Globalization and Offshoring of Software

A Report of the ACM Job Migration Task Force

William Aspray, Frank Mayadas, Moshe Y. Vardi, Editors

Overview

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Overview

1. The Big Picture

Over the past decade, low-wage countries such as India have developed vibrant, export-oriented software and IT service industries. Attracted by available talent, quality work, and most of all low cost, companies in high-wage countries, such as the United States and the United Kingdom, are increasingly offshoring software and service work to these low-wage countries. Trade (together with automation) cost many jobs in the manufacturing sector to be lost from the West and many developing nations in East Asia to increase their wealth and industrial prowess since 1970. Changes in technology, work organization, educational systems, and many other factors have caused service work—previously regarded as immune to these forces—also to become tradable. This trade in services, led by the trade in software and IT-enabled services, presents many opportunities and challenges for individuals, firms, and policymakers in both developed and developing nations.

Many people in the United States and Western Europe fear that sending software work offshore will cause wage and job suppression in the high-wage countries. Others believe that the process of getting good labor at lower prices will make the economy more productive, enabling the creation of new wealth and new jobs. Many people in the low-wage countries are excited by the economic development that their software and service industries are bringing them; while some are concerned about the side effects such as congestion, pollution, and loss of traditional cultural values. One thing that is clear is that the globalization of software is here to stay, so that policymakers, educators, and employers all need to address the realities of offshoring. This includes, for example, how to help people whose jobs are shipped to another country to get assistance with their careers, how to create innovative environments that help to create new jobs, and how to revamp educational systems for the realities of a globalized world.

"Offshoring" is the term used here. It is a term that applies best to the United States because, even though the United States does outsource work to Canada and Mexico, most of its work is sent over the seas—mostly to India, but also to China, Malaysia, the Philippines, and many other places. Germany, for example, also sends work across its borders, including to Eastern Europe, but there is no water—no shore—to cross. Some of the work that is offshored is sent to entrepreneurial firms established in these low-wage countries. Other times, multinationals headquartered in high-wage countries open subsidiaries in the low-wage countries to work on products and services for their world market. Multinationals may also open facilities in these low-wage countries in order to better serve the local market there, but that situation is not the primary interest of this study.

There are at least six kinds of work sent offshore related to software and information technology: (1) programming, software testing, and software maintenance; (2) IT research and development; (3) high-end jobs such as software architecture, product design, project management, IT consulting, and business strategy; (4) physical product manufacturing—semiconductors, computer components, computers; (5) business process outsourcing/IT Enabled Services—insurance claim processing, medical billing, accounting, bookkeeping, medical transcription, digitization of engineering drawings, desktop publishing, and high-end IT enabled services such as financial analysis and reading of X-rays; and (6) call centers and telemarketing. Our primary interest is with the first three of these categories, which are the ones most closely associated with the transfer of software work across national boundaries. However, it is almost impossible to study offshoring without at least at times considering the other three categories of work as well. This is because companies that do one of these kinds of software work may also do several other kinds of offshore work as part of their product and service line of offerings; and companies that send work offshore may send work of several kinds. Because companies and industries intermingle these categories of work, so does most statistical data that tracks this industry—and it is often impossible to disaggregate data to capture information about only the categories of work of greatest concern here. Thus we focus on the first three categories but discuss the others in passing.

The countries that send work offshore are primarily developed nations. The United States followed by the United Kingdom have been the largest offshorers, but other countries in Western Europe, Japan, Korea, Australia, and even India send work offshore. The countries that do the work fall into four categories: (1) those that have a large capacity of highly educated workers and have a low wage scale (e.g., India, China); (2) those that have special language skills (e.g., the Philippines can serve the English and Spanish customer service needs of the United States by being bilingual in these languages); (3) those that have geographic proximity ("nearsourcing"), familiarity with the work language and customs, and relatively low wages compared to the country sending the work (e.g. Canada accepting work from the United States, the Czech Republic accepting work from Germany); and (4) special high-end skills (e.g., Israeli strength in security and anti-virus software).

There are many drivers and enablers of offshoring. These include: (1) The dot-com boom years witnessed a rapid expansion of the telecommunications system, making ample, low-cost broadband available in many countries at attractive rates. This made it possible to readily transfer the data and work products of software offshoring. (2) Software platforms were stabilized, with most large companies using a few standard choices: IBM or Oracle for database management, SAP for supply chain management, and so on. This enabled offshoring suppliers to focus on acquiring only these few technologies and the people who are knowledgeable about them. (3) Companies are able to use inexpensive commodity software packages instead of customized software, leading to some of the same standardization advantages as with software platforms. (4) The pace of technological change was sufficiently rapid and software investments became obsolescent so quickly that many companies chose to outsource IT rather than invest in technology and people that would soon have to be replaced or retrained. (5) Companies felt a competitive need to offshore as their competition began to do so. (6) Influential members from industry, such as Jack Welch from General Electric, became champions of offshoring. (7) Venture capitalists pushed entrepreneurial startups to use offshoring as a means to reduce the burn rate of capital. (8) New firms emerged to serve as intermediaries, to make it easier for small and medium-sized firms to send their work offshore. (9) Work processes were digitalized, made routine, and broken into separable tasks by skill set—some of which were easy to outsource. (10) Education became more globally available with model curricula provided by the professional computing societies, low capital barriers to establishing computer laboratories in the era of personal computers and package software, national plans to build up undergraduate education as a competitive advantage, and access to Western graduate education as immigration restrictions were eased. (11) Citizens of India and China, who had gone to the United States or Western Europe for their graduate education and remained there to work, began to return home in larger numbers, creating a reverse Diaspora that provided highly educated and experienced workers and managers to these countries. (12) India has a large population familiar with the English language, the language of global business and law. (13) India has accounting and legal systems that were similar to those in the United Kingdom and the United States. (14) Global trade is becoming more prevalent, with individual countries such as India and China liberalizing their economies, the fall of Communism lowering trade barriers, and many more countries participating in international trade organizations.

At first it was believed that the only software work that would be offshored was low-level work, such as routine software maintenance and testing, routine business office processes, and call centers. Offshoring suppliers, however, have made strong efforts to move up the value chain and provide services that have higher value added because this is where there is the greatest opportunity for profit. Research and development, project integration, and knowledge process outsourcing such as reading X-rays and doing patent checking are increasingly being offshored. Today, some people believe that any kind of software or IT-enabled work can be offshored. While there is an element of truth in this belief, there are some important caveats. Some kinds of work have not been offshored. Even if it is possible to offshore a particular type of work, it does not mean that every job of that type actually will be offshored. In fact, there are a number of reasons why a company might not wish to offshore work: (1) the job process has not been made routine. (2) The job cannot be done at a distance. (3) The infrastructure is too weak in the vendor country. (4) The offshoring impacts too negatively on the client firm such as the client firm losing control over an important work element, losing all its in-house expertise in an area, or too high a loss of worker morale in the client firm. (5) Risks to privacy, data security, or intellectual property are too high. (6) There are not workers in the supplier firm with the requisite knowledge to do the job, which happens for example when the job requires application domain knowledge as well as IT knowledge. (7) Costs of opening or maintaining the offshore operation are too expensive. (8) There are cultural issues that stand between the client and vendor. (9) The company can achieve its goal in another way, such as outsourcing within its home country or consolidating business operations.

One might wonder whether IT is still a good career choice for students and workers in countries that offshore software and IT services work. Despite all the publicity in the United States about jobs being lost to India and China, the size of the IT employment market in the United States today is higher than it was at the height of the dot-com boom. Information technology appears as though it will be a growth area at least for the coming decade, and the US government projects that several IT occupations will be among the fastest growing occupations during this time. There are some things that students and workers in this field should do to prepare themselves for the globalized workplace. They should get a good education that will serve as a firm grounding for understanding the rapidly changing field of IT. They should expect to participate in life-long learning. They should hone their “soft skills” involving communication, management, and teamwork. They should become familiar with an application domain, especially in a growth field such as health care, and not just learn core technical computing skills. They should learn about the technologies and management issues that underlie the globalization of software, such as standard technology platforms, methods for re-using software, and tools and methods for distributed work.

2. The Economics of Offshoring

Much of the economic debate about offshoring centers around whether the theory of comparative advantage applies to the offshoring of software and IT services. Economists have argued on both sides of the issue. The arguments are sophisticated and nuanced, and the results often depend on whether the underlying assumptions hold in the current context. While a majority of economists are proponents of free trade, the underlying question is an empirical one and can be answered by analyzing reliable data when it becomes available.

The theory of comparative advantage states that if each country specializes in the production of goods where it has a comparative (relative) advantage, both countries can enjoy greater total consumption and well being in aggregate by trading with each other. Offshoring enables, for example, US firms to lower costs and save scarce resources for activities in which they have a relative advantage, while offshoring has led to significant employment and wage gains for Indian workers and rapid profit and revenue increases for Indian businesses.

What the theory of comparative advantage does *not* mean is that all members of society will benefit from trade. In general, imports of an "input" have economic effects that are similar to those of an increase in the supply of the input, namely, lower returns to the suppliers of the input, lower costs of production, and lower prices for consumers. If the input were a service, the wages and salaries of those producing the service would fall, but so also would costs for firms that are buyers of the service. In the exporting country, the opposite effects hold. That is, the returns to the owners or suppliers of the service or input increase and the wages of the employees at the service providers increase due to the higher demand.

Economists believe that trade generally leads to significant gains for society. These gains are not inconsistent with employment losses in specific sectors that will cause economic pain to the workers affected. To achieve an equitable result, many analysts believe that it is important to establish a safety net that provides income and training opportunities to affected workers. Components of the safety net might include extended unemployment benefits, wage insurance, and retraining.

A key assumption underlying the theory of comparative advantage is that the economy enjoys *full employment*. Thus, this theory is best thought of as a theory of the long-term, in which workers displaced by imports or offshoring find work in other sectors. By contrast, most popular discussions of the offshoring phenomenon tend to focus on questions such as "where will the new jobs be created" and "can the workers be retrained for these new jobs". In general, peering into the crystal ball to predict where and what types of new jobs will be created is both difficult and unrewarding. A dynamic economy such as that of the United States creates and destroys millions of new jobs in response to changes in tastes, and more importantly in response to innovations and advances in technology. There is no guarantee that the economy will continue to create these new jobs, but policy makers can take some comfort from the historical evidence that thus far it has managed to do so. The key to job creation is of course the ability of the economy to rapidly generate and adopt innovations—new types of goods and services, and productivity-enhancing process improvements.

In general, trade stimulates innovation and economic growth in both trading partners. Some, such as Ralph Gomory and Gregory Baumol, have argued that innovation opportunities create new possible conflicts of interest between trading partners. For example, insofar as offshoring stimulates, in countries such as China, innovation and productivity growth in goods and services where developed countries such as the United States enjoy a comparative advantage, this will cause the "terms of trade" to become less favorable over time for the United States. In other words, even if free trade is the best policy, it may well be that free trade, by stimulating innovation overseas, may impose long-term losses. However, Gomory and Baumol's analysis shows that this conflict of interest is present when the two trading partners are at similar stages of development. Since most offshoring involves countries at very different levels of development, this conflict of interest is presently unlikely.

In the IT services sector, there is a related concern. Currently, it is efficient to offshore "low-end" IT services, such as coding or maintenance, to a low-wage country while "high-end" activities, such as requirements analysis, design, and R&D, remain in the high-wage country. The concern is, however, that eventually the high-end IT activities would also move offshore. Were this to happen, the current technology leaders (United States, Germany, Japan, United Kingdom, et al.) may relinquish that leadership role. There is some anecdotal evidence that some IT process innovations are moving to low-wage, offshoring operations.

Most economists, however, argue that current technology leaders will not lose their technological leadership position. Even if production moves to other countries, history shows that in many industries the locus of production and the locus of invention are physically separated. There are two key resources required to remain at the center of innovation in software: access to talented designers, software engineers, and programmers; and proximity to a number of large and technically sophisticated users. Current technology leaders, and the United States in particular, currently dominate on both counts. More broadly, the United States has other important capabilities, including the best universities and research institutions, highly efficient capital markets, flexible labor markets, the largest consumer market, business-friendly immigration laws, and a large and deep managerial talent pool. As a result, the evolution of business in the United States has followed a consistent pattern: launch innovative businesses here, grow the business, and as products and services mature migrate lower-value-added components and intermediate services over time to lower-cost countries. Nevertheless, there are those who argue that globalization will diminish the comparative advantage of current technology leaders, which may lead to the loss of their current dominant position and create a long period of adjustment for their workers.

Data on current and future trends of offshoring leave much to be desired. First, the definitions of offshoring vary from one study to another, making it hard to compare statistics. For example, some studies count all service jobs, some count IT jobs, some include IT-enabled jobs, and some are simply not precise about what they are counting. Second, there is a question of what metric to use in measuring the extent and trends in offshoring. One might measure, for example, jobs lost in the developed country, jobs in the developing country's IT industry, or dollar value of business outsourced. In the case of each of these metrics, however, it is either difficult to make the measurement or the metric is not directly enough relevant to the offshoring situation. For example, it is difficult to calculate dollar value of business offshored because these are internal transfer costs for multinationals, which they may not be willing to report or do not report in an appropriately disaggregated way.

Projections of future trends are more suspect than data on the current situation. One type of projection identifies types of jobs that are vulnerable to offshoring. These vulnerability projections provide at best a high upper bound on expected job loss, and for this reason they are blunt policy-making tools. It may be that routine programming jobs are vulnerable to offshoring, but it is highly unlikely that every last one of them will be lost to offshoring. Moreover, even in cases where the methodology is sound and soundly applied, projections of any kind about the future are much less likely to be accurate than data about today's or yesterday's situation since it is difficult to predict all the factors that will come into effect over time.

Another important issue to consider is the source of the data. Data from the United States and many other national governments tends in general to be reliable. The US government, however, collects data to handle established policy issues. If a new phenomenon arises, the existing data sets may not be well suited to studying the new policy issue. This is the case with offshoring. US data on job layoffs and on service trade are both designed for other purposes, and there is widespread belief among economists that both seriously undercount offshoring trends. Data collected and analyzed by trade associations and consulting firms may be very useful, but there is skepticism in the economic community about the quality of these data in many cases because the methods for collecting and analyzing the data are often not made available for scrutiny, the data they collect (from members of their organization) may not be a representative sample of society as a whole, and these organizations have particular objectives in mind that they hope their data will bolster.

The United States is the source of the greatest number of offshored jobs and where the phenomenon has received the greatest attention. But even for the US, it is difficult to be certain of the extent of offshoring. Federal data is not very helpful, and most of the existing data comes from consulting firms. The numbers generally indicate that 12 to 14 million jobs in the United States are vulnerable to relocation through offshoring, and that annual losses have ranged from under 200,000 to about 300,000 service jobs from the United States to offshoring. The number of IT jobs is somewhat lower than these estimates because these estimates include service jobs such as working in call centers and sometimes other IT-enabled services such as business process and knowledge process offshoring. Importantly, these estimates do not include newly created jobs. The consensus seems to be that about 20% of US companies are currently offshoring work but that the percentage is rising. The current value of offshoring contracts from the United States seems to be in the $10 to 20 billion range, with an expectation of rapid growth. It should be remembered, however, that we do not know the methods used to arrive at these numbers and how independent the data from one consulting firm's study is from that of another.

Statistics for the entire world or for other individual countries are even harder to come by and more suspect than those for the United States. The annual dollar value of worldwide offshoring trade for recent years has been estimated to be between $1.3 billion and $32 billion, depending on whether certain exported products are counted and whether the numbers for multinational companies are included. An estimated 30% of the world's largest 1000 firms are offshoring work. Europe has lower levels of offshoring than the United States. It is estimated that only 5% of European businesses (of all sizes) are offshoring, and at most 2 to 3% of European IT workers will lose their jobs to offshoring by 2015. The United Kingdom has the highest rate of work sent offshore of any European nation, with an estimated 61% of firms now offshoring. In Germany, only 15% of companies are now offshoring, and perhaps a total of 50,000 German jobs have been lost to offshoring so far; however, there seems to be an increase in German offshoring in the recent past. Statistics about India show a vibrant IT industry, with annual growth of 20 to 30%, the vast majority of the growth coming in the export rather than the domestic market. Data on the rest of the world are too spotty to trust.

3. Understanding Offshoring from a National Perspective

The first countries to develop software industries primarily for export rather than domestic purposes were Ireland and Israel. The big player to come in a little later was India, beginning in the mid-1970s and growing rapidly from the late 1990s. To some degree, a global division of labor is beginning to form: India serving the English-speaking world, Eastern Europe and Russia serving Western Europe, and China serving Japan. But India is also providing service to Western Europe, and China provides service to the United States. In addition, there are many smaller supplier countries. The greatest attention is given in this report to the United States and India, the two biggest players.

The United States has historically dominated and continues to dominate the software and services industry, with about 80% of global revenue. It is highly dominant in the packaged services industry, with 16 of the top 20 companies worldwide, and slightly less commanding but still dominant in the software services sector, with 11 of the top 20 companies. This dominance is due to a number of factors, including a legacy of government funding of R&D, computer science research in the open US higher education system, early adoption by sophisticated users, the world's largest economy and market, and leading semiconductor and data storage industries that helped to spread the use of computing.

The centrality and dominance of the US industry has been a given during the past five decades. What is emerging is the globalization of the software and software services industry. This creates opportunities around the world for people and companies in both developed and developing countries to participate in this profitable industry. It also creates challenges for the former leaders, notably the United States, Western Europe, and Japan.

Software services is India's largest export. As a large developing nation, India faces many challenges, including high rates of poverty, corruption, and illiteracy; a substandard infrastructure; excess government regulation; and various other problems typical of a poor nation. These challenges are offset by a number of strengths, especially for software and services production. It has a long history of developing capable mathematicians. India is unique because of the large number of individuals with adequate English language capability, and also for the large cadre of Indian managerial and technical professionals working in North American and, to a lesser degree, in European high-technology occupations and organizations. For those who can afford it, India has a strong and highly competitive K-12 educational system emphasizing science and mathematics. Despite its democratic socialist tradition that involved large amounts of bureaucracy and state regulation, it has been a market economy and has a history of managerial education and competence. These assets have given India many advantages in establishing a software export industry.

India's software export industry began in 1974, when it began sending programmers to the United States to do work for the Burroughs Corporation. Political liberalizations related to trade in the 1970s and again in the early 1990s helped to support the development of the Indian software industry. Offering solutions to the Y2K problem helped the industry to grow substantially. The industry expanded beginning in the late 1990s, first by bringing back to India much of the software development, maintenance, and testing work it had previously done on the client's premises, then developing export businesses in business process offshoring, call centers, and research and development. India is moving up the value chain and is seeking people with considerably more skill than low-level programmers to do these higher value jobs. Software and service export firms in India are growing at 20 to 25% per year according to the best statistics available, and each of the three leading Indian software firms (Infosys, TCS, and Wipro) already employs over 40,000 people.

India is likely to continue to grow its software industry in scale, scope, and value-added. There is little reason to believe that offshoring as a process will end in the foreseeable future, but it could slow down. The enormous investment by leading software multinationals will expand the number of Indian project managers with strong managerial skills. This, together with the relocation of portions of startup firms to India, is likely to result in greater levels of entrepreneurship and lead to firms able to sell their skills on the global market. The offshoring of IT services and software for export will dominate the near future of the Indian software industry. There are several possible trajectories. Custom projects could become more complex and large, leading Indian software professionals to move from programming into systems integration and systems specification and design. The average size of projects Indian firms are undertaking has already grown from 5 person-years in 1991 to 20 person-years in 2003. As multinationals deepen their Indian operations, domain skills are developing in India and some other nations, so that managed services are likely to become more important; this will match global trends in the outsourcing of applications management and business processes.

Despite the fact that India's software production for the US market exceeds that of any other nation, it holds only a small share of the global market for all software value-added. The only part of the software value chain in which India has made substantial inroads is in applications development, where it has captured 16.4 percent of the world market. But applications development is only approximately 5 percent of the entire global software services market. This implies that there is much room for growth. In order to grow, the Indian industry will have to shift to more complex activities by securing larger projects, undertaking engineering services, integrating and managing services, or bidding on projects that include transforming a client's entire work process. India, however, will have some difficulty achieving this growth unless it strengthens its R&D capability.

Software offshoring to India is likely to grow, not only through the continued growth of indigenous Indian firms, but also because foreign software firms are increasing their employment in India in product development and particularly in software services. Competition is likely to grow between multinationals based in developed countries, such as Accenture, IBM, and Siemens Business Services, and the large Indian firms, such as HCL, Infosys, TCS, and Wipro, as the Indian companies expand their global reach and the multinationals expand their operations in low-cost countries. The Indian subsidiaries of multinationals play an important role in the development of India's software capabilities, because they are more willing to undertake high value-added activities, such as software product development, within their own subsidiary in India than they are to send the work to an Indian independent firm.

For at least the medium term, India should be able to retain its position of primacy for software offshoring from the English-language world. In the longer term, unless India makes an even greater effort to upgrade its universities and the technical capabilities of its graduates, China may become an important alternative destination.

China's software and services industry does not currently have a major impact on the world economy. The industry is highly fragmented into many small companies, few of which are large enough to take on large projects for developed nations. The hardware industry is well established in China, and in the future it may drive the software industry to a focus on embedded software. Unlike India, where the multinationals are focused mainly on serving the world market, in China multinationals are more focused on positioning themselves to serve the enormous, emerging domestic Chinese market.

Japan has the second largest software and services industry in the world, after the United States; and it is the fastest growing industry in Japan. Japan makes games software and custom software for the world market and packaged software for its domestic market. It imports a significant amount of systems and applications software from the United States; and it calls on China and India to provide custom software.

There are three typical patterns of Japanese offshoring. Most commonly, a Japanese firm will identify a need for custom software, contract with a Japanese IT company to provide the software, and the IT company will in turn contract with a Japanese subsidiary of a Chinese firm to do the programming work. This programming used to be done almost exclusively in Japan, but as the cost of locating Chinese workers in Japan has become expensive, more and more of the programming is being done in China. A second approach that is more recent is for Japanese firms to invest in China to form wholly owned subsidiaries or joint ventures with Chinese firms. A third approach is for multinational corporations to move programming and back-office functions of their Japanese subsidiaries to lower-cost locations, often in China. The Dalian software park in China is growing rapidly as a result of this emerging Japanese business. The amount of offshoring from Japan is still small, but cost pressures are likely to cause it to increase; and since Japan has such a large software industry, the opportunities for offshoring are considerable.

The European Union represents the second largest market in the world for software and IT services, after the United States. There are many differences, however, from country to country, and the European Union cannot be viewed as a unified, homogeneous market. The European software industry and employment patterns are different from those of the United States, with much more software production done in-house and embedded in physical products. This does not prevent offshoring, and certainly many leading European industrial firms are establishing offshore facilities to produce embedded software. Much of this employment is subsumed under R&D and other activities such as application-specific integrated circuit design.

About two-thirds of the work offshored from Europe is offshored by the United Kingdom. Continental European firms continue to lag UK firms in sending software work across their borders. The Germanic and Nordic nations have only recently begun to build offshore software and software service delivery capabilities, but firms with global practices such as SAP, Siemens, and others are moving rapidly to build their offshore capabilities in Eastern Europe, China, and India. The geography of European offshoring will be somewhat different from that of the United States in that Nordic and Germanic firms will use Eastern Europe and Russia in addition to India. Latin (Romance-language-speaking) Europe has been slower to begin offshoring, but now its major firms are sending work to Romania, Francophone Africa (particularly Morocco), and Latin America in addition to India. Despite these geographical differences, there is no reason to believe that the pressures to offshore software-related work will be substantially different than in the Anglophone nations. In part this is because the US-based multinationals with strong global delivery capabilities, such as Accenture, EDS, Hewlett-Packard, and IBM, are present and competitive in all European markets. European firms may continue to experience a lag due to union and government opposition to offshoring, but their cost and delivery pressures are similar to those experienced by US firms.

In Russia, software was a relatively neglected field during the Soviet era, but in the 1990s as the country transitioned to a market economy, many scientists and engineers moved from low-paid government and university positions into entrepreneurial firms and Russian subsidiaries of multinationals; and some of these people entered the software field. So far there are relatively few programmers. Wages are low. Technical skill level is high, but there is little project management experience. Software firms are typically small, not able to take on large international software integration projects. Nevertheless, the high skill level of the Russian research community, a legacy of its Soviet history, has led Intel and a few other multinationals including Boeing, Motorola, Nortel, and Sun to open R&D facilities in Russia.

4. Understanding Offshoring from a Company Perspective

Instead of examining offshoring by country, it is also possible to examine offshoring by the type of company. We will consider five types of firms. The first are large, established software firms headquartered in developed nations that make and sell packaged software. Examples include Adobe, Microsoft, and Oracle. As a general rule, the largest and most successful packaged software firms are headquartered in the United States; the notable exception is SAP in Germany.

Most large packaged software firms have global operations. In many cases, their offshore operations are for localization work for the local domestic market. However, particularly in the case of India, and also to some degree in Russia, the work is for development of their worldwide software packages. Locating in these low-wage countries enables these firms to have access to lower-cost programmers, many of whom are comparable in skill levels to the company's workers in the developed nations. This is not the only benefit. Having operations in other time zones can speed up production by facilitating round-the-clock production. These opportunities are encouraging major packaged software firms to expand their workforce in India and other lower-cost nations.

Offshoring will have a complicated effect on the packaged software firms. First, it might and likely will put employment pressure on developed nation software firms to decrease employment in the developed nations. On the other hand, the lower cost and faster production could allow the development of new features in old software and could contribute to the creation of new, well-priced software products, which would in turn increase income for these firms and perhaps lead to greater hiring.

Next we consider large, established software firms headquartered in developed nations that are large providers of software services. These companies may also provide packaged software, though not all of them do so. Examples include Accenture, EDS, and IBM. Software service firms have been among the fastest growing firms in the IT sector, and in general they are far larger than the packaged software firms. Firms coming from the software side (e.g., Hewlett Packard or IBM) and from the service side (e.g., Accenture) are converging. In the case of IBM, this has been through both direct hiring and its recent acquisition of the Indian service firm Daksh (with its approximately 6,000 employees). Hewlett Packard has built its global non-IT services to over 4,000 persons in the last three years, largely through in-house hiring.

Software services is in most respects a headcount and labor-cost business; these companies grow their revenues by hiring more persons. The multinational software services firms have been experiencing increasing pressure on costs due to competition from developing nation producers, particularly from the Indian service giants such as Infosys, TCS, and Wipro. This has forced the multinationals themselves to secure lower-cost offshore labor. Service firms such as Accenture, ACS, EDS, IBM, and Siemens Business Services operate globally, but only in the last five years have they found it necessary to have major operations in developing nations to decrease their labor costs. Today, the larger service firms, including Accenture and IBM, are rapidly increasing their headcount in a number of developing nations, particularly India. At the same time, these firms are holding steady on their developed nation headcount or gradually drawing it down. Given the ferocious competition in software services, there is little possibility that prices will increase substantially. This suggests that, for the large multinationals, the offshoring of services will continue to increase in both absolute numbers and percentages of their global workforce.

Next we consider firms headquartered in developed nations that have software operations but are not part of the software industry sector. This is the enormous and eclectic group of companies that provide all the non-IT goods and services in the economy. Software is now at the heart of value creation in nearly every firm, from financial firms such as Citibank, to manufacturing firms such as General Motors. Customizing, maintaining, and updating IT systems has become an increasingly significant expenditure for businesses in developed countries, and thus firms are actively trying to lower these cost. One way to lower them is to offshore the work to nations with lower labor costs.

It is difficult to estimate the amount of software work that is offshored by these companies. Businesses often do not break out this particular kind of expense, and if work is transferred to an overseas subsidiary, this is considered an internal transfer and may not be reported at all. However, it is clear who does the work. If it is not an overseas subsidiary of the company, then it is likely to be one of two other kinds of firms that provides the service: a large service firm from a developed nation (e.g., Accenture, CapGemini, IBM, and Siemens Business Services) or a firm from a developing nation (e.g. Infosys or TCS in India, Luxoft in Russia, or Softech in Mexico).

It is not certain whether offshoring will lead to a decline in the number of software service employees employed in the developed nations. In the current economic recovery, existing firm headcount throughout the IT sector in the United States appears to be stagnant. In other sectors, limited data are available. For example, in financial services it is unknown as to whether the increasing headcount in developing nations has had any impact on employment in the developed nations. The most that can be said is that non-IT firms are increasing their IT employment in developing nations to serve the global market, and this trend is underway across many different firms, including industrial firms such as General Electric and General Motors.

Next we consider software-intensive small firms, particularly startups, based in developed nations. For small startups, offshoring is often a difficult decision, although more recently a number of firms in the United States have been established with the express purpose of leveraging lower cost offshore skilled engineers. For many smaller firms, an offshore facility can be demanding on management time. This is especially true in India because hiring and retaining highly skilled individuals is difficult. The protection of intellectual property, which is typically the most important asset that a technology startup has, is problematic in India and especially China. There is substantial anecdotal evidence that, despite these challenges, under the pressure from their venture capital backers and the need to conserve funds, small startups are establishing subsidiaries abroad, particularly in India, to lower the cost and increase the speed of software development.

A pattern is emerging for US startups. They may initially use outsourcing to, say, an Indian firm as a strategy, but many soon establish a subsidiary in place of the Indian firm. They do this for a variety of reasons, including worries about intellectual property protection, control of the labor force, and management efficiency. The minimum size of an offshored operation is reportedly as few as 10 persons. If this report is accurate, then it may be possible for many more small firms to establish subsidiaries in developing nations than have done this so far. Unfortunately, data on the scale and scope of offshoring by startups are unavailable.

It is tempting to view offshoring by startups (whether to an Indian firm, say, or to their own overseas subsidiary) as an unmitigated loss of jobs for US workers. Nevertheless, the real situation is more complicated. Lowering the cost of undertaking a startup could mean that the barriers to entry are lowered, thus encouraging greater entrepreneurship. The jobs created by this entrepreneurship should be counted against those lost by offshoring. So, correctly estimating employment net effect of offshoring in the case of startups is very difficult.

Finally, we consider firms in developing nations providing software services to firms in the developed nations. The availability of capable software programmers in developing nations provided an opportunity for entrepreneurs and existing firms to offer programming services on the global market. It was in India where this practice first began in a significant way. Because telecommunications links were not so sophisticated, the Indian programmers initially were placed in the US customer's premises. This practice was profitable and gradually expanded to include remote provision of services – often to do Y2K work—when telecommunication improved and demand heated up in the late 1990s. These developments created an environment within which major corporations were willing to experiment with overseas vendors, and a sufficient number of these experiments were satisfactory. The result was that offshore vendors, particularly Indian firms, were validated as candidates for software-related projects. These projects also allowed offshore vendors, again particularly Indian firms, to grow in headcount, experience, and financial resources, so that they could undertake larger and more complicated projects.

Software services firms from a number of the developing nations have become players in the global economy. The large Indian firms (HCL, Infosys, Satyam, TCS, and Wipro) are at present the global leaders. However, in China, Mexico, and Russia there are growing software service firms that employ between 1,000 and 5,000 people. Currently, the firms from other nations are not large enough to compete with either the multinationals headquartered in developed nations or the large Indian firms. Medium-sized firms in other geographies can, however, reduce the risk for customers of having all their offshore work done in one country, where it might be interrupted by a natural disaster or by political or military problems. The larger multinationals and Indian firms are also establishing facilities in other geographies, particularly Eastern Europe and, more recently, Mexico.

Firms are leading a global restructuring of the geography of software and software services production. They are experimenting with a variety of strategies meant to utilize workers that have become available in the global economy. This is true of software product firms as well as multinational and developing-nation software service providers. The impact of firms outside the IT sector with large internal software operations transferring some of the software operations to lower-cost environments has been less remarked upon; however, should the current trend continue, this will have a substantial effect on IT employment. These firms have already relocated a significant amount of work from high-cost to lower-cost environments, and this process appears likely to continue, and possibly accelerate, as firms become more comfortable working in developing nations. The offshoring of startup employment bears particular observation because the US high-technology economy in particular is dependent upon the employment growth that small startups provide.

5. The Globalization of Research

IT research is concentrated in only a few countries. About a third of computer science papers come from the United States alone. A few additional traditional centers of concentration of IT research (Australia, Canada, France, Germany, Israel, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom) account for about another third.

This is not surprising considering the large part of world Gross Domestic Product (GDP) concentrated in these same countries. There is a correlation between Purchasing Power Parity (PPP) Adjusted Gross Domestic Product and computer science publication. However, the share of computer science paper production by scientists in the traditional centers of concentration of IT research is more than 60% greater than their share of world PPP GDP (65% vs 40%). In contrast, Brazil, China, India, Indonesia, Mexico, and Russia together account for 27% of world PPP GDP, but only 7% of computer science paper production.

IT research was even more concentrated in the past than it is today. The initial bloom of IT research occurred in a few select locations in the United States and a few other countries in the aftermath of the Second World War. This concentration has been perpetuated by the natural tendency of strength to build on strength. Particularly in the United States, this bloom was driven by ample government funding and a significant migration of scientific talent from the rest of the world. In fact, there is little doubt that government funding has played an important role in most countries. For example, on a *per capita* basis government funding is significantly larger in Sweden and Israel than in the United States. The pattern of strength in only few countries is amplified by a general migration of scientists from countries that do not support graduate education and research to countries that do.

Research-driven innovation is seen by many countries as a way to increase national wealth and standard of living. Both developed and developing countries are attempting to build up or shore up their research capabilities. This means greater competition among nations in the research area, and in particular competition for talent. Until recently, the United States had won the research talent competition, but that situation is changing. Due to strong efforts to foster research on the part of a number of national and local governments outside the traditional centers of research, IT research is slowly but steadily, and almost certainly inevitably, becoming more global. This globalization of IT research has been accompanied by a significant increase in the production of PhDs outside the traditional centers of concentration, and a reduction in the migration of researchers to these centers. In the long run, there is no obvious reason why IT research should be any more concentrated than world economic activity in general.

Globalization allows more and better people to participate in IT research. Increasing educational opportunities around the world means that more people are able to realize their research potential, thereby increasing the size of the IT researcher pool and the quality of the best researchers. A freer worldwide market in research means that potential funding for IT research can more easily be targeted to those that can most effectively and efficiently create research results. Both of these trends increase the amount of scientific advance that can be obtained from a given level of resources. There is little doubt that this is good for the field of IT and for the world as a whole; however, while we gain as a group, localities and individuals may end up suffering losses.

Globalization provides improved opportunities for people who live outside the traditional centers of concentration of IT research. It also provides improved opportunities for the best researchers, due to increased global competition for their services. It may, however, limit opportunities for other researchers in the traditional centers of concentration, for whom global competition may mean declining wages or even the loss of jobs.

6. Risks and Exposures

Businesses that make offshoring and outsourcing decisions increase their own exposures to risk, and at the same time potentially create additional risks and exposures at many other levels, all the way from individuals to nation-states. Many of these other communities of interest have scant awareness that they are being exposed. For every risk of privacy invasion into an employee database that an employer might fear, data about ordinary citizens is exposed to tens of risks. Bank records, transaction records, call center traffic, and service centers are all offshored today. Voluminous medical records are being transferred offshore, read by clinicians elsewhere, stored and manipulated in foreign repositories, and managed under much less restrictive laws about privacy and security than in most developed countries. The higher exposure to terrorist incursion, sabotage, or extortion attempts has not received wide discussion by companies employing offshore labor.

A basic principle of security is that the longer the supply chain and lines of communication, the more opportunity there is to attack them. The inherent difficulties in international data communications are compounded by jurisdictional issues regarding regulation and legal responsibility. Offshoring risks include data communications vulnerabilities, loss of control of business processes, loss of control over network perimeters, increased network complexity, clashing security policies and procedures, gaps in personnel security, and drastically diminished ability to know about and respond to security breaches.

What seems particularly lacking within many procuring companies is an overall line of authority and responsibility for primary data records as they pass through one, two, or more subsequent offshore companies that perform work on the data set or perform operational tasks for one purpose or another. Such *"hands-off"* management responsibility cannot be presumed to work in the best interests of anyone concerned with risk attenuation.

Risks turn into incidents through two basic kinds of action—accidents and intentional acts. The vast majority of incidents that can be anticipated originate with threat actors: rogue employees, hackers, criminals, organized crime syndicates, industrial espionage, unfriendly nation-states, and terrorists. Effective risk management strategies include security due diligence, business due diligence, active risk management, and third party auditing.

Commercial risk from offshoring is multi-faceted and different from security risk. Business issues are primarily operational—concerning productivity, efficiency, and quality. Business managers everywhere struggle with costs, delivery times, and product quality. Geographic and cultural spread can adversely affect the latter two even as costs seem to be reduced. Communication paths become longer and more convoluted; they are more apt to suffer distortion and error from language and cultural difference. Supply chain networks become more diverse, less centralized, and hence less controlled. Protection from manufacturing sabotage and theft becomes more difficult because of the breadth of the system. Intellectual property protection becomes more porous as the infrastructure expands on an international scale. Legal barriers and costs increase as companies cross international boundaries, due to conflicting regulations, procedures, and practices. Safety issues are exacerbated by decentralized operational logistics.

The most contentious and perhaps most challenging aspect of offshoring is its risk impact on individuals. Individuals are often pawns in this global restructuring of business. They are at risk of loss of privacy, loss of jobs, loss of property through identity theft and credit card fraud, and loss of security. Moreover, they have little say in these business decisions and little they can do to protect themselves.

Offshoring adds threats and vulnerabilities that do not exist in domestic outsourcing, and increases vulnerabilities that exist in all inter-network commerce. Multiple legal jurisdictions add new risks. Distance adds complexity and vulnerability because cyber-space is actually a complex of real-world service providers in distinct jurisdictions with varying cultures, all under cost pressures. A company acting under a business culture not easily known to clients cannot be assumed to be exercising all the same precautions that might be common practice in the client business's country. As more and more countries provide offshore services, the price pressures on providers of outsourced services increase. With increased price pressures, the temptation to skimp on security measures gets stronger.

There are a number of steps that can be taken for protection. Data that is being transmitted should be encrypted. Offshoring providers should be vetted carefully. Companies should have security and data privacy plans and be certified to meet certain standards. Service providers should not outsource work without the explicit approval of the client. Mass export of databases should not be permitted. Data should be accessed one record at a time and on a need-to-access basis. The database should be encrypted. Certain types of data should not be allowed to be exported across national boundaries.

Offshoring can also place national security at risk by threatening both military and critical infrastructure operations. For example, the United States and other countries' IT-based military systems have adopted COTS (Commercial Off-The-Shelf) product purchasing strategies, shared national and international commercial infrastructures, and Internet Protocol technologies to facilitate network-centric warfare systems. It is more difficult for the buyer to gain insight into source and application code documentation for COTS products, especially if the providing companies are offshore. Many COTS components and sometimes whole systems are developed and maintained by providing companies, which may themselves procure development and services from other nations with privacy, intellectual property rights, security, diplomatic, and defense policies possibly at odds with the original procuring country. Thus, a COTS strategy increases the possibility of a hostile nation or non-government hostile agents (terrorist/criminal) being able to compromise the system or services. Attacks can cause malfunction and destruction of critical infrastructure such as transportation, power, and financial systems, and loss of citizen confidence in their infrastructure and government.

The offshoring of homeland security technology development and management systems that send vital information such as biometrics, identification codes, tax and personal information overseas are of critical concern. Until better controls of this information are developed, this presents a risk to all nations. Further research in methods to secure this data and the development of nation-to-nation and international treatment of both the data and how compromises will be handled is vital.

Globalization is here to stay and so are its international effects. National security and social effects can never be completely mitigated, but country-specific and international strategies can be put in place. Problems cannot be solved until they are defined and accepted as valid by a sovereign entity and its citizens. Topics needing national attention include legislation, international agreements, policing, tariffs, Internet policies, and more equitable tax-structure strategies for companies investing at home. Other topics needing public attention include more formal government-commercial agreements and funded research to address data protection and communications between stakeholders involved in homeland defense and critical infrastructure.

7. Education in Light of Offshoring

Offshoring creates major changes in the demand for workers. Some countries need more workers, others fewer. Offshoring also causes the set of skills and knowledge of workers to change. Education is a tool that enables a country to provide the skilled workers that it needs, and thus it can be the centerpiece of a national policy on offshoring. Developing countries that are building up their software service export markets, such as India and China, need to prepare growing numbers of people to work in this industry. The developed countries are facing questions about how to revise their educational systems to prepare their citizens for the jobs that will remain when other jobs have moved to lower-wage countries. These developed countries also have to find ways of making their education system serve to increase the technological innovation that has historically driven productivity gains, new employment, and new wealth for nations.

The United States has a well-established and complex IT educational system. The bachelor's degree is the primary degree for people entering a computing career. While degree programs appear under many names, five majors cover most of the programs: computer science, computer engineering, software engineering, information systems, and information technology. Although there are some differences among these five types of programs, they are many similarities in providing foundational knowledge related to computer programming, the possibilities and limitations of computers, how computers and computing work in certain real world applications, various skills about communication and teamwork, and other topics.

In addition to the five traditional kinds of departments, a variety of new academic units related to computing and information technology have begun to emerge in US universities. These include schools and colleges of computing that typically include the degree programs in computer science as one component, new schools that are separate from computer science and information science programs that fill an additional need in the computing and information technology space, information schools that in almost all cases evolved from library schools, and campus-wide multidisciplinary information technology institutes aimed at fostering collaboration of faculty and students across departments. While they are not the programs intended to produce ace programmers or deep technical experts, the mix of skills and perspectives is a reasonable educational experiment to try to produce students well suited for higher-value-added jobs. There is also rapid growth in degree programs offered by for-profit universities, which provide a convenient entry to the profession for working adults.

Non-degree programs also play an important role in US IT education. They include certificate programs, non-degree courses offered by traditional colleges and for-profit organizations, training associated with specific technologies, and corporate training programs. These alternative kinds of training programs appear to be growing rapidly, but it is difficult to quantify their extent or growth. There are many different goals being sought through enrollment in these non-traditional programs: training for a specific IT career, career advancement within the IT field, move from a non-professional to professional IT job, continuing education to keep technical skills current, or gaining specific product information or usage skills. There is also training provided by corporate universities for employees, customers, and suppliers, which might include technical training, background information about the company or its industry, or core competencies such as learning skills, communication and collaboration, creative thinking and problem solving, global leadership, or career self-management.

Recent changes in Europe, under the Bologna Declaration, have the goal of unifying the European educational system along the lines of American system of separate bachelor and master degrees. The Bologna process provides a standardized sequencing of degree programs, makes it less time consuming to obtain the first undergraduate degree, and makes the system more open for students who received their baccalaureate degrees in developing nations to enter masters programs without having to repeat some of their earlier training. The Bologna initiative has stimulated new interdisciplinary and specialized studies in computing within European universities, especially those incorporating domain-specific knowledge such as bioinformatics and media-informatics, and has also created separate programs in software engineering and telecommunications. The increasing uniformity of IT education across Europe will provide additional incentive for offshoring work from higher to lower wage countries within Europe; in the long run it may lead to a leveling of IT wages across Europe.

The German model is particularly important since the German-speaking nations represent approximately a quarter of the European population. There are some major voices in Germany in opposition to the Bologna initiative. For example, the T9 initiative, by the nine largest and leading technical universities in Germany, argues that the traditional model of university education leading to a diploma after nine semesters has considerable advantages over the system that leads to separate bachelor's and master's degree. It is unclear whether this will lead to modifications in the Bologna model over time.

India, as the largest supplier of exported software services, faces a different set of educational challenges from the United States or Europe, namely to ramp up its higher education system to staff its rapidly expanding software industry. Soon after India achieved its independence in 1947, a decision was made to invest a greater amount in higher education than is typical for a developing nation, even though there was not enough money to finance primary education for all. This decision was taken in part to support the efforts to build an educated workforce for the heavy industry that India's leaders envisioned would provide an important part of its revenue base. The investment in higher education was advantageous to India when it opened up its markets and began to participate more extensively in global trade in the early 1990s. There have been many competing claims on government funds, and the central government has not been able to keep up with the increasing demand for higher education. Policies were liberalized in the early 1990s, allowing the formation of new private institutions of higher learning, resulting in the rapid development of private postsecondary education. Whereas only 15% of engineering seats in university had been at private institutions in 1960, 86% are private today. The rapid advancement of the private university system has created some problems. Quality varies widely, from clearly substandard to the highest international quality, and the government has not established, much less enforced quality standards. Some Indians also object to the high tuition and fees as being counter to the equal access goals of the nation.

Today the higher education system in India is extensive and rapidly expanding. It currently includes more than 300 universities, 15,000 colleges, and 5,000 training institutions. Nevertheless, only 6% of the college-age (18-23 year old) population is enrolled in college or university. Some of the schools, such as the Indian Institutes of Technology and the Indian Institutes of Management are world-class; but the quality falls off rapidly after the top 15 schools. Total bachelor and master degree production in the computing and electronics fields is approximately 75,000 per year. There are also some 350,000 students in other science and engineering fields at universities and polytechnics receiving degrees each year, and many of them enter the IT industry upon graduation.

Training in the latest technology, English-language skills, and other work-oriented topics are also important to the Indian software industry. This training is offered both by many independent training organizations and some of the large IT companies such as Infosys and Wipro, which run their own training operations.

China faces the same educational issue as India in building a trained workforce for its software industry, but its approach is different, through centralized planning. When the Communist Party came to power, it was committed ideologically to education and the use of science and technology for economic development. Upon the establishment of the People's Republic of China in 1949, the Western powers pursued a policy of isolating China; a by-product of this was China's adoption of the Soviet Union's model of comprehensive and specialized universities and a large network of research institutes. In 1978, the Chinese university model was reformed to one that more resembled that of the United States and emphasized comprehensive universities. In the 1980s, China began sending many of its brightest science and engineering students to the West, especially to the United States, for graduate education. Nevertheless, the government research institutes within China are still enormous and play an important role in graduate education. Until recently, only a very few universities undertook research; their highest priority was pedagogy.

As in the case of India, Chinese universities graduate an enormous number of students every year. In 2001, 567,000 students received their first degree, including 219,000 in engineering and 120,000 in science. The quality of these graduates varies dramatically, but the sheer volume means that China has a large reservoir of technically trained individuals.

Until 2001, Chinese universities neglected software studies as an academic discipline. At the end of the 1990s, the Chinese government recognized that it had a shortage of trained software personnel and called for improvement in Chinese software capabilities as part of its central planning efforts. In response, 51 Chinese universities established masters degrees in software engineering. These degree programs quickly attracted students. Including all the different kinds of curricula, China is now training about 100,000 people per year for the software industry. There are internal criticisms of the education, including overemphasis on theoretical education, insufficient attention to practice, and lack of familiarity with international standards.

There are many challenges to implementing an educational response to offshoring. Consider the challenges in the United States. IT work encompasses many different occupations, each with its own skill and knowledge requirements. There are five major types of undergraduate degree programs in IT, and each would require revision in order to address offshoring. There are similarly four different degree levels (associate, bachelors, masters, and doctorate) to revise. Non-degree programs, such as certificate programs, corporate training, and non-traditional universities all also play an important role in preparing the IT workforce. There are multiple career paths in IT to take into consideration, not just the traditional one from a college degree to a career in the same field. Universities are slow to make changes in their employees and their course offerings. It is hard for national bodies to predict and match supply and demand for the IT workforce, so it is hard for the higher education system to know how to set its production levels. The mission of a university is not only to prepare tomorrow's workers; there are other goals such as research, preparing tomorrow's teachers, giving students a liberal education, and teaching them to think critically that must be considered when revising a university's program to address workforce needs. Offshoring itself is rapidly changing (from bodyshopping, to call centers, to business process outsourcing, to knowledge process outsourcing and other higher value added tasks), so how is a higher education system to know what occupations to prepare its students for? These challenges mean that educational systems will have to continually adapt to serve well their students and countries in the face of increased globalization.

Although the educational needs and issues may look different from different national or individual perspectives, this study has identified six overarching principles that should apply in developing as well as developed countries wishing to participate in the global software industry.

There is a need to consider the levels of IT work that are predominant in the national or multinational economy being served by the educational institution, and which are likely to be predominant in the coming years. Software and IT work can be thought of as consisting of a spectrum from the more routine (e.g. system and computer maintenance and support, basic programming) through the more advanced (e.g. application programming that requires knowledge of IT and specific applications, whether business, science, media or otherwise, or sophisticated systems programming and IT architecture development) to the advanced strategic (development of approaches that utilize IT to advance the organization strategically and provide it with a competitive advantage). As computer science and IT curricula are developed, particularly at the national level, it is important to consider the levels of workforce preparation to which the curriculum is addressed. In nations that are current recipients of offshored work consisting of programming and routine software testing and maintenance, for example, it may be desirable to focus the curriculum more heavily on the lower levels. This may change, however, as the roles played by IT professionals in these countries evolve and the offshoring providers aim to perform higher level work. In countries that are seeing their commodity IT work being offshored, it will be desirable for the curriculum to prepare students for the middle and upper levels of IT work, where the ability to merge computer science and IT with applications and strategy are important. This is likely to lead to an increased emphasis on application knowledge and a reduced emphasis on programming skills. It should be stressed that in all cases, however, the predominance of a certain level of IT work in a certain nation or region is just a generalization; all levels will exist in all countries, and students will be needed to move into all of these levels. It is the distribution that will vary.

There is a need for CS education to evolve, whether due to globalization or not. The skills and talents needed by software and IT professionals have evolved over the past half century, independent of issues such as outsourcing and offshoring. In general, IT professionals are more likely to work in an application-specific context than previously, and conversely, less likely to work on computer-specific areas such as compiler or operating system development. They are more likely to work on large software applications in teams that include applications specialists, and depending on the organization, also to collaborate with sales and marketing staff. They are also more likely to work in an environment where they are expected to be masters of certain software platforms and interoperability standards, and know how to reuse code. Thus in general, it will be increasingly important that a computer science or IT education involves training that enables the student to work on large-scale software applications, to understand important business, scientific, or other application areas, and be familiar with the tools and platforms that are increasingly the standards in the international marketplace. It also is increasingly important that the education emphasizes teamwork and communication skills, especially as they are practiced in a geographically distributed fashion.

There is a need for education to begin to prepare students for a global economy and its possible impacts on their careers. It is increasingly likely that an IT professional will be working in a global context. This may include being part of a multinational team, or collaborating with customers or suppliers from other parts of the world. Thus, it will be increasingly important that an education in computer science and IT help prepare students for this global workplace. Education that acquaints students with different languages and cultures, whether through courses, study abroad, or other means, will be increasingly beneficial. Finally, to the extent that English is the common language of the IT industry, the ability of nations to educate their IT professionals to be fluent in English will be a major factor in determining their success in the outsourcing economy and in multinational endeavors.

Educational systems that help prepare students to be creative and innovative will create advantages for those students and their countries. As the lower tiers of software and IT work become more commoditized, creativity and innovation will become even more important, particularly in countries that experience the loss of support and programming work. The creation of new products and new businesses will continue to lead to the greatest commercial and scientific successes, and even more, become the differentiator between organizations and between nations. Historically, some educational systems are seen as fostering creativity in students more successfully than others. One crucial differentiator in fostering a creative mentality in students is the research component of the educational system, and the participation of students at all educational levels in the university's research enterprise. Another differentiator is the degree of rote learning versus more open problem solving. Nations that currently have an advanced research enterprise in their university systems may increasingly see this as their greatest competitive advantage in educating computer science and IT students for the higher tiers of the IT workforce. Nations that do not include a research component in their university systems will need to consider whether, strategically, the investment in developing this component and culture is needed to attain their goals for the IT economies in their countries.

Educational systems that not only pay attention to current business and industry needs but also provide a core foundational knowledge will create advantages for those students and their countries. To cite two national examples, the Indian educational system has been particularly good at teaching the latest technology that is needed in business and industry today. The United States has been particularly good at teaching foundational knowledge that is likely to serve a student through most of his or her career. Foundational skills help students remain current, and not become obsolescent, as the technology changes rapidly around them. Although the particulars of a new technology in the workplace may be different from what a student was taught in school, a basic understanding of computing principles and ways of addressing problems will remain current even as the particular technologies change. Of course there needs to be a balance between fundamentals and currently relevant technologies in the student's education. In order to prepare students to be productive workers when they enter the job market, it also is important that the educational system pay attention to the current needs of business and industry and select the technologies it exposes students to in order to address industry needs. This goal can be achieved through respectful interchange between people in the academic and industrial/business worlds. No IT education can possibly fulfill all of the student's educational needs for an IT career, however, and IT workers should expect to have to engage in life-long learning in order to keep up with the rapid pace of technological change and the rapid changes in the way that organizations employ information technology.

A good educational system requires the right technology, a good curriculum, and good teachers. Fortunately, personal computers are relatively inexpensive, software for them has been commoditized, and fast, inexpensive broadband communication is readily available most places in the world. Thus, the technology for training an IT workforce is within reach of much of the world. The model curricula that have been designed by the professional societies have been and should be used in many places around the world. There is probably value in developing a process by which these curricula can have greater business and industrial input and react more rapidly to changes in the way that IT gets used in the world. Although adopted around the world, the model curricula have been designed primarily for degree programs in the United States. If the professional societies truly aspire to be world bodies and develop world curricula, they should pay attention to the needs of other countries and their degree programs as well. The teacher problem may be the most difficult one to address. For example, in the United States, there are serious problems with the preparation of high school teachers who introduce students to IT, and several times in the past (in the late 1970s and again during the dot-com boom of the late 1990s) American universities had difficulty recruiting and retaining quality faculty because of the lure of industrial IT positions, and had inadequate number of students obtaining doctorates, which are required to become faculty members. In India, critics complain about the general quality of IT faculty, salaries are low, and there have been no funds to enable research either by the faculty members or their students. Inducements to improve the quality of the faculty would be helpful in India, the United States, and other countries.

8. The Politics of Offshoring

Globalization, especially in its manifestation as offshoring, is a hugely disruptive force that effects the national movement of wealth and jobs. In addition to the educational responses to offshoring discussed above, countries might adopt political responses. Developed nations might take political action to stem the loss of jobs and wealth to globalization, either through protectionism or measures to make the country more competitive. Developing nations might take political action to create an environment in which its software export industry can flourish. Our initial focus here is on the United States, which is largest global offshoring procurer.

Public policy debate about offshoring began in the United States as a result of the wide news coverage of the report in November 2002 by Forrester Research that 3.3 million US jobs would be lost by 2015 as a result of offshoring. The most common response to offshoring in the United States has been actions by the executive and legislative branches of the state and federal governments to create protectionist laws and executive decrees to control the movement of work out of the country. Bills have been introduced that limit the citizenship or visa status of workers allowed to do work for US organizations or require that call center operatives working outside the

United States inform callers of that fact. There are reasons to question the legality and efficacy of this protectionist legislation. Some legal scholars believe that most proposed state laws and executive orders will be ruled unconstitutional because of the Commerce Clause of the Constitution, which leaves control of international commerce agreements in the hands of the federal rather than the state governments. Legal scholars also believe that proposed federal legislation on offshoring may break existing international agreements. There is also a risk of retaliation by other countries to protectionist American legislation.

A second policy approach has been to propose reforms to the H1-B and L-1 worker visa programs. The purpose of these programs is to help US companies find skilled workers, but critics claim that they are being misused as part of a strategy that enables companies to export jobs, especially to India.

A third approach is to ensure that US tax law provides no incentives to moving jobs overseas. These proposals would normalize tax rules between the United States and other countries so that US-based multinationals will have incentive to repatriate earnings to the United States that they earn in other countries. Tax law is hard to enact; and even if it were enacted, there would still be disparities because of costs of health care, safe workplace legislation, and environmental protection.

A fourth approach has been directed at providing support to Americans who lose their jobs through offshoring. In 1962, the US Congress passed the Trade Adjustment Assistance Act to offer job training and extend the length of time of unemployment benefits to American workers who have lost their job through trade agreements. There has been a political and legal battle over whether the Trade Adjustment Assistance Act does or should apply to software workers. Progressives want to go beyond this act and also require companies to provide three months of notification to workers whose jobs are to be eliminated because of trade, extend the term length of unemployment benefits, provide wage insurance paid for by the companies that offshore work to make up some of the drop in wages typical in the displaced worker's next job, improve retraining and reemployment services, offer temporary health care and mortgage assistance, and allow multi-year income averaging on federal taxes.

A fifth approach is to improve the innovation base. The basic idea is that, although some jobs will undoubtedly be lost to low-wage countries, America can produce a substantial number of new jobs, including many of them that are high on the value chain, through policies that create a climate of innovation. Innovation policy generally has four elements: making it more attractive for foreign students and scientists to work in the United States, improving the educational system in the United States, attracting US citizens to the science and engineering disciplines, and increasing federal support for research and development. There have been numerous criticisms that the United States is not now doing enough to build that innovation base, and there are proposals under discussion by both Democrats and Republicans in Congress, as well as suggestions from various non-profit organizations, to create new innovation initiatives.

How do policy issues in other countries that offshore work compare to those in the United States? Australia presents an interesting case study in the politics of offshoring in that Australia offshores work but is itself a country that has benefited greatly from free trade, both in terms of its important export markets for wheat, wool, coal, wine, education, and tourism, and also for the range of products that are available to its citizens through imports.

Debates over free trade arose in Australia over offshoring in 2004. There was sharp criticism from the opposition Labor Party to the lack of policies protecting Australian jobs and workers. Interestingly, the Australian Computer Society published a policy paper that advocated free trade and resisted any protectionist measures. Instead, it called for improvements in existing government programs to help displaced workers with re-training and re-tooling, check-lists that would educate Australian companies on the cost-benefit analysis of offshoring so that they would not rush headlong into it, and changes in industrial policy to enhance Australian R&D. The sitting Howard government was pleased with the report and outlined its own policy initiatives, which included more government support for displaced workers, an effort to increase foreign direct investment in Australia's IT industry, and various improvements in teacher training, educational programs, and educational assessment.

New Australian government data appeared this year, showing that many of the temporary visas for skilled workers are held by Indians, and many of these visa holders are doing programming work. These numbers concerned the Australian Computer Society, and they have taken harder-line positions on both the skilled temporary visa program (known as "457" visas) and on a permanent residence visa program, known as the General Skilled Migration Program. While still endorsing the basic immigration policy of the Australian government, ACS has called for adjustments in the 457 system to make it fairer. It has also called for the permanent immigration program (General Skilled Migration Program) to be substantially reduced until the market can absorb ICT graduates from Australian universities, Australian computer science enrolments begin to increase, and unemployment levels for computer workers fall to the level of other professions in Australia.

Sweden provides an example of the policy stance of a Western European country that engages in offshoring. The Swedish economy and welfare has benefited greatly from a long tradition of free trade, starting in the late 19th century. The policy includes agreements between employer and worker associations on the basic principles for wage setting and job assurance and a commitment to overall Swedish industrial competitiveness in knowledge-intensive and high-wage industries. This industrial policy caused Sweden to create one of the biggest high-technological industries in the world; and it has among the highest rates of investments in R&D and outputs in terms of scientific publications and patenting. Sweden has also become one of the most internationalized economies in the world, having a high dependence on foreign trade for its Gross Domestic Product. Part of its industrial rationalization is through offshoring to countries with lower production costs.

On several occasions, specific industrial policy measures have been taken by the Swedish government to support industries with low and decreasing international competitiveness. In the 1970s, considerable industrial support was given to the steel, clothing, and marine industries when they faced large-scale failures, but the measures turned out to be futile. As a consequence, Swedish policy has to a large extent returned to the basic policy principles of free trade, so in the current globalization trends Swedish policy is almost completely free from protectionist and direct job-protection arguments. There have, however, been a number of initiatives to improve Swedish competitiveness and counteract the negative impact of offshoring. They are all related to a new national innovation strategy advanced in the spring of 2004, which has three fundamental points: technological development and R&D as the key to Swedish competitiveness, investments in large-scale public-private partnerships to achieve centers of excellence in R&D for specifically targeted industries, and reorganization and increased funding for R&D startups and growth of small and medium-sized research-driven companies. Software is not explicitly mentioned in the plan. In Sweden, software development and production is primarily embedded in other manufacturing or service-providing value chains.

Turning now to the developing countries that export software service work, there have been significant policy issues at the national and state levels that have shaped the climate for the Indian offshoring industry. These include regulatory policy as it affects foreign direct investment, taxation, building an infrastructure, protecting intellectual policy, data protection and privacy, and education and training policy.

The regulatory history is the longest and most comprehensive of all Indian policies affecting offshoring. From the 1950s to the early 1970s, Indian economic policy focused on identifying ways for domestic companies to replace imports. Policies enacted in the 1970s that severely limited foreign ownership in companies operating in India drove out some multinationals, including IBM. Regulation in the 1980s promoted the development of the hardware industry and identified software as a promising export business; however, India had limited success in the 1970s and 1980s in building an indigenous IT industry. India was forced to liberalize its economy in 1991 in the face of severe cash problems. The new industrial policy included reduced licensing requirements in most industries, allowed foreign companies to hold majority interest in Indian companies in many industries, provided for automatic approval for hiring foreign technicians and foreign testing of technologies developed in India, and reduced restrictions on the ways in which mergers and acquisitions could take place.

Tax policy also had a shaping effect on the Indian software industry. In 1981, the Indian tax code was revised to establish tax-free zones on profits and gains for manufacturers, including software manufacturing. In 1993, the law broadened the tax-free zones to include various science and technology parks. The law was again broadened in 2005 to give tax breaks to software firms outside these parks.

Infrastructure policy also shaped India's software industry. Laws intended to build a favorable infrastructure and reduce labor regulations and other bureaucracy for the software industry were enacted primarily by individual state governments, mostly in the southern part of India. The one infrastructure issue subject to federal governance was telecommunications policy. Beginning in 1991, the telecommunications sector experienced a series of deregulations that continued until recently. Deregulation enabled the Indian software industry to have access to a completely modern telecommunications system with a capacity and cost that enabled the offshoring service companies to be internationally competitive.

China provides an interesting contrast to India. China is a policy-driven society, and one sees much more significant intervention of the state in the economic development of the software industry in China than in India. The national software strategy in India has been focused on the export service market, whereas the Chinese are interested in capturing their domestic software product and service markets as well as participating in the export market.

Until the 1980s there were mainly local rather than national companies in China. Much of the capital available to businesses was tied in one way or another to the state, and many of the decisions on capital allocation were made at the local level. Since then, internal trade barriers have been dropped, enabling companies to build scale and move into neighboring markets. In recent years, the national government has promoted economic reform through competition among provinces and growth for individual companies by access to capital through the national stock market. Consolidation and focus on the international market has not yet occurred in the

Chinese software industry. As of 2002, there were over 6,000 software firms in China; only 19 of them had sales exceeding $120 million.

Chinese policy towards forming technological capabilities has changed over time. From 1978 to 1985, the focus was on central planning and state control. In the period from 1985 to 1991, the focus was on enhancing the innovation system through greater state support for both public and private R&D. Since 1992, the focus has been on enabling market-oriented reforms to improve the quality of research and the skills of the workforce, and to broaden the focus on development beyond the defense and heavy technology industries.

The government has taken a strong hand is the development of trained personnel for the software industry. This included not only new educational programs, as described above, but also concentration of highly skilled software talent in certain geographic areas, by having the government facilitate transfers of skilled software personnel to the chosen places, including providing accommodation for their spouses and children. The Chinese government has also provided incentives for overseas Chinese software workers, especially managers, to return home through such incentives as cash payments, cars, houses, and promotions.

The Chinese government supports R&D in universities, research institutes, and to some extent industry. The best known of these initiatives is the Ministry of Science and Technology's High Technology R&D Program, known more commonly as the "863 program", which has provided more than a billion dollars of government funding for basic research since 1986. Other programs to provide research support include the Development Fund on Electronic Information Industry, an R&D Fund on Industrial Technology, and a Technological Innovation Fund. Although the government has continued to support important state research institutes, such as the institutes of the Chinese Academy of Sciences, there has been an effort to make them less dependent on the state and encourage them to reach out to obtain external funding sources.

The government has also taken steps to improve the competitive business environment. China does not have a long history of controlling anti-competitive behavior in a technological sphere, and it has thus had to pass a series of acts that protect a competitive environment, making illegal certain kinds of behavior such as impugning another company's reputation, bribing, threatening, and dumping. There have been targeted tax reductions to companies that meet certain sales and export figures. Exporting firms have been given favorable terms on bank loans, export insurance, and taxes and duties.

China has one of the world's worst software piracy problems. The Chinese government has taken a series of steps to try to curb piracy. In addition to the general copyright law, China has passed several laws targeted at fighting organized crime that is manufacturing and distributed copies of pirated software. Government organizations are coordinating anti-piracy campaigns, and are being encouraged to be model citizens themselves by using no pirated software. A registry system has been established, under which owners who register their copyrighted software are given extra protections under the law. However, software piracy remains a big issue.

Politics is one of the ways (together with education, consumer boycotts, and labor action) that nations can respond to offshoring. The general movement has been to avoid protectionist legislation. Australia and Sweden have completely espoused free trade even though they risk some level of unemployment for their IT workers. In recent years, India has moved away from its protectionist and isolationist politics of the 1960s and 1970s. The United States has had a number of protectionist actions suggested, but most of these efforts have not been enacted into law, and today there are calls for policies to enhance its competitiveness rather than to protect its jobs by legal and economic barriers. China is the most protectionist of the countries studied here.

All of these countries understand that they have to make their national laws conform to some degree with global practices if they want to be players in the global marketplace. Thus China, for example, has been willing to revalue its currency despite the short-term gain from keeping it artificially low; India has eased many of its trade barriers; the United States has entered into numerous international trade agreements; and Sweden has conformed to international monetary policies.

All of the countries studied here recognize that there are certain risks of sending software work across national boundaries. These include questions of intellectual property, privacy, and data security. Europe has taken the lead in strong privacy policy, and India has seen the economic value in meeting European and US standards on privacy. China is not so far advanced in managing these risk issues as India is, but there is every reason to believe it will have to do so if it wishes to continue to attract international business. China is struggling with balancing openness of information with political control, and so far it leans in the direction of control rather than individual rights.

For the developed countries that send work offshore, a common political approach is to build new jobs and prosperity through policies that increase innovation. Sweden is increasing government support for research and development, and there are calls for this to be done in the United

States. The two countries differ on parts of the innovation platform, however. Sweden currently has an abundance of highly educated workers, so it is not interested in ramping up its educational system. The United States is facing declines in foreign scientists studying and working there, as well as declining numbers of American students studying technical disciplines; so an integral part of the innovation platform for the United States is to improve the education system and attract foreign workers and students (to the degree this is compatible with national security policies).

India and China have a number of similar policies for developing their offshoring industries. Both are interested in ramping up their educational systems to supply an adequate number of skilled workers for their IT companies. Both are concerned about having adequate infrastructures (power, transportation systems, telecommunications) to provide good service to their IT companies. Both have adopted a series of policies intended to attract foreign investment. China has implemented policies to try to produce a reverse Diaspora, so that native-born scientists who have been working primarily in the United States and Europe return home to be part of the senior technical and business leadership in their IT industries; India has achieved this same effect without explicit national policies. India has more experience in developing policies to support the export software market than China, but China is advancing rapidly and has a more centralized government-planning model in place.