manpower shortage and employee attrition as a more serious problem as compared to firms primarily catering to the domestic industry. Probably, this is because it is software export firms that have shown phenomenal growth in the last decade. The Indian software development industry currently revolves around export with very few firms solely focused on domestic business. Table 1 shows the number of firms who indicated the seriousness of problems facing them. Manpower shortage/skilled manpower shortage was considered a more serious problem than the availability of physical or commercial infrastructure, a reflection of the criticality of manpower for the software development industry.

[6] Around 30,000 software developers, most of whom are believed to be software developers are believed to have availed of H1-B visas in 1999- Interview of Mr. Clyde Jones-Chief of Consular Services, U.S Consulate India and reported in The Economic Times, Hyderabad edition Wednesday 30th June 1999. In line with what we mention later in the report about the distribution of engineering colleges being heavily loaded towards states in South India, Chennai, (the only state in the south that has a U.S Consulate) reported a H1-B issuance of around 20,000 such visas out of the 30,000 that were issued this year from the three U.S Consulates (Mumbai, Chennai and Calcutta) and the U.S Embassy (New Delhi). The quota of 115,000 visas approved for this year (September 98-September 1999) by the U.S Workplace and Competitiveness Act 1998 was filled by May 1999.

Table 1: Major problems for Indian software firms

Problem	Export firms	Domestic firms
Manpower shortage/skills	57	32
Employee attrition	44	27
Physical Infrastructure	12	12
Commercial infrastructure	24	17
Quality certification	11	6
Visas	33	NA
Finance/ Capital	20	14
Marketing access	42	17
Lack of domestic computerization	6	21
Lack of government support	10	11
Tariffs and other barriers	11	8

Note: The firms were asked to indicate their top three problems.

Source: CMUSoft Dataset -- CMU Survey of Indian Software Industry. N = 104

A strong preference for hiring engineers is a key to the potential excess demand for labor. Although India graduates over 155,000 engineers a year, there is high demand for software engineers (or engineers potentially trainable as software engineers), and wages have been rising at about 20% per annum (NASSCOM 1999). Despite paying substantially above Indian standards, virtually all firms find it difficult to attract and retain talented software developers.

Most software development firms recruit either engineers[7] or students with degrees in mathematics or science. Many also have in-house testing and training

[7] Bachelor/Master of Engineering (B.E/M.E), Bachelor/Master of Technology (B.Tech. /M.Tech.) or Master of Computer Applications (MCA).

programs. All of the firms we interviewed claimed to recruit engineers alone, or engineers and students with a first degree in mathematics or science.

A potentially serious constraint on the ability to rapidly increase the output of trained software and computer engineers is the shortage of engineering doctorates being awarded in India. Recent data show that the PhDs awarded in engineering disciplines have fallen from their high of 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%! Although there are a substantial number of engineering doctorate holders of Indian origin working in universities and research institutes outside India who can be called on, a long run solution will require an increase in the postgraduate research and training infrastructure.

There are number of public sector and industry initiatives to address this perceived shortage of software developers. The government has recently announced the establishment of Indian Institutes of Information Technology, along the lines of the well-known Indian Institutes of Technology. A number of private sector for-profit, training institutes are also coming on line. Examples of this are institutes set up by Silverline, and Mahindra-BT, a joint venture between the Mahindra Group and British Telecom. The latter is an ambitious effort, where the objective is to teach methodologies and techniques for software development. The partners include the Software Engineering Institute, and Carnegie Mellon University.

Firms are responding to the problem of employee attrition in a number of ways. One popular way is by providing opportunities for career growth for their employees. Some firms stress their ability to provide a career path for their employees, wherein they could move to being managers and would not have to remain programmers, apparently something valued by Indian software developers. Interestingly enough, few claimed to pay more than their competitors to attract and retain workers. A number of firms were actively considering stock options for their employees. Some of the firms expressed the need to make the organization individual-independent by addressing the loss of knowledge due to employee turnover. The loss of employees is especially severe among consultants (programmers and analysts) sent overseas to work onsite in the U.S., and our interviewees assert that a very substantial fraction quit within two or three years.

Firms do hire workers who have graduated from private training institutes (PTI's) but without an engineering degree. There however seems to be a perception among the software industry about the quality of graduates from private training institutes and the potential negative signals this could send to firms contracting work with them. Despite the apparent unwillingness of software development firms to hire them, there are a large number of students trained by private, for-profit, training institutes such as the National Institute for Information Technology Ltd. (NIIT) and Aptech Ltd., resulting in high profits and growth for these firms. The (software development) training industry has grown sharply along with the software industry, with total revenues in 1997-98 estimated at around $300 million, up from $150 million the year before. Although nearly 90% of

revenues are from the individual training sector, corporate training is also growing rapidly.[8]

Many of the students trained by private training institutes are apparently employed in the IT departments and divisions of Indian industry, such as in banking & financial institutions, and in IT enabled services such as back office operations, Revenue accounting, data-entry conversion, remote maintenance and support, medical transcription, insurance claim processing, call centers, database services, and content development and as educators in training institutes.

We also found evidence that some large and reputable firms had tie-ups for professional practice with graduates from private training institutes and frequently ended up recruiting these graduates. The increase in certification courses offered by institutions such as the Microsoft Certified Software Engineer/Developer (MCSE/D), Certified Novell Engineer (CNE), IBM Net Professional certification has also attracted a number of engineers interested in a software development career.

2. Supply

The Indian Software development industry has in the last two decades of its growth focused primarily on the supply of software services to foreign countries[9]. A large chunk of all exports is to the U.S and Europe where English is the language of choice. Thus, one of the important factors affecting supply of skilled software developers to

[8] Many multinationals have started authorized training centers (ATC) that provide their own certified courses. These include IBM Global services, Oracle, Microsoft, Adobe, Cadence, Lotus, and Sony.

[9] One estimate suggests that India has 16% of the global market in customised software, and that more than 100 of the Fortune 500 had outsourced to India (Dataquest, 31 July, 96; pp 43-44).

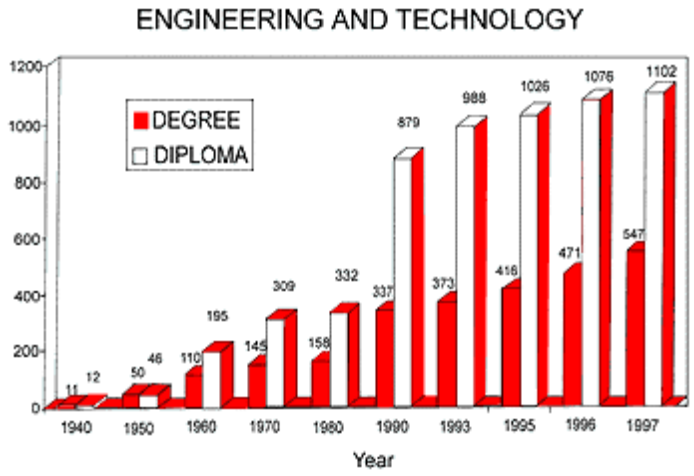
software development firms in any country has been the availability of English-speaking software developers. India currently has the largest English speaking scientific labor population in the world.[1] In particular, the supply of engineering software developers from what is characterized as the formal system of education in India has played a vital role in the development and growth of the industry. However, as discussed later in this paper, a number of software developers with non-engineering backgrounds also enter software development firms after being trained and certified by private training institutions.

2.1. Supply of engineering graduates

The supply of graduates in the engineering fields is governed by policies made by the All India Council for Technical Education (AICTE). [10] Figures 1 and 2 show the growth in the number of engineering colleges and student enrollment over the last fifty years. The number of AICTE approved technical degree institutions in the 1990's has grown at an average annual rate of 9 % with a jump of around 16% from 1996 to 1997 and 21% from 1997 to 1998.

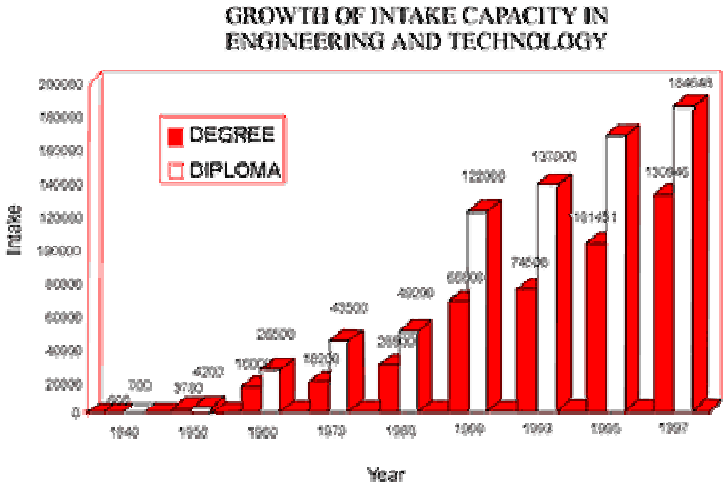
[10] The AICTE Act, 1987 provides for the establishment of an All India Council for Technical Education (AICTE) to plan and coordinate the development of the technical education system in the country, and maintain norms and standards for technical education. One important bureau in the council called the Bureau of Engineering and Technology concerns itself with the accreditation of new programs, approval of new institutions, sanction of new courses, and sanction of additional intake of the University Grants programs, post-graduate programs, and MCA/MBA programs.

Figure 1: Growth in Number of Engineering (degree and diploma) institutions in India



Source: AICTE web site: http://www.aicte.com/approved_inst.html

Figure 2: Growth in Student Intake for Engineering (degree and diploma) institutions in India, 1940-1997



Source: AICTE web site: http://www.aicte.com/approved_inst.html

The growth in student enrollment in AICTE approved degree institutions in the 1990's has grown at an average rate of 11.5% per annum with a growth of 29% from 1996-1997 and 19% from 1997-1998. Table 2 (Appendix 1) shows the breakup by state,

of the number of institutions and student intake into diploma and degree programs in engineering as well as into the MBA (Master of Business Administration), MCA (Master of Computer Applications) degree programs, and other post-graduate courses in 1998. Engineering institutes from southern and southwestern India account for over half of the engineering graduates (82,000 of 156,000 graduates).

One can also derive a rough estimate of the number of graduates in engineering and technology available to join the Indian industry in 1998. From a total intake of 156000 individuals, we assume a drop-out rate of 5% i.e., 7800 individuals, a loss after graduation to other technical post graduate programs of around 20,000 graduates, another loss to MBA or MCA programs of about 25,000 (which is about 40% of the intake into these programs). This leaves a balance of approximately 104,000 engineering graduates available for employment in all sectors of the economy, including the Information Technology (IT) industry. In addition, we have around 10,000 post-graduates with MCA degrees most of whom join the IT industry, along with some fraction of the 52,000 MBA graduates and 20,000 graduates with other post-graduate degrees.

In addition to the annual flow, the software industry has also drawn from the stock of engineers and technologists. The recession in other sectors of Indian industry in the 1990s has led to a substantial number of these graduates and post-graduates joining software development firms. However, we do not have any way of estimating the number of engineers and managers that have made such a move.

2.2. Supply of software developers from private training institutions

Private training institutions train individuals specifically for work in software development (NASSCOM 1999). For instance NIIT, one of the largest such training institutions has around 10,000 students (in 1999) in its GNIIT (Graduate NIIT[11]) program, a three year program for software developers including 1 year of internship (professional practice) with a software development firm. Similarly Aptech which claims to be the world's largest software training organization in terms of number of students (it has 1200+ franchisees and a presence in 40 countries including the U.S, Europe and Australia) has an arm, Asset International, that specializes in training software development software developers. Asset International, the high-end training arm of Aptech currently trains both software developers with work experience and recent graduates in certification course such as Microsoft Certified Systems Engineers (MCSE)[12] and Microsoft Certified Systems Developer (MCSD), Certified Novell professional (CNP), Oracle and IBM net commerce software developers. In 1999 around 30% of the 7,200 software developers Asset International trained were engineering graduates. They

[11] A play on words because according to current Indian laws, private training institutes are not allowed to award degrees.

[12] Last year around 50,000 software developers obtained the MCSE's certification in the world, of which around 35-40,000 were certified from India (Interview with the Regional Manager, Asset International). Certification for most of the software development firms such as Microsoft, Oracle and Lotus is conducted by Sylvan Prometric, an Australian firm that makes available online the tests required for certification for a certain fee. The results are collected and transmitted to the various development firms such as IBM, Oracle for evaluation. Since the cost of obtaining training and certification is quite expensive in the U.S, Indian software developers often travel to India to renew their certification. These certifications are globally valid and apart from giving a pass/fail status also give the marks obtained in the test as an indication of the aptitude of the student. This certification is typically restricted a specific version of the software on which the student is tested. Whenever a newer version of the product is released the development firm usually gives a period of 6 months within which the professional needs to upgrade his skills and obtain a re-certification of his skills in that software by undergoing another certification exam. Thus, for example, the initial Oracle certification involves being tested in 5 modules or 5 independent tests and the re-certification involves giving an additional skills upgrade test.

expect to train an additional 5000 students annually in their recently introduced (in 1999) course in e-commerce.

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.[13] The general perception in the industry (NASSCOM, 1999; Arora et al, 2000) seems to be that graduates from private training institutes are not suitable for software development, unless they also have engineering degrees or have interned with software development firms during the course of their private training. An earlier study (NASSCOM, 1999) reported that only 2% of all software developers trained in private training institutes join software development firms. In our study, however we found instances where graduates from private training institutes, sometimes through tie-ups with development firms for professional practice[14] did end up joining the development industry.

One should also note that private training institutes are also important for helping existing software developers acquire new skills. As discussed below, many engineers

[13] 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.

[14] NIIT for instance offers a 3-½ year GNIIT program that includes 1 year of professional practice (internship) with a software development firm. Software developers trained with this degree usually end up being offered a job with the firm on completing the internship. Ramco, a large and one of the first successful Indian developers of software package and ERP package called Marshall, has recruited software developers using this source and there are currently around 100 such software developers working with them. Other firms too appear to recruit such professional. For instance, CITIL, a software development firm recently used the placement services of Aptech and recruited around 100 Aptech students for various areas of application. Similarly Hexaware Software, which was initially a part of Aptech but which was subsequently spun-off as an independent entity directly contacts the placement cell of Aptech and recruits students who have completed various certificate courses with Aptech. A large number of the graduates however end up being employed as teachers/trainers in these non-formal institutions or start up private training institutions of their own. Similarly IIS Infotech, a Delhi based software development firms (recently taken over by a British group) employs 20-30% graduates from NIIT/Aptech. (Source- Interviews with project leaders/managers/CEO's of Ramco and Hexaware, the COO of NIIT and the regional manager of Asset International (a subsidiary of Aptech)

also undertake further training in software development on their own from private training institutes. This points to the rapidly changing nature of the industry and the high rate of obsolescence of narrow, technical skills, such as knowledge of a specific programming language.

2.3. Supply of software developers with Government certification

The Department of Electronics through the Department of Electronics Accreditation of Computer Courses (DOEACC) provides accreditation to private training institutes in the non-formal sector ranging from foundation level courses to a post-graduate level in the computer field. A number of small private training institutes rely on this method of accreditation[15]. This is viewed as one way of establishing their credibility in the market and is frequently advertised as such.

2.4. Supply of software developers returning from the U.S

In the last two years there appears to be a phenomena where software developers who have worked in the U.S return to India to either work with firms or get involved in new start-ups. In interviews conducted in December of 1997, we interviewed several software developers who returned for personal or professional reasons. We believe that

[15] The DOEACC scheme provides accreditation at 4 levels: the O level, which is the foundation level to the post-graduate C level. The B level is considered equivalent to an MCA degree by the industry. The National center for Software Technology (NCST), a government society, also conducts tests for competence in software at various levels. The G level tests software developers with B.E/B.Tech/MCA degrees and postgraduate degrees in software technology. The C level is for B.Sc, Computer Science degree holders (BCS) and graduates or equivalents in any discipline who have done a minimum of three months full-time or six months part-time training and are aspiring for programmer level jobs, and E level which is an entry level exam open to all graduates to test their aptitude for computer-related training.

this flow of software developers back to India who have worked in the U.S. on H-1B[16] visas and are now unable to obtain green cards will increase in the future especially due to the current backlog in issuing green cards[17]. However there is some concern about the specific skills such software developers have gained in the U.S. and how relevant these skills would be in Indian software development firms.

Software developers in India are frequently asked to take on a greater responsibilities vis-à-vis their training and educational backgrounds. Thus a professional with around two years of experience is frequently expected to take on the role of a project leader, a job which usually involves skills such as performing requirements analysis and systems analysis and design in addition to the coding, debugging and testing that is the usual job of an entry level software programmer. Individuals sent to the U.S. on an H1-B visa are typically not given this level of responsibility and frequently end up performing fairly narrow and specialized programming activities. On their return to India, these individuals tend to expect a managerial position for which, according to the managers we interviewed, they sometimes lack the required experience.

[16] The temporary work visa, called H1-B, is a category for non-immigrant foreign workers to work in a specialized field in the U.S. for up to six years. Almost half of those visa holders are working in the U.S. IT industry as engineers, computer programmers or medical software developers.

[17] Also see Vic Goel: "The Green Card Waiting Game", In Silicon India - Technology and Business Magazine, May 1999 pp.54-56. Another issue is that while H-1B visas are issued to qualified software developers on which basis they can bring their families to the U.S, green cards have to be issued separately to individual members of a family.

3. Demand

3.1 Changes in demand:

The explosive growth of software development firms in the last decade had led to an increase in the wages paid to software developers, which on average has increased by 20% annually (in 1998)[18]. The software development industry is a very human capital-intensive industry and the projected 50% annual growth rates are approximately comparable to the growth rates in demand for workers.

3.2 Changes in employer preferences

In the beginning, software development firms had a distinct preference for engineering graduates from the prestigious Indian Institutes of Technology. However, not only were such graduates difficult to recruit than graduates of lesser known engineering colleges, they were more likely leave the firm to study or work in the U.S. Many firms then decided to focus on engineering graduates from regional and state engineering colleges. Subsequently firms have also begun to consider graduates in computer science from non-engineering degree colleges (Bachelor of Computer Science or BCS) and software developers with a post-graduate degree in computer science (Master of Computer Science or MCS). More recently, smaller firms have also begun to recruit software developers with any graduate degree but with a certificate or diploma from private training institutes.

For software developers at the entry level in software firms the general perception among firms appears to be that 2-3 months of training can provide an individual with the

[18] Of basic pay. This did not include any payment of bonus/perks, employee stock options (ESOP) etc.

required skills to begin entry-level software development tasks such as programming. Thus, while any graduate is potentially a suitable candidate for a job in a software development firm, there still seems to be a distinct preference for engineering graduates, not just engineering graduates with a specialization in the computer sciences or related fields but even engineering graduates from unrelated fields such as mechanical, chemical, or metallurgical engineering. We shall later show that this preference appeared to be strong for recruiting entry-level software developers but not for experienced software developers. Our empirical evidence discussed later suggests that this is not what firms actually prefer but they are constrained by the shortage of software developers trained in computer science, software development and related fields.

3.3 Migration overseas

A large number of skilled software developers have traditionally gone to the U.S. every year, a factor that has significantly contributed to the high attrition rates in Indian software firms and consequently, the shortage of skilled software developers at the *project leader* and *project manager* levels. In the last few years, this number has gone up even further due to the severe shortage of skilled software developers in the U.S. and consequent modification in the U.S. Workplace Competitiveness Act of 1998 and an increase in the H-1 B quota from 65,000 to 115,000 per year. Last year around 20,000[19]

[19] Most of the firms sponsoring these visas were located in the U.S Thus for instance, in 1998, Infosys Technologies Ltd. (ITL), one of the large software firms based in India had 231 employees working in the U.S on H-1 visas and another 111 employees on L-1 (intra-company transferee) visas. (Source: Form F-1 of ITL filed with the SEC). Last year 46% of all H-1 visas issued were to software developers from India. Most of these visas were for skilled software developers based upon our study of the firms that sponsored these visas-Mastech (11%), Computerpeople (6%), Oracle (5%), Pricewaterhouse Coopers (4%) and Lucent Technologies (3%) based in the U.S. Tata Consultancy Services based in India accounted for 7% of all H-1B visas issued. (Source: The Indian Express, Pune, July 14, 1999). Countries with the highest

software developers relocated to the U.S. Last year (1999) around 30,000 software developers[20] have been reported to obtain H-1 B visas from India. Most of these software developers have some experience working in software development firms in India. Another category of visas used by firms to send software developers to the U.S is the B-1 business visitor visa which permits a short term stay for business purposes in the U.S. Anecdotal evidence however suggests that it is possible for a B-1 business visa to be converted to an H-1B visa quite easily and *there appear to be no yearly limits or restrictions on the numbers of such converted visas*. Thus, the actual number of software software developers coming to the U.S from India in 1999 would be much higher than the estimates given earlier.

3.4 Demand Estimates

NASSCOM estimates the current demand by software development firms to be in the region of 140,000 software developers for 1999 and 2000.[21] The total stock of software developers employed was believed to be around 160,000 in 1998 of which 70% or 112,000 are estimated to be in software development. Based on productivity measures we can estimate the annual demand by the software industry as follows: In 1998 the total revenue to the software industry, both development and services was around $4 billion. From earlier studies (Arora, et. al., 2000), the average annual productivity of software developers in the industry is estimated at about $0.035 million. Dividing $4 billion by

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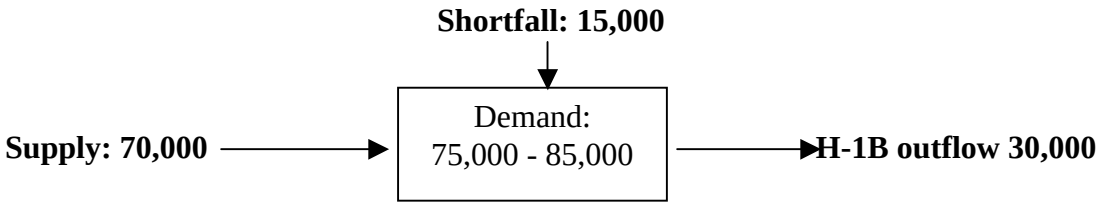
percentage of total recipients of H-1B visas: India -46% China -10% Canada- 4% Philippines-3% (Valbrun, 1999)

[20] Interview with Mr. Vivek Savant, C-DAC, Interview of Mr. Clyde Jones-Chief of Consular Services, U.S Consulate India and reported in the The Economic Times, Hyderabad edition Wednesday 30th June 1999.

[21] Approximately 56,000 in 1999 and 84,000 in 2000 (assuming a growth rate of 50%).

$0.035 million, we get around 115,000 software developers, which also matches the NASSCOM estimate of 112,000. Assuming a 50% growth in revenues for 1999, this implies that the industry needs to recruit 57,500 software developers. To this, one must add the need to replace those lost to the U.S. software industry. In 1998, around 20,000 software developers moved to the U.S., and the number is likely to be larger for 1999. This implies a total demand of about 75,000 to 85,000 developers.

By comparison, NASSCOM's estimate of the total supply in 1999 is about 70,000 as shown in Table 3 (Appendix 1). This figure includes around 15,000 graduates in Computer Science, Electronics and Telecommunications, another 10,000 engineering graduates with degrees unrelated to software development[22], around 10,000 MCA graduates, 10,000 graduates with B.Sc. (Computer Science) and B.Sc. (Math) degrees. In addition, there are about 20,000 software developers with diplomas in Computer Science or Electronics, with certificates in specialized software development areas from NIIT, Aptech or other private institutes, and around 10,000 software developers with post-graduate degrees such as a M.Sc., an M.Tech. or an MBA. If current hiring practices continue, this implies an excess demand of 15,000 in 1999.



[22] We think that the NASSCOM estimates are low as they consider only 41 engineering colleges as potential sources of engineering graduates for the software industry- India currently has around 662 public

Firms have responded to this shortfall so far in three ways. First, they have recruited more entry-level employees from engineering and science disciplines other than computer science, electrical and electronics engineering, software engineering and related disciplines. Second, they have tried to recruit software developers from other sectors with relevant work experience such as project management, although the quantitative significance of this move is uncertain in terms of numbers of software developers who have moved from other industries to the software development industry. Finally, firms have increasingly turned to software developers trained in software development by private training institutes.

The projected excess demand, driven largely by an excess demand for engineers, itself raises the question of why, given the nature of work, engineers are preferred so strongly over non-engineers? Though the Indian software industry tends to primarily recruit engineering graduates, their motivations for doing so vary among firms. The bulk of the work is relatively non-technical and requires mostly logical and methodical work and a familiarity with software development tools and languages. Data from the firms surveyed in Arora et al (2000) show that about 17% of the software developers had been recruited from private training institutes and did not have an engineering degree. Of the rest, over 70% had an engineering or advanced scientific degree. Few of the firms we interviewed admitted to hiring any non-engineers, although since the bulk of the engineering graduates are not trained in software engineering or computer science, a substantial fraction of the hires also have diplomas from private training institutes.

(state) and private engineering colleges (Table 2, Source: AICTE web site: http://www.aicte.com/approved_inst.html).

Further, some of the smaller and younger firms do hire graduates from these institutions, as do some domestic market focused firms.

This preference for engineers is even more puzzling since the bulk of the work is relatively non-technical and requires mostly logical and methodical work and a familiarity with software development tools and languages. Given the large number of science and arts graduates, and the widespread availability of private training institutions, the pool of potential software developers is much larger than merely graduates from engineering colleges. However, some software firms are reluctant to tap this pool because of the potential negative signals to their customers.[23]. As one CEO we interviewed 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.)

This is a clear instance of a "race to the top" rather than a race to the bottom. With only 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. 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. The CEO of a small firm developing innovative products stated:

[23] U.S. visa restrictions are another reason why firms prefer engineering graduates.

"[B] ecause things are changing so fast in this industry, knowledge of a particular operating system, a particular language, a particular technology is not as important as the ability to learn and adapt to change."

Software exporters also prefer engineering graduates because they are more likely to satisfy the U.S. H1-B visa restrictions that require technical credentials. Engineering graduates are much more likely to have 16 years of education compared to the typical BA or BS graduate. The preference for engineers may also be due to the high screening ability of the Indian education system – admission to engineering colleges is seen as indicative of academic ability and aptitude.

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. Earlier experiences of the software development industry with such graduates were not very favorable primarily because of the quality concerns related to the educational process in such institutes. However, in the last two years the certification of software development software developers has increased dramatically. Since the testing and certification is carried out by an independent authority (Sylvan Prometric Inc.) a Australian based firm that conducts the tests and then contracts with individual reputed software firms such as Microsoft, Novell and IBM who then verify the results and award certification. This has led to some level of quality being established for private training institutes, which is useful for graduates from such institutes to signal their quality. If this succeeds, it is probable that in the future, graduates from such institutes would be considered as substitutes to engineers and other graduates from formal institutions. Private training institutes are also being increasingly being used by graduates from

private and state engineering colleges to obtain better jobs offers from software development firms.

To investigate further, we analyzed two types of data. First, we analyze a dataset developed from newspaper advertisements in India to recruit software developers. Since the advertisements could specify the types of skills and formal qualifications, these data can illuminate the attributes of expressed demand for different types of skills required by software firms. The second dataset is based on responses to a short questionnaire survey administered to 61 software developers working in the Indian software industry. Interviews with CEO's and HR managers of software firms, representatives from private training institutions, and policy experts complement quantitative evidence on the current reality of the manpower situation.

4. Analyzing demand of the Indian software industry for different types of skills using advertisement data

4.1 Research method

Data were collected from advertisements placed by software firms in The Times of India and The Economic Times, two leading English dailies and published simultaneously from Mumbai, Bangalore and Delhi. The advertisements were to recruit software developers, and were from firms from the following industries: Computer Applications, Computer Networking, Computer Systems, Banking & Insurance, Consultancy, Telecommunications, Internet and New Media and Business Services and hosted on the Jobs & Careers website.[24] We selected advertisements that specified the job functions to be Software Development, Consulting or Systems Development. The three

[24] http://www.timesjobsandcareers.com/jobsrc2s.html.

cities –Mumbai, Bangalore and Delhi are large metropolitan cities and have large concentrations of software development firms. Between 26th April 1999 and 26th June 1999, a period of two months, we found 102 advertisements for software developers in these seven industries. The coding criterion employed to analyze the data is given in Table 5 (Appendix 1).

4.2 Results

A large percentage of the advertisements (68%) appeared to be from the computer systems industry[25] followed by the Internet and New Media industry (15%) and Consultancy industry[26] as shown in Table 6. The job specifications described in the advertisements were predominantly related to software development (82%), followed by system development (12%) and consultancy (6%).

Table 6: Distribution of Advertisements across Industry

Industry	Frequency	Percent
COMPUTER APPLICATION	2	2
COMPUTER NETWORKING	1	1
COMPUTER SYSTEMS	69	68
CONSULTANCY	6	6
TELECOMMUNICATIONS	9	9
INTERNET & NEW MEDIA	15	15
TOTAL	102	

Source: Jobs and Careers website of the Times of India and The Economic Times (1999)

The distribution of advertisements across industries with the job specification as software development is very similar to the distribution of the entire sample. In view of the possible

[25] Some names include: Nucleus Software Exports Ltd, Akiko Sherman Infotech, Datamatics Staffing Services, Infosys Technologies Limited, Network Programs India Pvt. Ltd and SiCore Systems (P) Ltd,
[26] Some names include: PriceWaterHouseCoopers Limited, A.F. Ferguson & Co., Sai Corporate Services Pvt. Ltd., Text 100 India and ABC Consultants Pvt. Ltd.

ambiguity in descriptions of other job specifications and the limited focus of this study, we limited our subsequent analysis to advertisements by software and IT (information technology) related firms and where the advertisement was explicitly for software developers.

Of the 84 advertisements for software developers, only 48, or a little over half of the advertisement explicitly specified formal educational qualifications. Table 7 shows that 36 (75%) of these 48 job listings also specified an alternative qualification. The first qualification, specified by 83% of the advertisements was for software developers with a graduate technical degree (B.E or B.Tech), followed by 8% for a post-graduate technical degree (M.E or M.Tech.) and another 8% for any graduate degree. The second qualification (Table 8) specified by 42% of the advertisements was an MCA degree, 25% specified an M.E or M.Tech., and 17% asked for advanced diplomas in a specialized field of software development such as Multimedia.

Table 7: First Qualification specified in Job listing Advertisements for Software Development

First Qualification	Frequency	Percent
B.E\B.TECH	40	83
M.E\M.TECH	4	8
OTHER GRAD	4	8
TOTAL	48	

Source: Jobs and Careers website of the Times of India and The Economic Times (1999)

Table 8: Second Qualification specified in Job listing Advertisements for Software Development

Second Qualification	Frequency	Percent
DIPLOMA	6	17
B.E\B.TECH	4	11
M.E\M.TECH	9	25
M.C.A	15	42
B.SC	2	6
TOTAL	36	

Source: Jobs and Careers website of the Times of India and The Economic Times (1999)

Of the 48 advertisements that specified qualifications, 24 (50%) also mentioned the fields of specialization. As Table 9 shows, 58 % required a specialization in Computer Sciences & Engineering; another 17% required a specialization in Electronics and Communications, and another 17% in Multimedia.

Table 9: Specialization fields for advertisements that stipulate qualifications

Specialization	Frequency	Percent
MECHANICAL	1	4
COMP.SC\ENGG	14	58
ELECTRICAL	1	4
ELEC & COMM	4	17
MULTIMEDIA	4	17
TOTAL	24	

Source: Jobs and Careers website of the Times of India and The Economic Times (1999)

The average work experience required was specified was 5.23 years indicating a need for slightly more experienced software developers than the current average experience as determined by other sources (NASSCOM 1998).

These data show a clear preference among employers for engineering graduates: a B.E or B.Tech degree was strongly preferred as the first qualification of choice followed by an MCA as the second qualification of choice. Interestingly, most employers that required an engineering degree also specified a specialization in computer sciences & engineering, or electronics or communications, and most of the remaining in Multimedia, thus indicating that the preference for engineering graduates was not for graduates with specialization in any field but in specific fields clearly related to the software development field. Additionally the specialization in Multimedia required by employers is something that at present is mostly provided by non-formal training institutions and thus it is possible that this category of employees recruited mostly included graduates in engineering who also had diplomas or certificates from private training institutes.

One interesting finding is that 52% of advertisements did not specifically mention any education qualification requirement but instead just described the project and the skill sets required. One possible explanation is that only employers who wanted to recruit experienced software developers, who might not have the specified qualifications and thus might be hesitant to respond to the advertisement, may have advertised. To test if this was indeed the case, we correlated the experience variable with a dummy variable that indicated whether the advertisement specified a qualification requirement. We computed a Pearson's coefficient $r = 0.08$ which indicated a very low correlation between these two variables. Thus, the failure to indicate specific educational qualifications is not simply because of a desire to recruit more experienced software developers.

From the above we can infer that either a) employers are desperately in need of people hence they do not wish to restrict their options by specifying a particular

qualification, or b) employers believe that irrespective of formal qualifications, they can train software developers whom they recruit to perform the tasks to which they are assigned, or, c) that neither formal nor informal qualifications matter, the skill sets or the ability of software developers as observed during the recruitment process suffice to identify suitable employees. All in all this points to a fairly chaotic and unsystematic method of recruitment indicative of the young age of the industry and the turbulent times it is passing through.

5. Data from personal questionnaires

To evaluate the match of skills provided by the educational system with the requirement of the industry, we then interviewed software developers that had worked on at least a couple of projects. We focused on project experience rather than experience as a function of duration (such as six monthly or annually) as this would better help U.S. understand the skills and domain knowledge that software developers gained during their work experience. It was also cognitively less trying for a professional to detail the skills he or she used in a project because this is the usual information they would have on their resume or curriculum vitae. We collected information on the first to the seventh projects (beginning with the first software development related project) on which the respondent worked. Our choice of number of projects was guided by a couple of considerations. First, since the rate of obsolescence of technical knowledge is high, the relevance of the educational experience of software professionals would be the highest in the first few years (six or seven projects) of joining the industry. Subsequently corporate training and experience would affect the technical knowledge of a professional and affect our

evaluation of the match between the needs of the software industry and the supply of human capital. This could also happen if education was not the critical variable but on-the job training after employment was what mattered. Secondly, we needed to keep the questionnaire short. We selected software developers employed in either software export firms or domestic software firms at different locations in India. We wanted to explore the differences in skill and capability between engineers and non-engineers as software developers.

5.1 Research method

We interviewed 61 software developers in Pune, Madras, Bangalore, and Hyderabad, which are major software centers in India.[27] Face to face or telephonic interviews enabled us to collect information on the specific skills and abilities, and their links to the educational training of the individual. We selected from major categories of software developers (B.E, B.Tech., M.E, M.Tech., MCA, B.Sc, M.Sc., certificate from private training institute) as given in Table 4. At least 5 individuals in each category were interviewed using a structured questionnaire format (Appendix 2). The selection of firms was done randomly in these four cities. However, within a firm, we specifically (over sampled) software developers who had graduated from a private training institute. In addition, we interviewed professionals who directly managed software developers (such as project managers & project leaders) or were indirectly associated with their selection, recruitment and career growth (such as human resource managers) to ascertain their views of the factors affecting demand and supply of software developers using an open-ended interview format. We also interviewed industry experts and senior management

software developers from the two largest non-formal training institutions in India viz. NIIT and APTECH. These interviews were carried out face-to-face or telephonically over the summer of 1999 in India.

In the structured questionnaire (See Appendix 2) administered to software developers, the specific questions related to the following aspects:

i) Demographics information such as age and sex

ii) Educational information such as educational qualifications after high school (both formal and non formal), specializations chosen and the year of graduation.

iii) Project information (for each of the first 7 projects in the software developers' career), including the description, size and duration of the project, a description of the tasks and programming languages, technologies, and skills used, and from where those skills were attained (e.g., college, on the job exposure, on the job training program, private training or certification program and or own effort)

5.2 Preliminary statistics for the sample

Of the 61 software developers in the sample, 11 (18.03%) were female while 50 were male (81.97), which corresponds to NASSCOM figures for 1998 as well. The sample mean age was 26.5 years while the median age was 25 years. NASSCOM figures for 1998 put the median age for software developers in the industry at 26.6 years. The median duration of projects in the sample was 8 months while the median work experience was 3 years. NASSCOM estimated the median working experience for IT workers at around 5.9 years, thus indicating that our sample had software developers who

[27] The interviews were carried out by the first listed author.

were somewhat less experienced than the national average. The median size of the average project was around 60 man months. These 61 software developers had worked for 111 firms and on 230 software development projects by the time of their interview. The list of firms in which these software developers worked for one or more projects during their first seven projects is given in Appendix 3.

The breakdown of initial studies undertaken by software developers in the sample after high school is shown below in Table 10. Most software developers have a B.E, B.Tech. or a B.Sc. (Computer Science) [56%] followed by a B.Sc. (Non Computer Science) [26%]. The highest numbers of specializations were computer science or engineering (31%) followed by the other category (29%). Recall however that we over sampled non-engineers and therefore these figures are not representative of the industry as a whole.

Table 10: Distribution of First Educational Qualification of Sample Software Developers

First Educational Qualification	Frequency	Percent
DIPLOMA	5	8
B.E/B.TECH/B.SC (COMP. SCIENCE)	34	56
B.SC (NON-COMP. SCIENCE)	16	26
OTHER GRAD	6	10
TOTAL	61	

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)

On average, the sample software developers have 41.3 months (3 ½ years) of undergraduate education and 26.5 months of formal postgraduate education (for those that did have graduate education). Finally, about one-third of the sample also had 19

months of non-formal post-graduate education. Table 11 shows the average duration for formal undergraduate studies, formal and non-formal graduate studies and mostly non-formal studies undertaken in private training institutions.

Table 11: Duration of Formal and Informal Education, Sample Software Developers

Duration of Education	n	Mean	s.d	Min	Max
FORMAL-UNDERGAD	59	41.3	6.31	36	60
FORMAL GRAD	39	26.5	11.45	6	48
NON-FORMAL POST-GRAD	18	19.1	14.9	1	48

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)

Table 11 highlights the extensive education software developers pursue, with more than half of the sample having formal graduate degrees (MCA most frequent) or non-formal certificates from private training institutes and a quarter of the sample also having some additional form of non-formal post-graduate education. The subsequent graduate studies undertaken by around 70% of software developers in the sample was more varied than the initial undergraduate studies as shown in Table 12

Table 12: Post-graduate educational qualification for sample software developers

Second Educational Qualification	Frequency	Percent
ME/M.TECH	4	9
MCA	6	14
MBA	4	9
CERTIFICATE FROM PRIVATE TRAINING INSTITUTIONS	18	41
OTHER FORMAL GRADUATE/POST-GRADUATE	6	14
OTHER	1	2
M.SC (COMP. SCIENCE)	4	9
TOTAL	43	

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)

Our figures (Table 13) for software developers with non-formal certificates from private training institutes as their second educational qualification are on the higher side than would be representative of software development firms in India. This over sampling was done on purpose to enable us, as part of our research design, to compare project experience related differences between software developers who had formal engineering or Computer science degrees vis-à-vis those who had other formal graduate degrees from private training institutes.

Table 13: Post-graduate educational qualification for sample software developers- Non-Engineering/Non-Comp. Science graduates vis-à-vis Engineering/ Comp. Science graduates.

Second Educational Qualification	Non-Engineering/Non-Comp. Science graduates		Engineering/ Comp. Science graduates	
	Frequency	Percent	Frequency	Percent
MCA	1	4	5	26
MBA	1	4	3	16
CERTIFICATE FROM PRIVATE TRAINING INSTITUTIONS	**15**	**63**	**3**	**16**
ME/M.TECH/ M.SC (COMP. SCIENCE)	0	0	**8**	**42**
OTHER FORMAL GRADUATE/POST-GRADUATE	6	25	0	0
OTHER	1	4	0	0
TOTAL	24		19	

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)

Of the 34 software developers in our sample with engineering or computer science degrees, 19 (56%) undertook further education as compared to software developers in our sample without these degrees of whom 24 out of the 37 or around 65% undertook further education. We also observe that only 16 % of those with an engineering or computer science degree went for a diploma or certificate from a private training institute with the majority of them opting for an engineering or computer science related graduate degree,

compared with around 60% for those without an engineering degree. The average duration of studies undertaken on a full time basis for all software developers during the attainment of their second educational qualification was 26.5 months (slightly more than 2 years) with software developers with engineering degrees spending around 28 months on average as compared to 25 months for software developers without engineering degrees.

An additional 17 software developers, a larger proportion of whom were software developers without engineering degrees also had a third educational qualification with the distribution shown in Table 14. The largest number (59%) was of individuals obtaining training and certificates in software development from private training institutions with an average duration of around 18 months.

Table 14: Distribution of third educational qualifications among software developers.

Third Educational Qualification	Frequency	Percent
MCA	1	6
MBA	2	12
CERTIFICATE FROM PRIVATE TRAINING INSTITUTIONS	10	59
OTHER FORMAL GRADUATE/POST-GRADUATE	3	18
OTHER	1	6
TOTAL	17	

Thus, we observe that a) professionals with engineering or related degrees (B.Sc-Computer Science) appear to be better off in terms of the extent of educational background needed. b) A large proportion of professionals in our sample appeared to have spent a substantial amount of time training in non-formal training institutions, and c)

professionals without formal engineering degrees appear to be very willing to undertake an extensive amount of education prior to joining software development firms.

In general, our descriptive statistics reveal that a) software developers with engineering or related degrees (B.Sc-Computer Science) appear to be better off in terms of the extent of educational background needed. b) a large proportion of software developers in our sample appeared to have spent a substantial amount of time training in non-formal training institutions, and c) software developers without formal engineering degrees appear to be very likely to have undertaken an extensive amount of education prior to joining software development firms.

5.3 Detailed Analysis

In order to examine the differences between engineering graduates and those who had certificates from private training institutions we created two categories of software developers in our dataset. The first included all software developers who received an engineering graduate or post-graduate degree at one or more of the three educational levels, with no exposure to private training institutions at any level. The second included all software developers who had a diploma or certification from a private training institution in their second or third educational levels and with a non-engineering degree in their first educational level. The first category of software developers with engineering degrees (n=28), were then compared with the second category of software developers with degrees from private training institutions (n=24). Software developers with both engineering degrees and certificates from private training institutes (n=9) were not included in the analysis as they had a substantial exposure both to engineering and formal

training institutions making it impossible for us to distinguish analytically whether their current skill set and employment characteristics were due to the one or the other.

A comparison (Table 15, columns 3 and 4) of the average duration of projects worked on (in months) showed no sizeable differences with the two categories working an average of 8.1 months on each project. However there was a large and significant (0.05 level of significance) difference in the average size of projects worked on (in man-months) with software developers with an engineering degree working on projects with an average size of 220 man-months while those with diplomas or certificates from private training institutes working on projects with an average size of 87 man months.

Table 15: Difference between PTI grads and Engineers on Job characteristics

(1) Professional category	(2) N	(3) Average Project duration (months)	(4) Average Project size (man-months)	(5) Average Projects Worked (# of Projects)	(6) Average Jobs Worked (# of Jobs)	(7) Average Experience (Years)
PTI grads	24	8.1	87	3.5	1.5	2.9
Engineers	28	8.1	220**	3.9	2.1**	3.7

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)
** Significant at 0.05 level.

Table 15 also shows (columns 5, 6 and 7) that there was no significant difference in the average number of projects worked or in the average experience at the time of the survey between graduates from private training institutes and engineering college graduates in our sample. However there was a significant difference (at the 0.05 level) in the average number of jobs worked on during the course of these projects, with engineering graduates having worked on a higher average number of jobs as compared to graduates from private

training institutes. This indicates lower job mobility for graduates from private training institutes as compared to software developers with an engineering degree in our sample. In general, the median length of time spent in one job by software developers in our sample was 2 years. Alternatively, Table 16 shows the distribution in our sample by number of firms worked for the whole sample, PTI graduates and Engineers. For 66% of PTI graduates their current job was the only one they had worked in whereas this was true for around 43% of engineering graduates.

Table 16: Difference between proportion of PTI grads and Engineers on # of Jobs worked

JOBS WORKED	ALL %	PTI GRADS %	ENGINEERS %
1	52	66	43
2	23	21	25
3	15	13	18
4	5	0	7
≥5	5	0	7

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)

Software developers Skills Analysis

We then coded the languages and skills used by both these groups of software developers for each of the projects they worked. These were then recoded into skill categories based upon similarities between them as shown in Table 17:

Table 17: Languages and Skills comprising a skill category

CODE	SKILL CATEGORY	LANGUAGES/SKILLS
1	SCRIPTING LANGUAGES	ACTIVEX, CGI, HTML, JAVASCRIPT, MS ASP, VB SCRIPT, XML, LOTUS SCRIPT
2	OBJECT ORIENTED LANGUAGES	C++, JAVA, OOPS, VC++
3	PROCEDURAL LANGUAGES	BASIC, C, COBOL, PASCAL, PERL, LEX/YACC
4	TOOLS	CASE TOOL, CCCA TOOL, GUI TOOL, ER-IN TOOL, SEEC TOOL, CT TOOL
5	DATABASE SKILLS	ORACLE, FOXPRO, GUPTA SQL, IMS, INFORMIX, INGRESS, MS ACCESS, FOXPRO, UDB, PL/SQL
6	PLATFORM SKILLS	MTS, RTOS
7	SYSTEM LEVEL CODING SKILLS	NT DEVICE DRIVER, NT INTERNALS, UNIX INTERNALS
8	ARCHITECTURE KNOWLEDGE	COM, CORBA, MAPI
9	OPERATING SYSTEMS	CICS, DOS, JCL, MVS, UNIX, PL1
10	APPLICATIONS	ADOBE PHOTOSHOP
11	DEVELOPER TOOLS	POWERBUILDER, VISUAL BASIC, DEVELOPER2000

Our subsequent analysis looked at project-wise differences in proportions of skill categories used by both categories of software developers, the change in the use of these skills within a category and the effect of time (as measured by changes from one project to the next) on changes in the proportions of use of these skills. Table 18 shows how the proportion of use of the top five skill categories changed between PTI graduates and engineers across their first six projects. (These top five skill categories accounted for more than 80% of the skills used by both categories of software developers across all projects). For instance, the topmost cell reading from the left is 0.05 or 5% indicating that in the sample, the percentage of software developers from private training institutes using scripting language skills in their first project (P1) was 5 percentage points more than the percentage of engineering software developers using scripting language skills in their first project, although the difference was not significant.

Table 18: Difference between PTI graduates and engineers in proportions of skill categories used across projects

SKILL CATEGORY	P1	P2	P3	P4	P5	P6
SCRIPTING LANG.	0.05	-0.03	0.06	-0.21*	-0.27***	-0.31**
OBJECT ORIENTED LANG.	0.06	0.20**	0.02	0.14	0.33**	-0.08
PROCEDURAL LANG.	-0.09	-0.14*	-0.15**	-0.03	0.01	0.32
DATABASE LANG.	0	-0.04	0.07	-0.01	0.14	0.17
DATABASE SKILLS	0.01	-0.08**	-0.09**	-	-0.10*	-

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)
*** Significant at the 0.01 level; ** Significant at the 0.05 level; * Significant at the 0.10 level

At the first project level, there appear to be no significant differences in the skills used by engineering versus PTI graduates. By the second project, some significant differences emerge with PTI graduates using more of object-oriented language skills and less of procedural language and database skills as compared to engineering graduates. With the passage of time and a gaining in project experience for all software developers, we see that the scripting language and the database skill category shows a marked decline across projects with more engineering graduates ending up using this skill by the end of the sixth project as compared to software developers from private training institutes.

To examine the changes in these skills within the software developers categories we were examining we then averaged the proportions of each of the top five skill categories across the first and second project and the sixth and seventh project and then computed the changes in proportions between these two averages (Table 19).

Table 19: Difference between PTI graduates and engineers in proportions (average) of skill categories used between the First/Second and Sixth/Seventh Project.

Skill Category	PTI	Engineers
Scripting Lang.	-0.15***	0.02
Object Oriented Lang.	-0.29***	0.06
Procedural Lang.	0.08	-0.21***
Database Lang.	0.30**	0.08
Database Skills	-0.02	-0.02

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)
*** Significant at the 0.01 level; ** Significant at the 0.05 level; * Significant at the 0.10 level

For example, the topmost cell on the left indicates that the average proportion of software developers from private training institutes who used scripting language skills in their first and second projects decreased by 15 percentage points (significant at the 0.01 level) between their first/second projects and their sixth/seventh projects. Overall, differences emerge in the changes in skill categories with the use of scripting and object oriented languages decreasing but the use of database language skills increasing for PTI graduates. On the other hand, engineers do not exhibit any significant differences in the changes in skills categories between the first two and the last two projects in our sample except in the use of procedural language skills (Basic, C, COBOL, Pascal, PERL, LEX/YACC) where the change is negative and significant.

To examine in more detail the effect of shifting from one project to the next on the change in skill categories used by both categories of software developers we then regressed the proportion of each skill categories on project worked (Table 20). We see that for PTI graduates, the proportion of use of scripting language skills declines by 3.6% over time (measured in projects) and of object-oriented skills declines by 4.5% while database language skills increase by 5.9%. For engineers on the other hand a similar change results in a decrease of 3.8% in the use of procedural language skills and a 2.2% increase in database language skills. Database skills for both categories of software developers show almost no change across projects.

Table 20: Regression of proportion of use of skill category on project

Skill Category	PTI		Engineers	
	Coeff	R^2	Coeff	R^2
Scripting Lang.	-3.6**	0.58	0.2	0.00
Object Oriented Lang.	-4.5*	0.45	1.0	0.04
Procedural Lang.	1.8	0.13	-3.8***	0.89
Database Lang.	5.9***	0.79	2.2*	0.52
Database Skills	-0.5	0.38	0.0	0.00

Source: Carnegie Mellon Software Developers Skills Questionnaire (1999)
*** Significant at the 0.01 level; ** Significant at the 0.05 level; * Significant at the 0.10 level

In general, these findings point to some interesting differences in skills. However, whether these differences reflect training or inherent (or perceived) differences in ability between the two groups is an open question. One explanation of this difference could be the differences in average project sizes worked on by the two types of software developers as being indicative of the complexity of projects and requiring a higher order of skills. Another possible explanation is that Scripting and Object Oriented languages need a greater problem-solving ability and logical thinking capabilities for which engineers are better equipped to handle, or at least, are perceived to better.

6. Conclusions

Our interviews with industry experts and industry heads and the analyses presented above points to the mismatch between supply and demand for labor in the Indian software industry. The substantial preference for engineers combined with rapid growth in demand and the relatively inelastic supply of engineers are the basic cause of the mismatch. A substantial attrition of experienced software developers to the U.S., under the H1-B visa scheme, which has dramatically increased over the past few years exacerbates the situation. As a CEO of the software development firm bluntly put it, “We

don’t have an infinitely large supply of software developers here. What I know is that whatever the supply, there will still be a demand for it….” The recession in India has also contributed to this by making the software industry an attractive recruiter even for graduates with a non-related degree. However there is no certainty that these favorable conditions will continue in the future.

The mutual attraction between engineers of unrelated disciplines and the software industry has serious implications for other sectors of the Indian economy. The AICTE in a recent report talks about the “unstoppable exodus of students from the parent engineering disciplines to the IT sector, resulting in an acute shortage in these disciplines." Engineering institutes are now believed to produce around 7,000 M Techs a year, a mere one-third of their capacity. The number of doctorates in engineering has also fallen drastically raising serious concerns about the falling research standards in engineering and technology and a potential shortage of qualified faculty in engineering colleges.

We find that although there are some interesting differences in the types of skills used by engineers and non-engineers, these differences are not very large at the outset. If the differences were primarily due to training, rather than unobserved differences in the *perceived* abilities of the individuals, one might have expected greater differences in the skill sets used during the earlier projects. Further research is needed to probe whether the preference for engineers is merely because admission to engineering school is a useful screening device or whether engineering training develops the problem solving and other skills useful for software development. Even so, it is clear that given the slow pace at which engineering education capacity can be expanded, sustaining the growth rate of the

Indian software industry will require expanding the potential pool of recruits beyond engineers and computer science graduates. India has a large pool of college graduates, a reasonable fraction of which can be trained to develop software. Rising wages for software developers are already providing incentives for employers to tap sources other than engineers in order to close the gap between demand and supply. Until now, the gap is the smallest at the entry level. There is a much greater shortage at the experienced project leader and project manager level thus leading to a) software developers with inadequate experience being compelled to handle these tasks with job quality and employee motivational consequences, and b) firms being unable to undertake new tasks and move up the value chain, thus inhibiting growth, productivity and profitability. This shortage is largely because a large number of experienced software developers (4-6 years of experience) who move to the U.S are potential managerial material for firms. The drastic loss of these software developers (a conservative estimate of which is around 30,000 software developers[28] in 1999, of whom many could be presumed to be experienced given the stringent criteria established for issuing an H1-B visa) has the potential for creating a serious problem for software development firms even in the short run. The opportunity costs of the loss of these software developers who usually leave after working around 3-4 years in the firm include projects forsaken due to a shortage of qualified project leaders or managers, the disincentive of software firms to impart training to software developers and poorer quality software. Given the nearly guaranteed loss of experienced software developers whose work for Indian firms is viewed as a stepping stone to a job in the U.S, firms may decide in the future not to invest in the

[28] A higher estimate of this number in 1999 is around 71,000 software developers (Arya, 1999) although current estimates are that nearly 50% of last year's quota of 115,000 H1-B visas went to Indians.

identification and training of engineers with managerial potential. Any change in the current situation (recession) in other sectors of the Indian economy could lead to a shortage of graduates for the software development industry at the entry level as well.

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Appendix 1

Table 2
Engineering and Managerial Institutions Approved by the AICTE along with Student intake in 1998.

ZONE & STATE	Engg. & Tech (Degree)		Engg. & Tech (Diploma)		MBA		MCA		Other PG	
	Instns.	Intake	Instns.	Intake	Instns.	Intake	Instns.	Intake	Instns.	Intake
Central										
Madhya Pradesh	30	5675	55	7730	25	2570	13	390	12	1024
Eastern										
Arunachal Pradesh	1	210	1	180					1	54
Assam	3	660	9	1255	5	330	2	60	7	134
Andaman & Nicobar			2	170						
Manipur	1	150	3	215	1	30				
Meghalaya			2	190						
Mizoram			2	260						
Nagaland			1	90						
Orissa	20	3795	26	4144	25	1128	15	480	5	487
Sikkim			2	270						
Tripura	1	120	1	125						
West Bengal	19	3492	43	5475	14	2180	1	30	10	1377
Northern										
Bihar	12	2385	29	3824	14	1670	1	30	8	804
Uttar Pradesh	51	9030	107	14345	82	7150	19	580	19	2217
North-western										
Chandigarh	3	530	4	640	1	150			7	400
Haryana	27	4095	29	4370	15	1125	4	120	4	211
Jammu & Kashmir	8	1060	12	2870	5	240				
New Delhi	6	1490	26	4917	30	5600	1	30	8	1090
Punjab	19	3810	36	6755	10	640	2	60	6	483
Rajasthan	11	2129	24	2783	20	1260	1	60	6	614
Himachal Pradesh	2	350	4	695	1	60				
Southern										
Andhra Pradesh	88	20285	89	14945	108	5019	101	3050	17	1414
Pondicherry	2	540	4	622	1	60	3	90	4	100
Tamil Nadu	129	32160	207	43634	105	7565	106	3760	38	2985
South-western										
Karnataka	70	24752	188	33025	43	2487	24	770	33	2021
Kerala	19	4860	50	7880	10	510	3	120	5	759
Western										
Gujarat	20	4850	38	7400	20	220	2	60	10	1035
Maharashtra	118	28985	168	31215	115	12230	11	330	40	2362
Goa	2	330	8	1100	2	120			2	85
Daman & Diu			1	90						
	662	**155743**	**1171**	**201214**	**652**	**52344**	**309**	**10020**	**242**	**19656**

Source: AICTE web site: http://www.aicte.com/approved_inst.html

Table 3: Software developers Potentially Available for Employment in Software Development firms

	Degree	Number of Software developers (1996)	Number of Software developers (1998)
Grad	Doctorate (PhD's)	95	95
Grad	Master of Technology (M.Tech)	2,050	2,130
Grad	Master of Science (M.Sc)	2,250	2,800
Grad	Bachelor/Master of Computer Applications (BCA/MCA)	5,050	7,700
Grad	Post Graduate Diploma	3,000	5,000
Undergrad	Bachelor of Technology (B. Tech)	14,060	16,160
Undergrad	Bachelor of Science (B.Sc)	2,800	3,200
Technical	Diploma	16,200	16,700
Technical	ITI/Certificate	15,000	14,000
	Total	60,505	67,785

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

Table 4: Current and Projected Demand for Software developers in IT-enabled Services

IT-enabled services	1998		2008 (Projections)	
	Employed	Rs. Crore	Can be employed	Rs. Crore
Back Office operations/ Revenue accounting/data-entry conversion	9,700	420	2,60,000	19,000
Remote maintenance and support	1,600	65	1,80,000	13,500
Medical Transcription/Insurance claim processing	3,800	140	1,60,000	11,000
Call Centers	1,400	40	1,00,000	6,000
Database services	1,000	45	1,00,000	6,500
Content development	5,500	270	3,00,000	25,000
Total	23,000	980	11,00,000	81,000

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

Table 5

Coding scheme for Advertisement data

INDUSTRY:
1. COMP APPLICATION
2. COMP NETWORKING
3. COMP SYSTEMS
4. BANKING\INSURANCE
5. CONSULTANCY
6. TELECOMMUNICATIONS
7. INTERNET \NEW MEDIA
8. BUSINESS SERVICES

FUNCTIONS:
1. SOFTWARE DEVELOP
2. CONSULTANCY
3. SYS MGMNT

QUALIFICATIONS:
1. DIPLOMA
2. B.E\B.TECH
3. M.E\M.TECH
4. M.C.A
5. B.SC
6. M.SC
7. PH.D
8. OTHER GRAD
9. NIIT
10.APTECH
11.OTHER NON-FORMAL
12.OTHER P.G
13.M.B.A
14.C.A.
15.LAW

SPECIALIZATION:
1. MECHANICAL
2. COMP SC\ENGG
3. ELECTRICAL
4. ELEC & COMM
5. ECO
6. ARTS
7. COMP MGNT
8. MATHS
9. C.A.
10.OTHER
11.SOFTWARE ENGG
12.P.G
13.GRAD
14.P.G. ENGG
15.DIPLOMA

Appendix 2

Carnegie Mellon Software Developers Skills Questionnaire 1999

Name: _____ 2. Age:_____

3. Educational Qualifications:

Institution	Graduation Year	Degree Awarded

4. Work Experience after graduation:

First Project:

Name of Firm:			
Project Title:			
Project Duration:	months	Duration you worked on Project:	months
Project Size:	man months	Rs./$:	
Job Title:			
Job Description:			
Prog. Languages used:			
Skills Used: (please indicate whether skills were imparted through: 1: College education 2: Training program 3: On the job exposure 4. Non-formal education 5. Own Efforts 6. Any Other)	Skill		Code

Appendix 3

List of firms covered by the survey and # of Software developers who worked in these firms on various projects in their career.

Firm Name	Frequency	Percent	Firm Name	Frequency	Percent
Accel	1	0.43	SSI	1	0.43
Aeronautical Development Agency	2	0.87	Satyam Computers	9	3.91
			Satyam Infoway	1	0.43
Aishwariya Freight Connection	1	0.43	Sherlock Infotech	10	4.35
			Smart Software	1	0.43
Aptech	1	0.43	Sonata Software	2	0.87
Asset International(Aptech)	1	0.43	Synergy Software Services	1	0.43
BEML	1	0.43			
BFL Software	3	1.3	Synmech Enterprises	1	0.43
BITS Computer Education	1	0.43	Systech Solutions	1	0.43
BSL Software	2	0.87	System Logic	3	1.3
Birla Consultancy	1	0.43	TISL	1	0.43
C-DOT	2	0.87	TVS Brakes India	1	0.43
CITIL	8	3.48	Tata Infotech	21	9.13
CMC	2	0.87	The Hindu	1	0.43
Citation Computer Consultants	1	0.43	UUNET India Ltd	1	0.43
			Value Software	2	0.87
Classic Tours and Travels	1	0.43	Wipro Systems	12	5.22
Computer Power	7	3.04			
Cybermedia Software	1	0.43	**TOTAL PROJECTS**	**230**	
Cybersource	1	0.43			
DSS	2	0.87	**TOTAL FIRMS**	**111**	
Datacom Computers	1	0.43			
Datacon	1	0.43			
Digicon India	3	1.3			
Dr. Reddy's Labs	1	0.43			
Funskool Software	1	0.43			
Development Centre	1	0.43			
Futura	2	0.87			
GCMMF	4	1.74			
HCL-HP	1	0.43			
Hardcore (Div. of Aptech) Hyderabad	1	0.43			
IBM	1	0.43			
IBM Global	14	6.09			
ICM Computer Consultants	2	0.87			
IDL Chemicals	1	0.43			
ITSpark	1	0.43			
Indotroniks International	4	1.74			
Infomatics	1	0.43			
Infosys	7	3.04			
Institute of Public Enterprises	6	2.61			
Intelligroup	13	5.65			
Intergraphics	9	3.91			
Jayram Cybernetics	1	0.43			
Link Software	1	0.43			
Lucent	2	0.87			
Maars Software	1	0.43			
Martian Computers	2	0.87			
Mastek	1	0.43			
Microaids	1	0.43			
NIIT	1	0.43			
NTS Computer Consultants	2	0.87			
OMC Computers	1	0.43			
Orchid Soft Systems	1	0.43			
Progressive Software	1	0.43			
Ramco Systems	27	11.74			
S/W Consulting	4	1.74			