AN OVERVIEW OF WORKFORCE GLOBALIZATION

IN THE

U.S. IT SERVICES AND SOFTWARE,
U.S. SEMICONDUCTORS
AND THE
U.S. PHARMACEUTICALS
INDUSTRIES

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Executive Summary

The Consolidated Appropriations Act of 2004 (P.L. 108-199) tasked the Department of Commerce's Technology Administration to examine the impact and implications of workforce globalization in knowledge based industries. Three industries, representative of the United States innovative and competitive strengths, were selected for analysis: the information technology (IT) services and software industry, the semiconductor industry, and the pharmaceutical industry. This study also examines related business strategies and practices of U.S. companies within the industries, as well as the education and training approaches of select nations in developing scientific and technical workers. The key findings of this study are:

- **The United States business climate, large consumer markets, and a formidable research and university system remain magnets for business activity and continue to attract leading scientific and technical talent within these industries.**

- **Despite the challenges and risks associated with relying on foreign workforces, U.S. firms have and will continue to globalize in today's competitive global marketplace.** U.S. companies operate worldwide to be close to their global customers, both geographically and culturally, and to meet the round-the-clock expectations for customer service delivery. These companies are responding to their customers' demands that suppliers improve quality and efficiency, lower costs, offer more products and services, and reduce time to market.

- **U.S. businesses use workforces in other countries for a variety of reasons: cost savings, market expansion, increased focus on core competencies, and service of customers in other nations.** Access to labor pools in other countries allows U.S. companies to scale their workforces in response to constantly changing business requirements.

- **U.S. companies tap labor pools in other countries for specific segments of their operations, rather than the entire value chain of work, and appear to have maintained most higher-value work close to their home base.**

- **U.S. firms are dividing business processes into smaller discrete elements – rather than the traditional divisions of research, production, and marketing – allowing them to outsource pieces within a larger business process.** This can occur: through geography, as a result of dispersed centers; in particular components of a work process, such as semiconductor design or customization of a standard IT application; in work sharing, 24-hour operations with teams around the world; or through arrangements where companies work with affiliates in other locations.

- **The ability of developing economies to acquire sophisticated technology and to rapidly develop business and telecommunications infrastructure to support modern commerce allows the countries to attract foreign business investment and their domestic companies to compete with both U.S. and multinational businesses.**

- **Although, both India and China are attempting to develop national science and technology education systems that meet international standards, they face large obstacles in creating such systems.** Mass post-secondary enrollments in both countries reflect a movement from education of the elite to greater universal access.

- **Limits in available data make it difficult to quantify the effects of workforce globalization on an industry, worker displacement, national productivity, and economic growth.** The Commerce Department's Bureau of Economic Analysis and the Department of Labor's Bureau of Labor Statistics are seeking to create better measures to understand these trends.

Information Technology (IT) Services and Software

In the global competition for IT services and software work, the United States has capabilities and strengths that make it a choice location for work with certain characteristics. Other nations have different capabilities and strengths that make them attractive for work with different characteristics. U.S. IT services and software firms move work to where they believe it will be done most effectively and cost-efficiently.

- U.S. businesses tend to retain IT services and software work with the following characteristics in the United States: work with uncertainty in customer needs, projects requiring highly iterative development processes, and high levels of personal interaction with end-users; inter-disciplinary and complex application development work; work requiring high cultural understanding of the United States; work involving leading-edge research and non-rule-based decision-making; tasks requiring high levels of creativity, innovation, and management; process design and business analysis; technology and systems integration; and fusion of industry knowledge, high-level IT skills, and business process expertise.
- U.S. businesses are more likely to offshore IT services and software work with the following characteristics: work characterized by high wage differential with similar occupation/level in destination country, high labor intensity, clearly defined requirements with few nuances, repetitive tasks, rule-based decision-making and problem solving, documented or easily transferred content and process knowledge, low degree of personal interaction with end-users and clients, stable processes, long projected useful life, low-to-medium business criticality, and less time-sensitive, low-to-medium technical complexity, not multi-disciplinary projects involving standard hardware and software.

While industry groups have estimated that offshoring currently represents a small fraction (less than 3 percent) of United States IT services and software spending, the forecasts are for continued growth. However, the lack of detailed domestic and international data on workforce, industry, and trade prevents a strong quantitative assessment of the full extent of offshoring of IT services and software work, or an assessment of longitudinal trends.

The landscape for workforce globalization in IT services and software is complex, with different countries offering different skill sets and capabilities, varying wage rates relative to those in the United States, different levels of cultural compatibility with the United States, different industry structures, and different levels of sophistication in business and project management. For example:

– India, the leading offshore destination for U.S. IT services and software work, has a large and growing number of skilled IT workers with good English-speaking skills, many with engineering or IT degrees whose wages remain very low relative to U.S. IT worker wages. The indigenous Indian IT services and software industry is dominated by a handful of large companies with annual revenues of approximately $500 million to $1 billion. The largest business line of these companies is applications development and maintenance -- moderately skilled IT work often performed on behalf of or for large international companies.
– Although the Irish IT workforce is much smaller than India's IT workforce, its revenue levels are similar. The workforce comprises college-educated, English-speaking workers, with high cultural compatibility with the United States. Irish IT worker wages are much higher than those in India; though lower than those in the United States. Ireland's IT services and software industry is largely made up of smaller Irish-owned companies, though large IT multinationals have located there. While Ireland's workforce had initially focused on IT services work, it has shifted its focus to software products for niche markets. Private investment in IT-related research and development (R&D) in Ireland in 2002 totaled approximately $113.5 million. In addition, Irish academic institutions conducted an average of $63 million per year in IT-related research, some of it leading edge.
– The Russian IT workforce is smaller than both India and Ireland's IT workforce; however, it is more highly skilled than both, and is capable of working on the most complex IT projects. While the Russian IT workforce performs a substantial amount of applications development and maintenance, its portfolio of skills runs the full spectrum of IT capability, including software product development. Wages are comparable to those in India; however, English language capability is poor.

In addition to its complexity, the workforce globalization landscape in IT services and software is rapidly changing. For example:

– Large indigenous Indian IT services and software companies are growing rapidly -- both in terms of revenues and employment. They are expanding staff annually by the thousands. They are shifting the proportion of onshore and offshore work in their typical IT project management model with more work now performed in India, and they are also attempting to enter the IT consulting business through acquisitions and the creation of new divisions. Recently, Ireland's IT services and software industry shifted its focus from services to software products. Russian companies appear to be ready to expand their physical presence in the United States by establishing offices staffed with technical personnel.
– Venture capitalists are now encouraging U.S. IT start-ups to use lower cost offshore destinations for software development to reduce the "cash-burn rate."

- There is growing pressure in corporate America – from customers, consultants, and financial markets – to offshore IT work, as well as growing external and political pressure to stem the flow of American jobs going overseas.

The effect of offshoring on the competitiveness of the United States IT services and software sector currently appears to be negligible. While some foreign firms, especially Indian companies, have experienced rapid growth, they represent only a small fraction of the U.S. market for IT services and software. In addition, U.S. IT and IT consulting companies are establishing their own operations in other nations to directly tap foreign labor and to control their value chain. In the long run, U.S. companies may face new competitive threats as other nations develop their capabilities.

Offshoring has affected United States IT services and software employment; however, a variety of coincidental factors impedes quantitative assessment of the extent of the impact. After a decade of rapid employment growth, both the IT services and software sector and the IT professional occupations have experienced reversals in recent years. It is difficult to assess the extent to which offshoring has been the source of these employment declines, as the acceleration in offshoring coincided with a variety of other factors that affected IT employment, including: a downturn in the business cycle, the bursting of the Internet and dot.com "bubbles," the end of Y2K preparations, and the terrorist attacks of September 11, 2001.

- Industry employment: From 1994 to 2001, IT services and software industry employment grew at a compound annual growth rate of 11.9 percent to nearly 2.1 million, while from 2001 to 2003, it declined by 306,000 – a decrease of 7.7 percent.
- Professional IT occupational employment: From its peak in 2000, professional IT occupational employment fell by about 5 percent, or 135,000, through 2002, following a decade of sustained rapid growth. The impact has not been uniform; some IT occupational specialties have been hit harder, while others have continued to grow. IT occupational unemployment rates are at a historic high, far above the unemployment rates reached during the recessionary highs of the early 1990's. Bureau of Labor Statistics projections for 2002-2012 show strong professional IT occupational growth, but only half the number of new jobs projected two years ago.

United States IT services and software companies believe that they can realize many benefits from offshoring.

- The main driver for IT services and software offshoring is cost reduction. Offshoring offers direct labor savings of 70 to 90 percent, with total savings reaching 35 to 60 percent compared to performing the work in the United States.
- Other advantages include: the ability to quickly tailor a company's IT workforce in size and skills to meet business requirements, enabling a greater focus on core competencies, providing round-the-clock customer service, increasing the speed of product development, capitalizing on foreign nation incentives, and improving the ability to serve local markets. In addition, lower costs could increase the amount of innovation, both through direct savings and by enabling more projects to achieve a requisite return-on-investment hurdle rate.

However, there are a number of risks associated with IT services and software offshoring. They include: vendor/contractor management challenges, cultural and communication barriers, data security and confidentiality, impact on current employees morale and future recruitment, difficulty in effective knowledge transfer, time zone differences, inadequate telecommunications and other infrastructure, unexpected costs, risk to intellectual property, exposure/loss of core business knowledge, lack of offshoring management skills, geopolitical instability of destination nation, political backlash and negative publicity, foreign government impediments, and different work schedules.

Semiconductors

The United States semiconductor industry retains competitive strength and can generate accelerating job growth, despite challenges it faces from emerging competitors.

- The semiconductor industry in the United States operates in a dynamic economy, capital market, and business environment that allow entrepreneurs to take new ideas to market quickly.
- The U.S. industry has a particularly creative design sector. For example, the United States has the only "fabless" company, which focuses exclusively on design and development without silicon wafer fabrication and manufacturing, in the top 20 semiconductor companies worldwide.
- U.S. semiconductor companies work with leading research universities in cutting-edge research, developing new technologies, and training talent.
- The industry can draw on a large educated, skilled, and experienced workforce within the United States. Even though some workers in lower wage countries can match U.S. workers in technical skills and education, they lag behind U.S. workers in experience and management skills.
- The U.S. semiconductor industry maintains a historical advantage in intellectual property and dominates the lucrative microprocessor market.
- Despite past challenges from Japanese and Korean competitors, U.S. industry remains the leader in world market share in the sector.
- Although most U.S. companies are deciding not to invest in new manufacturing facilities, it appears that the United States will maintain a core of cutting-edge manufacturing within its largest companies.

U.S. companies have the leading share of global semiconductor revenues. Highly skilled workers within the U.S. semiconductor industry – including engineers in manufacturing, design, and R&D – remain mostly in the United States. Seventy percent of the U.S. semiconductor industry's engineers and seventy five percent of its labor compensation were paid in the United States. The majority of the industry's R&D, design, and cutting-edge manufacturing remain in the United States.

The U.S. semiconductor industry has an established history of outsourcing and offshoring. Fifty percent of the industry's employees and 30 percent of its engineers were in offshore locations in 2003. The industry has long maintained sales and marketing operations around the world, semiconductor design centers in proximity to overseas customers, and some R&D in the European Union (EU), Israel, and other areas. The industry has also offshored assembly, testing, and wafer fabrication to locations around the world.

Offshoring and outsourcing of workers within the United States semiconductor industry has accelerated due to the specialization of the industry, decreased rate of capital investments in new U.S. wafer manufacturing facilities, and the growth in the educated, skilled and available engineering workforces of lower-wage countries. The structure of the industry has changed from one dominated by integrated electronics companies to one in which firms specialize in different parts of the value chain: R&D, design, wafer fabrication, testing, assembly, or sales and marketing.

The present outsourcing and offshoring trends will increase the competitiveness of the U.S. semiconductor industry in the short term. Offshoring manufacturing relieves companies of large re-occurring capital investments, while offshoring design work reduces the cost and time to bring new designs to market. Outsourcing and offshoring greatly reduce the cost barrier for market entry for design firms and start-ups.

The main drivers of outsourcing in semiconductor manufacturing are to reduce capital infrastructure investments and to provide flexibility in production capacity in a highly cyclical industry. For example, a new state-of-the-art wafer fabrication facility costs $2-3 billion. Given these costs, U.S. companies are deciding to outsource wafer fabrication to foundries – most of which are in Asia – built with foreign government incentives. Use of foundries is expected to grow from 15 percent in 2002 to 34 percent by 2010. Outsourcing production is also a way to manage the cyclical nature of revenues and employment within the semiconductor industry.

The primary driver of offshoring in semiconductor design is to reduce labor costs and shorten the time to market. Fixed engineering costs for design are ten times that of fixed manufacturing engineering costs. The availability of skilled engineers in lower-wage countries and automation of design through the development of tools, standardization of inputs, and division of work into discrete modules has enabled offshoring of design to other countries. Automation increases the productivity of the design process, while using skilled engineers in low-cost countries reduces labor cost. For example, the cost of employing a design engineer in Ireland, Taiwan, China or India has been estimated to be 75 to 90 percent of that in the United States.

Some countries with educated, skilled, and available engineering workforces have made development of a domestic semiconductor industry an integral part of their growth model. The number of engineers employed offshore by U.S. semiconductor companies rose by more than 10,000 between 2000 and 2003, while engineers employed in the United States dropped by 4,000 during the same period, according to estimates by the Semiconductor Industry Association.

- Foreign nationals educated and trained abroad have become an important resource for their countries – particularly in India and China – because they can provide the mentoring, management, and on-the-job training workers in those countries need to become high value-added employees. A survey shows that 57 percent of Chinese graduates of U.S. universities plan to return home within 10 years, at which point they would have U.S. citizenship.

- Many manage foreign affiliates for U.S. multinationals. U.S. firms employed 4,000-5,000 workers in India (4.4 percent of U.S. non-production employees), where salaries are 80 percent less than those in the United States.
- Government planning and incentives in China and Taiwan have resulted in large investments in wafer fabrication plants. Excluding Japan, Asia is projected to build 74 percent of the world's new semiconductor manufacturing capacity compared to North America's 8 percent.
- Some economists predict that the U.S. share of worldwide semiconductor revenues could be further reduced with China's entry. China is seen as having the critical mass of educated engineers, available capital, and business incentives to foster a strong domestic semiconductor industry; it is the world's fastest growing semiconductor customer, has invested more than any other country in new semiconductor manufacturing facilities, and has momentum to attract talent.

Present outsourcing and offshoring trends have the potential to affect the U.S. semiconductor manufacturing workforce.

- U.S. manufacturing jobs for semiconductor operators, technicians, and engineers may decline if present investment trends continue. With fewer companies investing in new wafer manufacturing in the United States, process R&D co-located with leading edge facilities may also decline, resulting in fewer high-skill jobs for U.S. graduates.
- Offshoring of design work can also impose downward pressure on U.S. wages and reduce the demand for U.S. design engineers. As the number of overseas design centers increases, it may draw foreign talent from the United States.

Pharmaceuticals

The United States is widely recognized as the current global center for pharmaceutical research and innovation. This reflects a constellation of favorable circumstances in recent years for innovation and some the result of deliberate U.S. policies and initiatives.

- These factors include: abundant support for pre-competitive research (most notably National Institutes of Health basic research), a continuing stream of U.S. scientific achievements, a strong pool of world-class scientific talent, strong business and capital market support for aggressive development and commercialization of potential new therapeutic drugs, an attractive U.S. marketplace that is the world's largest, and a well-established government regulatory regime for approving the market entry of new pharmaceuticals.

The pharmaceuticals industry is considerably global in scope and scale.

- The industry's top ten companies account for about 46 percent of global sales. Five of these companies are headquartered in the United States. All of the top ten indicate

production chains for research, development, manufacturing, marketing, and sales widely around the globe.
- The rest of the industry is composed of a large number of companies with varying product mixes, market geography, and production activities.
- The industry's largest and most successful companies perceive the markets for their products to exist beyond the shores on which they are headquartered. The industry's smaller companies also appear cognizant of global opportunities for product sales and sourcing of production activities.

While it has been a particularly successful sector of the U.S. economy for some time, the pharmaceuticals industry is a modest employer domestically. The industry directly employs about 294,000 workers in the United States.
- The industry's overall employment growth in the U.S. has averaged about 2.5 percent annually over the last five years. About 27 percent of these workers are engaged in scientific, professional, or technical activities.
- These employment figures do not account, however, for services provided by contract research organizations or for university and non-profit R&D organizations working in collaboration with pharmaceutical companies. These are important ancillary components of the pharmaceuticals innovation and production cycle, but their numbers are not well documented statistically.

Public data, currently available on pharmaceutical industry jobs from government and industry sources, do not enable a concise picture of the United States current employment share relative to the global industry or of the relevant employment growth trends.

Further consolidation of the industry globally, through mergers and acquisitions, is likely in the years ahead. Factors underlying this expected trend include:
- The industry's economic fundamentals, particularly the high cost and risk of research and product development, will relentlessly push management to search for reorganization opportunities, asset configurations, and investment portfolios with the promise of improved efficiencies and economies of scale and scope.
- Also, the increasingly global nature of the life sciences research enterprise will provide numerous opportunities for companies to incorporate creative new elements into their capabilities.

Pharmaceutical innovation will remain a growth opportunity globally for many years to come. The basic science frontier is likely to continue to advance at a fast pace (building on the recent progress in genomics and related molecular biology fields). This will open many new opportunities for pharmaceutical innovation.

With continued scientific strength and sufficient incentive for industry to take on and invest in the difficult and expensive task of new pharmaceutical development, the United States should retain its role as world leader in pharmaceutical innovation. There are, however, some challenges and issues now arising that must be overcome:

- Capabilities for strong science and technology in the life sciences arena (human talent, resources, and infrastructure) are growing abroad. Many other countries (in Europe, Asia, and Latin America) indicate strong future aspirations in the biosciences, biotechnology, and associated industries and markets. Some of this reflects country desires to respond to domestic healthcare needs, some to interest in eventually competing with unique products in the global pharmaceuticals marketplace. Aggressive efforts are now underway in Europe, some parts of Asia, and elsewhere to plan, invest in, and develop a globally competitive life sciences industry.
- National policy debate in the United States related to healthcare cost containment and cost effectiveness, and to the boundaries of acceptable life sciences research, has the potential to influence the risk and return expectations pharmaceutical companies will have in considering future investments in research and new drug development.
- There are numerous scenarios regarding how these various factors may play out over the next 5-10 years. In most cases, the U.S. part of the global pharmaceutical industry should remain on a path of significant business and employment growth – reflecting the comparative strength the U.S. industry currently enjoys relative to other players. It may be, however, that investment incentives and the global geography of capabilities and infrastructure will shift in the years ahead in ways that will help other countries' pharmaceutical industries take on a larger role than at present in the global pharmaceutical innovation engine.

Education and Training in Other Countries

The United States has historically been a leader in higher education and training, but other countries are beginning to provide comparable access to and quality of education. For example, in 2001, 30.4 percent of the 24 year-old population in Taiwan had bachelor's degrees, 26.8 percent in South Korea, as compared to about 33.8 percent in the United States.

Both China and India, with their large populations, have realized dramatic increases in the numbers of students entering secondary education, especially in science and engineering. These increases have allowed them to compete for tasks historically the purview of developed nations such as tasks in production, R&D, and services.
- While China and India have low overall enrollments as a percentage of their populations, they are closing the gap with the United States in terms of absolute number of degrees earned. Some 2.9 and 4.2 college students per hundred people in China and India, respectively, earned science and engineering degrees in 2001.
- In 2000, China awarded 337,000 science and engineering degrees compared to 398,622 for the United States, while estimates for India range from 392,000 (1997) to about 630,000 (2001).

Despite the movement to improve secondary education systems in science and engineering to international standards, both India and China need to surmount several challenges.

- Challenges in India include: increasing enrollments and stagnant state expenditures, inadequate policy framework for private financing and philanthropy, minimal university research budgets, non-competitive faculty compensation packages, outdated facilities, and rigidly bureaucratic academic structures.
- The demand for IT professionals in India has spurred the growth of private training institutes providing short- and long-term training; however, the quality of instruction at these institutions varies widely.
- Examples of challenges in China are: massive expansion in enrollments coupled with drastic reforms to transform to "world class" standards, a science and technology base that is heavily dependent on the government's ability to attract foreign direct investment and outside expertise, and obsolete and poorly funded government research institutes.

With the promise of improved economic environments in their home countries, foreign nationals educated and employed in the United States are now attracted to returning home instead of remaining here.

- China is making great efforts to bring back U.S-educated Chinese scientists and engineers to work on or start new businesses, and U.S. stay rates for Chinese graduates are beginning to decline. While NSF data indicated almost 95 percent of U.S. science and engineering doctoral degree recipients from China reported that they had plans to remain in the United States (1985-2000), a different survey (2001) reported that 21 percent had plans to go home within 5 years, 36 percent had plans to go home within 5-10 years, and 23 percent had plans to go home after 10 years.
- The Taiwanese government has estimated that Taiwan will need an additional 10,000 engineers if the country is to realize its goal of becoming a larger center for the design and engineering of sophisticated products like semiconductors. The government is also offering incentives such as tax breaks and direct subsidies to recruit multinational companies to set up R&D operations in Taiwan.
- The Philippines has a relatively small base of IT workers, and its government is attempting to create a local base of IT work by stimulating the development of domestic IT companies.
- The Irish government is also taking steps to ensure a steady supply of IT workers. Ireland is a key IT offshoring destination and is the largest exporter of software in the world outside of the United States. Government plans include support for in-company training, inter-disciplinary learning at universities, recruitment of women and disadvantaged groups, and favorable immigration policies to attract foreign students.

Summary of Findings

This study responds to legislative language in the Consolidated Appropriations Act of 2004 (P.L. 108-199) that required the Technology Administration to conduct an "assessment of the extent and implications of workforce globalization in knowledge-based industries such as life sciences, information technology, semiconductors and financial services." The language also directed that the assessment "focus on U.S. firms' business strategies and practices, as well as the education and training programs in countries such as Japan, China, and India."

This study will help guide and highlight critical workforce globalization issues for on-going reviews affecting the current debate on outsourcing and offshoring. It focuses on the forces driving worker globalization and the business strategies and practices of U.S. companies as they relate to their global expansion.

The analysis examines the effect of workforce globalization in key U.S. industries, especially those industries that contribute to a high national standard of living. Industries included in this study are information technology (IT) services and software, semiconductors, and pharmaceuticals. It focuses on two aspects of these industries: the extent and implications of workforce globalization, and related U.S. business strategies and practices. The review also includes an assessment of secondary education and training programs in China and India, with brief overviews of the scientific and technical workforces in China, India, Russia, Taiwan, the Philippines, and Ireland.

Background

This study examines workforce globalization in three key U.S. industries and related business strategies of U.S. and foreign companies within these industries. It explores the challenges and opportunities U.S. companies face in serving a global market, and the drivers for workforce globalization. It examines the reasons why companies may choose to offshore and examines challenges posed by the shift of work to alternative locations. In summary, the study focuses on the forces driving worker globalization and the related business strategies and practices of U.S. companies as they relate to their global expansion.

Industries and businesses have been at the forefront of economic globalization, through cross-border trade of goods and services. The rise in the development of the global marketplace has been fueled partly by reductions in communications costs, large-scale deployments of information technology infrastructure, and the development of business infrastructure in developing nations – allowing businesses to tap into sources of capital, labor, and infrastructure across the world.

For businesses today, "going global" is a strategic opportunity to access new markets, new sources of revenue, and new technologies. Increased earnings from global expansions can be allocated towards new product development or upgrades of manufacturing or research infrastructure, or passed on to the consumer or to the company shareholders. Successful and productive U.S. companies operate worldwide to be close to their global customers, both geographically and culturally, and to meet the round-the-clock expectations for customer service delivery. These companies are responding to their customers' demands that suppliers improve quality and efficiency, lower costs, offer more products and services, and reduce time to market.

As companies globalize their business operations, however, effects on work and workers follow. Recent media attention on offshoring, especially in IT occupations, has raised questions regarding the short-term and long-term effects of the work shift, particularly on U.S. competitiveness and innovation. Concerns revolve around the premise that as America's leading companies locate in or contract with labor in other countries, higher value work may shift from the United States to other locations, impacting U.S. industrial strength and high-salary employment. Layoffs in the United States, especially in the IT sector, have only exacerbated this concern. The Bureau of Labor Statistics has estimated that only about 1.9 percent of worker separations in the first quarter of 2004 in the United States were due to offshoring.

Workforce globalization into the United States – insourcing – also occurs. Production, research and development, and business services are some of the key activities insourced into the United States. Some see insourcing as a vital part of the globalization of industries and the workforce in the United States as contrasting with offshoring. In 2003, several million U.S. workers were employed by U.S. subsidiaries of foreign companies and approximately about 34 percent of these jobs were in the manufacturing sector. These subsidiaries also spent almost $30 billion in R&D activities in the United States. Given the dynamicism of these phenomena, quantifying the extent of workforce globalization must be on-going.

What is a Knowledge-Based Technology Industry?

Knowledge-based industries and companies are those characterized by an emphasis on creating value-added from new ideas and concepts, as distinct from material inputs and demanding physical labor. For example, the products of the software industry are among the most conceptual and intangible of all new products. Today, knowledge-based companies engage in areas from software development, pharmaceuticals, financial services, engineering services, biotechnology, and semiconductors, among others.

We are in a period where rapid innovation is yielding dramatic changes in the way goods and services are produced, and in the ways that they are delivered to users. It is well known that over the past half-century, the increase in the value of raw materials has accounted for only a fraction of the overall growth of U.S gross domestic product. The rest of that growth reflects the embodiment of ideas in products and services that consumers value, often generated by new insights into how to rearrange physical materials to better serve human needs. This shift in emphasis from physical materials to ideas as the core of value creation has accelerated in recent decades and is at the core of a knowledge-based industry.

This shift is also reflected by what workers do on the job, with a growing proportion of the U.S. workforce creating value through intellectual endeavors, rather than predominately through manual labor. In 1900, only one out of every ten workers was in a professional, technical, or managerial occupation – occupations most associated with knowledge work. By 1970, the proportion had doubled, and today these types of jobs account for nearly one-third of our workforce. Due to the growing role of knowledge and information in generating economic growth, knowledge-based industries contribute to higher national standards of living. In addition, their use of information and knowledge to rearrange physical materials to better serve human needs translates into a large contribution to improving the quality of life.

Knowledge-based industries are also characterized by the education and skill of their workers. These industries have a significant portion of their workforces in non-routine jobs, in which workers create, interpret, analyze, and transform information to create economic value from knowledge. In the pharmaceutical and medical manufacturing industry, almost half of workers perform these types of jobs. The computer systems design and related services industry is even more knowledge-intensive, with more than 80 percent of workers performing this type of work.

Today, knowledge-based industries are at the forefront of global business expansion. They operate in a highly competitive environment characterized by rapid change and globalize their production bases to capture advantages inherent in transnational operations; these advantages include economies of scale, new markets, and access to innovation, among others. They tend to have flexibility in their operations and a changing mix of products to readily incorporate new technologies and customer requirements. Innovation and speed of response to changing market conditions are critical success factors for them, and they are heavily dependent on the accumulated expertise of a workforce consisting of educated and skilled workers.

Workforce Globalization

For decades, globalization has taken place in several ways: in the manufacturing supply chain, in the movement of goods across borders through international trade, in the movement of capital, and in the flow of technology and intellectual property. Through these shifts and exchanges, the U.S. standard of living has continued to rise aided by increased productivity coming from technological advances.

In recent years, a variety of factors have increased the globalization of labor, allowing people and work to move more readily across national borders. They include:

- trade liberalization and increases in global commerce in other nations,
- investments in production and research capability in other nations,
- availability of surplus, low-cost, technically skilled labor,
- the growth of modern information infrastructure and the Internet, and
- a redesign of work and business processes.

Workforce globalization occurs in a variety of ways. From a U.S. perspective, work can flow to foreign workers by either bringing these workers to the United States or by having work done in other nations by non-U.S. workers. Conversely, Americans can perform work needed by other nations by physically relocating to those nations or by conducting the work in the United States.

Various terms have been used to describe these shifts in work. Definitions for some commonly-used terms follow.

- Outsourcing is when a company moves a whole process, a piece of a process, a function, or a discrete piece of work outside of its own corporate boundaries. Companies seeking to focus their management, workforce, capital, and other resources on their "core competencies" examine their business processes for work that can be performed outside the company – such as accounting, human resources management, call centers, or information technology operations – while preserving the company's competitive strengths and maximizing financial gain.
- Offshoring refers to the outsourcing of a whole process, a piece of a process, a function, or a discrete piece of work outside the boundaries of the United States. The work can be done in an offshore location either within the boundaries of the company or outside the boundaries of the company.
- Insourcing is used to describe work offshored by other nations to the United States.

Objectives and Methodology

This study explores the challenges faced and opportunities realized in the sample industry sectors. It takes a broader look at workforce globalization than the recently highlighted phenomenon of outsourcing and offshoring in the United States. The study addresses the types of shifts occurring in each of the sectors and the rationale behind the increasing tendency of U.S. firms to source work globally.

Research for the study was conducted over a period of five months. The study findings reflect analysis using existing sources of information including: industry sector surveys, annual reports, and Securities and Exchange Commission 10-K and 20-F filings; government data on employment, direct investment, and trade; and published articles and reports. Additional qualitative information on U.S. firms' workforce-related practices and strategies was collected through discussions with companies, workshops with academic and industry experts, and attendance at industry conferences.

One key challenge of this study was the ability to quantify the extent of workforce globalization within each industry sector. It was not possible to determine accurately how many workers or jobs were moving from one country to another, based on currently collected employment, trade, and industry sector data. It was also not possible to determine whether the shift of U.S. work to non-U.S. locations resulted in a one-for-one job loss for U.S. workers or whether the shift of work to alternative destinations was replaced by new work in the sourcing country. In both these scenarios it is also difficult to determine whether these movements resulted in net positive growth within the economy. The Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS) are both involved in efforts to better publicize the availability of existing data each agency has related to offshoring – especially data on international trade in services, multinational companies, layoffs, and U.S. employment. BEA and BLS are also working collaboratively to expand and improve the accuracy of the existing data.

The following sections provide a short description of the industry sectors and the specific findings for each sector. Attached as an appendix are samples of figures and tables for this study.

Knowledge-Based Industry
IT Services and Software

Throughout the last half of the 20th century, information technology (IT) played a pivotal role in transforming the United States and world economy through both its contributions as an industry and its effect on productivity and innovation in virtually all industries. Information technology has been a major source of U.S. wealth creation and has contributed substantially to growth in employment, GDP, and labor productivity.

Despite the slower rate of growth in the past three years, the U.S. IT services and software industry currently accounts for about 3 percent of U.S. GDP. In 2002, total employment in the IT services and software industry stood at approximately 1.8 million, with more than half (approximately 938,000) employed in professional IT occupations.

As defined for this report, this sector includes four major industries and their components:

- software publishers;
- computer systems design and related services;
- internet service providers and web search portals; and
- data processing, hosting, and related services.

This report does not address the impact of offshoring of information technology enabled services (ITES), such as accounting, call centers, transcription services, etc. Nor does this study assess the full scope of the impact of offshoring on all the professional IT occupations.

- A handful of factors were primary enablers for expanded globalization of work in the IT services and software sector:
  - Trade liberalization and global commerce: During the past two decades, global trade has expanded dramatically in volume, scope, and the number of participating nations. Trade has been fostered by market-opening initiatives such as the World Trade Organization, regional agreements (such as NAFTA and the European Union), and bilateral agreements, as well as by changes to domestic laws regulating trade. Participation in global commerce has often required countries to change laws affecting domestic market access, tariffs, company ownership (including privatization of state-owned enterprises), subsidies, tax, research and development, debt levels, and a host of other factors. These changes in scores of nations affecting scores of industries have rippled through the global economy, creating new market dynamics resulting in the global movement of capital, manufacturing, and knowledge work.
  - Infrastructure investments: Countries seeking to create conditions to attract global investment and business also have made substantial investments in building the infrastructure required to support modern commerce (including the sophisticated business needs of multinational corporations). Beyond classic infrastructure development -- such as transportation, power and water systems -- these investments and actions include: education, training, and workforce development; intellectual property law regimes; research and development; and banking, finance, and other business infrastructure. One of the most important enabling infrastructures for the digital age has been the rapid development and deployment of affordable, reliable, high-speed voice and data communications capabilities.
  - Availability of surplus, low-cost, technically skilled labor: While many developing countries have large pools of untapped labor, countries that have been especially successful in attracting knowledge work -- in particular India, Ireland, Russia and some countries in Eastern Europe -- have had a surplus of well-educated, technically trained workers. In addition, these workers have lower wages than those performing comparable work in the United States, though the wage differentials among the destination nations vary substantially. At the same time, IT workers in destination nations are well-paid and generally enjoy high standards of living by their national standards.
  - Digitization of workflows: The convergence of digital computing and communications systems served as both an enabler and driver of business process reengineering. Long before offshoring became prevalent, companies recognized the power of computers to improve capabilities and reduce cost through the automation of corporate activities. With the Internet came the ability to rapidly transmit and share data globally. Seeking to capture the value in increasingly powerful computing and communications technologies, companies increasingly documented and digitized work processes. In turn, this allowed work processes to be divided into smaller, discrete, and separate activities. Once divided into a value chain of separate activities, processes and their components could be evaluated to determine where they could be done most effectively and cost-efficiently, and then located globally.
  - Standardization of software platforms for corporate information systems: Unique, built-from-the-ground-up corporate IT systems have been increasingly supplanted by the use of standardized software platforms that can be customized for a specific business. The Y2K challenge accelerated this trend. Many companies, faced with significant time and labor

costs to review and fix the "Y2K Bug" in their legacy systems, chose instead to move their applications to standardized platforms. Today, standard IT platforms designed for mainframes and workstations exist for a variety of enterprise applications. These standard systems enabled IT workers outside the United States to acquire standard skills that would be portable and useful to many clients. U.S. companies, in turn, were no longer reliant solely on internal IT staff familiar with the idiosyncrasies of their unique corporate system. These factors led to standard IT training programs and skill certification that are recognized and available globally, greater investment in IT skill building by workers abroad, and greater use of those workers by U.S. companies.

- In addition to these early enablers, a variety of other factors have further facilitated the globalization of IT services and software:
  - Increases in the numerical cap on H-1B non-immigrant visas in the late 1990s, which opened the door to thousands of IT workers from India, China, and other nations.
  - The emergence of a large, successful Indian-American business community in the United States focused on IT.
  - The increasing body of knowledge within the United States on the effective management of projects offshore, which reduces risks associated with offshoring and increases savings.
  - The emergence of a U.S.-based offshoring broker/consulting firm infrastructure, which increases opportunities for more companies to tap global labor markets by reducing start-up and learning-curve costs.
  - Offshoring destination nations' efforts to expand their workforce pipeline through education and technical skills training to accommodate rapidly increasing demand, changing skill requirements, and a desire to move to higher level work. These efforts also include improving the English language skills of the workforce and reducing cultural barriers to working with U.S. companies.

- The landscape for workforce globalization in IT services and software is complex, with different countries offering different skill sets and capabilities, varying wage rates relative to those in the United States, different levels of cultural compatibility with the United States, different industry structures, and different levels of sophistication in business and project management.

- In addition to its complexity, the workforce globalization landscape in IT services and software is rapidly changing – new countries and companies are entering the market, business models are rapidly evolving, and advances in the technology are swift and broad in scope.
  - The large indigenous Indian IT services and software providers are growing rapidly and expanding staff by the thousands. They are making a shift in the proportion of onshore versus offshore work in their typical IT project management model, and attempting to enter the IT consulting business through acquisition and new divisions. Recently, Ireland's IT services and software industry shifted its focus from services to software products. Russian companies appear to be ready to expand their physical presence in the United States by establishing more offices here, including offices staffed with technical personnel.
  - In another recent development, venture capitalists are encouraging IT start-ups to use lower cost offshore destinations for software development to reduce the "cash-burn rate."

- In addition, there is growing pressure in corporate America to offshore IT work, and growing political pressure to stem the flow of American jobs going overseas.

- Impacts on the U.S. IT services and software sector and on U.S. IT professionals include:
  - Offshoring currently represents a small fraction of U.S. IT services and software spending, though the trend line and expectations suggest continued growth into the future.
  - Currently available trade, industry, and employment data are inadequate to assess the full extent of offshoring of IT services and software work, or to assess longitudinal trends.
  - The impact of offshoring on the competitiveness of the U.S. IT services and software sector appears to be negligible in the short-term, other than the cost savings firms in the industry are achieving from offshoring IT work.
  - IT services and software sector employment has fallen significantly in the past two years – in contrast to a decade of strong growth – but it is unclear how much of the drop is attributable to offshoring.
  - The extent of the impact of offshoring on U.S. IT professionals is uncertain, though it appears to be significant in some IT specialties and likely to become more significant if the offshoring trend continues.
  - The time frame in which technical skills in high demand become a commodity – and thus ripe for offshoring – is decreasing as a result of more rapid diffusion, improved education and training delivery systems, and knowledge capture and sharing systems. This means that labor arbitrage can occur more quickly, reducing the number of jobs the high-wage technology leader can capture as its innovations mature and diffuse.
  - The United States is not alone; other developed countries are experiencing the benefits and challenges of offshoring.

- U.S. companies perceive several advantages and benefits associated with moving IT work offshore.
  - The primary benefit and driver of offshoring is cost savings resulting from the lower cost of labor. Offshoring offers direct labor savings up to 70 to 90 percent, with total savings reaching 35 to 40 percent. These savings can be passed through to the customer, retained in the company, or paid out in dividends to stockholders. These savings achieved through offshoring enable companies to:
    - Remain cost competitive with other companies: Companies offshore to remain cost competitive with other companies; if not, they would find themselves priced out of the market and unable to compete for business.
    - Meet market demand for sustained or higher returns: A downturn in corporate IT spending pushed IT services and software companies seeking to maintain or improve their profitability to do so primarily through cost reduction. For IT services and software companies, labor costs – direct and indirect, which account for the lion's share of total costs – provide the largest opportunity for cost reductions. The general downturn also exerted pressure on a broad range of non-IT services and software industries. These industries also sought to reduce their costs by offshoring a variety of corporate functions, including information technology. These industries – such as the financial services and insurance – are primary customers of the Indian services and software industry.

- Meet venture capitalists' requirements to use offshore labor: Offshoring demands are now being placed on IT start-up companies. Venture capitalists are demanding that start-ups reduce costs by using lower cost offshore labor to slow the "burn rate" and improve their rate of return on investment.
- Increased innovation: Investments targeted at innovation can clearly go farther when labor intensive development work can be carried out at lower cost, thus enabling more innovations to be developed and commercialized. In addition, when the cost of innovation is lowered, more projects are able to achieve the required return on investment hurdle rate, allowing for innovations to be developed and commercialized that otherwise might not have made it to market.

- Other potential advantages of offshoring, as perceived by U.S. companies include:
  - Improving a company's ability to quickly tailor an IT workforce in size and skills to match business requirements during peak and non-peak periods: The availability of large labor pools with current skills and lower levels of worker protections make the use of offshore labor a useful tool for companies to adapt their labor force quickly to changing market opportunities – quickly tapping the people and skills required, and terminating employment when their services are no longer required.
  - Matching global reach of customers: Some IT services companies are establishing offshore operations because their global customers expect to be served in their global locations.
  - Serving local markets better: Some IT services companies are tapping offshore labor in order to better serve local markets. However, it appears that local markets in some countries that are primary destinations for offshored IT services and software work are small and account for only a small share of offshoring companies' revenues.
  - Capitalizing on foreign nation incentives: Other nations have established business-friendly policies and programs that offer attractive benefits for companies that locate operations there. Such incentives include: preferential tax treatment (even multi-year tax "holidays" during which a company pays little or no taxes), targeted education and training to provide a ready-workforce tailored to a company's unique requirements, targeted research and development investments, infrastructure investments, fewer worker protections, and lower regulatory burdens.
  - Enabling focus on core competencies: Competitive pressures have driven companies to focus their corporate resources and management efforts on their core competencies – strategic business capabilities that provide the company with a competitive advantage in the marketplace. To do this, companies have turned to outsourcing non-core functions, enabling specialized companies to provide these services often at a lower cost and higher quality. IT services has been one of the leading functions that corporations have outsourced.
  - Providing round-the-clock customer service: By locating support centers strategically around the world, companies can provide round-the-clock customer service.
  - Increasing speed of product development: By locating development centers strategically around the world – the "follow the sun" strategy – companies can also accelerate the speed at which they are able to develop a new product and bring it to market, or test and revise software by handing a project off at the end of the business day in one location to a site where the business day is just beginning.

- U.S. companies also understand that there are potential drawbacks and risks associated with offshoring. They include:
  - Vendor/contractor management challenges: Vendors and contractors may lack maturity in business management, project management, and quality processes.
  - Cultural and communication barriers: These can cause misunderstandings, unintended offenses, and failures to communicate effectively among the business partners or with end customers. In communications, problems may arise due to accents, colloquialisms, jargon, use of analogies, and lack of understanding of business nuances.
  - Data security and confidentiality: Laws and technical capabilities may vary from country to country, location to location. Foreign entities or personnel that breach U.S. laws may be out of reach of U.S. law enforcement and U.S. courts.
  - Impact on current employee morale and future recruitment: Faced with the prospect of losing their jobs or the loss of jobs by co-workers, employees may actively or passively resist the effort to offshore. Employee morale may suffer as well, leading to reduced productivity. A company also may find recruitment more challenging due to concerns about employment stability.
  - Knowledge transfer: Several factors related to knowledge transfer can impede effective offshoring, including: identification of the essential knowledge to be transferred, effectively communicating this knowledge to the offshore contractor, effective diffusion of the knowledge among the contractor's workforce, and reluctance of current employees facing the loss of their job to participate fully in the transfer of knowledge.
  - Time zone differences: While these can be beneficial for round-the-clock operations, they also reduce the opportunities for personal interaction among business partners operating in different time zones.
  - Inadequate telecommunications and other infrastructure: Companies may face electrical blackouts and telecom outages, slow Internet speed, high bandwidth cost, government Internet censorship, and damages due to severe weather.
  - Unexpected costs: Unexpected costs may arise because of communications, infrastructure deficiencies, problems with project definition, cost estimates, inadequate management, time delays, key staff turnover, employee separation costs, overestimation of labor cost savings, rapid offshore salary increases, increased travel, or simply vendor failure to deliver.
  - Risk to intellectual property: Variations in the intellectual property laws in different nations, less ability to enforce intellectual property rights, and lower consequences for violations may result in loss of intellectual property or its value. Some countries have a poor record of protecting intellectual property – for example, China, where piracy is significant.
  - Exposure/loss of core business knowledge: Some business knowledge may be proprietary or convey a competitive advantage. When that knowledge is transferred outside of the company or business partners, it may compromise the company. Also, knowledge accumulates in a scaffolding process or learning curve. If the company's knowledge becomes outdated, any disruption of access to the holder of accumulating knowledge could have negative consequences. Risk is even higher if knowledge that is core to the company's long term success is no longer resident in the company.

- Lack of requisite offshoring management skills: Managing work offshore requires acquisition of new skill sets.
- Political backlash and negative publicity: Workers, customers, shareholders, and the media may react negatively to the movement of jobs to offshore locations.
- Geopolitical instability: Border unrest, religious strife, a turbulent political situation, strained relationships between countries, war, and terrorism could all disrupt normal business operations.
- Foreign government impediments: Problems with government and government officials may include lack of support for business, lack of transparency in business regulation, slow and complex bureaucracy, and corruption.
- Work schedules: Some countries may have significantly more and different holidays and vacation time than those in the United States.

• Many nations are establishing a foothold in providing IT services and software development work.

- India is the largest destination for offshored IT services and software work. The Indian IT workforce numbers around 490,000 (205,000 in the IT services and software export industry) and is growing rapidly. In contrast, there were 3.2 million professional IT workers in the United States.
  - The indigenous Indian IT services and software industry is growing rapidly and dominated by a handful of large companies, principally IT service providers. These companies have revenues of about $500-$1 billion each; they are export-focused with a majority of their revenues generated by foreign sales. The United States is their biggest customer (accounting for 60-70 percent of revenues). Their client base is largely composed of the banking, finance, insurance, manufacturing, and telecom industries.
  - While Indian companies offer a range of IT services, their stock-in-trade is applications development and maintenance. This involves modifying a standard software platform for the particular needs of a customer, and maintaining those systems. The work has largely been project-based, rather than taking over the management of a company's IT operations (outsourcing), though they have moved into the outsourcing market.
  - These companies are not players in developing software products for global markets. Success in software products requires higher levels of investment for research and development, extensive marketing and sales operations, and often physical proximity to markets. The barrier to entry is much lower in IT services. The indigenous India IT companies' research endeavors (as opposed to IT product development) appear to be insignificant in size and scope.
  - In addition to the indigenous Indian IT services and software players, many multinational IT companies and IT consulting companies have located development centers in India to take advantage of the skilled and low-cost Indian workforce. These operations are expanding. Only a handful of multinational IT companies are conducting research (as opposed to IT product development) in India.
  - Some of the large indigenous Indian IT services and software companies are making attempts to integrate downstream by developing IT consulting services. This is being carried out through acquisition of IT consulting companies or divisions of

multinational consulting companies, and through establishment of their own IT consulting operations in the United States. It is believed that this will be a difficult undertaking for these indigenous Indian services providers; they are competing against well-established multinational IT consulting firms that also have operations in India to tap low-cost IT workers.

- The software project development model pioneered by the large indigenous Indian IT services providers is shifting in terms of the ratio of work performed onshore vs. offshore. Initially, these companies performed their services by providing Indian workers to perform work at client sites in the United States. This significantly increased Indian company use of the U.S. H-1B visa. This way, the client could exert close supervision over tightly-drawn project specifications or parts of projects. Over time, as U.S. clients gained confidence in the Indian IT services providers, they started shipping pieces of work on a project to IT workers in India. Recently, the ratio has shifted, with less work performed on the U.S. client site (principally developing project scope and requirements, project change management, implementation, and follow-up) and the bulk of development work is performed offshore. This results in higher profits for a project, since more of the project is completed by workers with lower wage rates.
- The indigenous Indian IT companies tout their quality, pointing to their achievements of CMM (Capability Maturity Model) certifications. This certification signals the maturity of the software development process in an organization, but is not a measure of worker productivity or creativity.

- Though smaller than India's, the Irish IT workforce is English-speaking, well-educated, and culturally attuned to the United States. The Irish IT industry has switched its focus from IT services to software products for niche markets. The United States is Ireland's largest market for software products. Despite its small size, Ireland's IT services and software industry's revenues are about $14 billion, compared to approximately $13.7 billion in revenues generated by the Indian IT services and software industry.
- The Russian IT workforce is also small, but capable of doing the most advanced and complex IT work – comparable to many IT professionals in the U.S. workforce. Many Russian IT workers are products of the high quality Russian university system, and have degrees in mathematics, physics, computer science, and economics. English language capability is poor; IT worker wages are low, roughly comparable to those in India.
- The Chinese IT workforce is large, about 600,000, but only a fraction of these workers (26,000) are reported to work in the IT services and software export sector. These workers are skilled and their wages are below $10,000 per year. However, there is low English language proficiency and low cultural compatibility with the West.
- The Canadian IT workforce is English-speaking, and culturally compatible with the United States. Its wage rates are similar to those in the United States.

- The United States is the world leader in information technology research. About 47 percent of U.S. private sector R&D investment is in information technology and electronics.
  - Indigenous Indian IT companies do not appear to be undertaking exploratory research of any significant size and scope; several U.S. multinational IT corporations have located research, as opposed to product development, facilities in India. Several U.S. multinational IT corporations have established IT research facilities in China.

– Public investment in IT-related R&D in Ireland in 2002 totaled approximately $113.5 million. In addition, Irish academic institutions conducted an average of $63 million per year in IT-related research.

- U.S. global leadership in the IT services and software industries has attracted work from companies located in countries around the world for decades – in effect, the offshoring of IT work by other nations to the United States. This insourced work, as well as foreign purchases of U.S. packaged software, continues to produce substantial economic activity and job creation in the United States.

- U.S. IT services and software companies move work to where they believe it will be done most effectively and cost-efficiently. In the global competition for work, the United States has capabilities and strengths that make it a choice location for work with certain characteristics. Other nations have different capabilities and strengths that make them attractive for work with different characteristics. These characteristics may be subject to change over time as offshore capabilities grow and mature.

- U.S. businesses have tended to retain IT services and software work with the following characteristics:

– Work in which there is uncertainty about what the customer wants or what the specifications should be
– Projects that require highly iterative development processes
– Work that requires a high degree of personal interaction with end-users/clients
– Work that crosses many disciplines
– Applications with complex procedures, including ones that involve substantial manual intervention and data fixes
– Applications that involve a high degree of integration with other systems developed and maintained on-shore
– Work involving nuances or deep cultural understanding
– Work in which much of the knowledge exists only in the minds of the on-shore IT staff
– Analytical tasks, leading-edge research, and non-rule-based decision-making
– High levels of creativity, innovation, insight, "thinking outside the box"
– High management requirements
– Process design and business analysis
– Technology and systems integration (applications, hardware, and networks)
– Fusion of industry knowledge, high-level IT skills, and business process expertise

- U.S. businesses are more likely to offshore IT services and software work with the following characteristics:

– High wage differential with similar occupation/level in destination country
– High labor intensity
– Clearly defined requirements, little nuance
– Repetitive tasks
– Rule-based decision-making and problem solving
– Documented or easily transferred content and process knowledge

- Discreet, separable; low degree of interaction across different services, applications
- Low degree of personal interaction with end-users/clients
- Stable applications with minimum "firefighting"
- Long projected useful life to amortize offshore set-up costs
- Low-to-medium business criticality
- Less time-sensitive, longer transition periods
- Projects involving simple and standard hardware and software
- Digital, Internet-enabled
- Low setup barriers
- Low-to-medium technical complexity
- Not multi-disciplinary
- Projects in business areas in which offshoring is a broadly accepted concept
- Tightly defined work processes
- Stable process

Knowledge-Based Industry
Semiconductors

Semiconductors are at the heart of the computing and telecommunications industry and are responsible for much of the productivity increases in the IT hardware industry. According to a McKinsey study, the semiconductor industry is estimated to have contributed 0.2 percent of the 1.33 percent increase in U.S. productivity during the 1995-1999 timeframe.

The semiconductor industry is also a source of high-wage jobs. Hourly earnings have risen 50 percent in the past 30 years from approximately $14.50 in 1972 to about $21.50 in 2002 (constant dollars), compared to the 6 percent decline in real wages in the manufacturing sector as a whole over the same time period. Semiconductor and other electronic component manufacturing's value added was $105 billion in 2002, the highest for any industry at the 4-digit NAICS code level. It is also an R&D intensive industry. U.S. R&D by semiconductor and other electronic components companies was almost $12 billion or 8.6 percent of sales in 2002, compared to an average of 3.6 percent of sales for all U.S. industries.

The U.S. semiconductor industry is a globally competitive industry and had worldwide revenues of $166 billion in 2003. U.S. companies lead in world market share with 48 percent. The next leading competitor, Japan, has 29 percent; the EU, Korea and Taiwan make up the remainder. The national affiliation of the top ten companies worldwide include three each from the United States, Japan, and the EU, and one from Korea.

U.S. semiconductor companies operate in different parts of production and design. Companies that own and operate wafer fabrication plants (fabs) and market semiconductor chips under their own name are called integrated device manufacturers (IDMs). Companies that own some fabs and outsource some wafer manufacturing are called fab-lite, and those outsourcing all their wafer production are referred to as fabless. Design firms are companies that provide design and intellectual property for hire, and companies that manufacture wafers for other companies are called foundries.

The structure of the industry has changed from one dominated by integrated electronics companies (owning and operating in all segments of the value chain), to one where firms specialize in different parts of the value chain: R&D, design, wafer fabrication, testing, assembly, or sales and marketing. Currently, the U.S. industry consists of a diminishing number of IDMs, a growing number of fab-lite companies, hundreds of fabless companies and design firms, and very few foundries. The top five IDMs capture 60 percent of U.S. revenues.

- In 2003, the U.S. semiconductor industry employed about 226,000 workers in the United States; 50 percent of its employees and 75 percent of its compensation were in the United States.
  - Approximately half of these employees were involved in manufacturing, and included occupational categories of engineer, engineering technician, semiconductor processor or operator, and assembler. Engineers tended to have a Bachelors, Masters or PhD degrees; technicians typically had a two-year college degree; and processors or operators usually had a one-year certificate.
  - Approximately 30 percent of all employees were engineers, the majority of who were electrical/electronics engineers. Engineers work in manufacturing, R&D, design, marketing and sales, and almost 54 percent of the engineers hired directly from universities had Masters or PhD degrees.

- Foreign students are an important part of the engineering workforce in the U.S. semiconductor industry. Sixty-five percent of doctorates in electrical engineering are awarded to foreign students. While non-U.S. citizens on H-1B visas represented only 2.5 to 3 percent of the semiconductor workforce and 8.7 percent of the total engineering workforce, they represented 23 percent of the new hires last year. Eighty percent of H-1Bs hired directly from universities had Masters or PhD degrees.

- The semiconductor industry is highly cyclical in revenue and employment, making it difficult to determine whether decreases or increases in U.S. semiconductor employment are part of a short-term cycle or a long-term trend.
  - Worldwide sales fell 32 percent from $204 billion in 2000 to $139 billion in 2001, but rebounded to $166 billion in 2003.
  - U.S. employment declined from a high of 292,100 in 2001 to 225,900 in 2003, a drop of 23 percent.
  - Companies tend to use contract labor to alleviate hiring challenges posed by these cycles.

- U.S. companies have the bulk of their R&D in the United States. R&D includes process R&D associated with manufacturing, R&D in semiconductor design, and basic research performed primarily by universities and research consortia.
  - Total U.S. domestic industry funding of R&D in semiconductors declined 16.5 percent from about $14 billion in 2001 to $12 billion in 2002. Of the $12 billion of R&D in 2002, only $48 million came from the federal government and the remainder from industry.

- At the same time, foreign affiliates of U.S. semiconductor companies increased their R&D funding by almost 94 percent from $852 million in 2001 to $1.6 billion in 2002.
- R&D insourcing remains small; a few foreign companies operate large manufacturing facilities in the United States, and R&D by foreign semiconductor companies in the United States was about $41 million in 2002.

• The main determinants in locating facilities overseas vary by function of the facility. However, the need to gain market access can override other considerations. In simplest terms:

- Low-cost labor is the main determinant in locating test and assembly plants.
- Financial incentives to offset the cost of building a fabrication plant (mostly capital equipment costs) and availability of engineers and skilled technicians are the main determinants in locating these plants.
- Talent used to be the main determinant in locating a design center, but now labor cost is an equal determinant.
- Close ties with a university or a research center are the main determinants in locating an R&D center.
- Access to potential customers is the determinant in locating sales and marketing facilities.

• Fewer U.S. companies are building new wafer fabrication plants. Instead, most are outsourcing manufacturing to foundries – most of which are in Asia. If this trend continues, it could adversely impact the U.S. semiconductor workforce and location of process R&D.

- A new state-of-the-art manufacturing facility today costs around $2 to $3 billion. The cost of a wafer fab has increased by a factor of eight over the increase in worldwide revenues since 1978. Only five of the largest U.S. companies are investing in these facilities. Given these costs, companies prefer to outsource part or all of their production to foundries.
- All new U.S. entrants in semiconductor industry are fabless. The U.S. has the largest fabless sector in the world. The United States also has very few foundries for contract manufacturing. Outsourcing allows the fabless sector to manufacture their designs.
- Use of foundries is expected to increase from 15 percent of worldwide industry revenues in 2002 to 34 percent in 2010, and most of the foundries are in Asia. Asia (not including Japan) is projected to build 74 percent of the world's new manufacturing capacity compared to North America's 8 percent.
- National and local governments in other countries are offering financial incentives to both domestic and foreign companies to build fabs in their countries. These incentives are generally more attractive than those offered by U.S. state and local governments. Government incentives in China and Taiwan have resulted in large investments for wafer fabrication plants.
- Finally, new fabs incorporate the latest technology; and process R&D in the semiconductor industry is often co-located with these fabs. As leading-edge facilities are built in other countries, more leading-edge R&D will be performed in those countries.

• Semiconductor design productivity has not advanced as much as manufacturing productivity and companies are trying to increase this by offshoring design to lower wage countries. This strategy has resulted in large increases in the number of engineers employed by U.S. semiconductor companies in offshore locations yet the R&D funding remains here. The industry is trying to increase productivity and decrease costs of chip design by developing more powerful design tools, building on existing design modules, and hiring less expensive chip designers.

- Design productivity is not increasing as is the number of available transistors on a semiconductor. Fixed engineering costs for design are 10 times that of fixed manufacturing engineering costs. Today's design does not take full advantage of all the possibilities presented by the hardware technology.
- The attempts to automate design through the development of design tools, standardization of inputs, and division of the process into discrete modules enabled the outsourcing and offshoring of routine design.
- The disaggregating of the industry into IDM's and fabless has given rise to design and intellectual property firms that license libraries of chip designs, allowing chip designers to build on existing designs.
- The growth of skilled engineering workforces in lower-wage countries has also enabled the offshoring of design work.
- Between 2000 and 2003, the number of engineers employed in the United States decreased from approximately 76,000 to 72,000, while the number of overseas engineers employed by U.S. companies increased from approximately 20,000 to 30,000
- The growth of the fabless model has allowed for the creation and growth of companies with low operating costs. Using design engineers in lower wage countries further reduces initial outlay costs for start-ups. As Asia becomes the center for electronics manufacturing, semiconductor companies are opening local design centers to support their customers.

- Other countries are making the development of a domestic semiconductor industry an integral part of their growth strategy and are drawing in U.S. semiconductor investments. The entry of other countries into the global semiconductor market will pose challenges to U.S. global market share and U.S. employment.
  - The United States struggled to regain leading market share in the 1980s after Japan and Korea entered the market. There is concern that new entrants to the market may further reduce U.S. global market share.
  - The United States now faces competition from countries with educated populations, skilled engineering workforces, university infrastructures, and lower wage structures than those in America – countries such as, Taiwan, Ireland, Russia, Israel, Singapore, and parts of Eastern Europe.
  - China and India, in particular, have the necessary ingredients to compete in the short term and have targeted the semiconductor industry for growth in their countries: China in both manufacturing and design, and India in design.

- The growth of the semiconductor industry in other countries coupled with the increased capacity for advanced science and engineering education abroad could make it more difficult to attract and retain foreign talent in the United States.
  - Half of U.S. engineering doctorates and 65 percent of doctorates in electrical engineering are awarded to foreign students.

- Post-9/11 security concerns in the United States have created a challenging climate for international students. One survey reported that 90 percent of graduate schools reported an average decrease of 32 percent in international graduate student applications for the 2004/2005 academic year from the previous academic year. Visa delays increased by 48 percent for international graduate students; 40 percent of the delays were for engineering students, and of this more than a third were from China.

• China is investing heavily in its semiconductor industry and has many of the elements needed to become a major competitor in the future – engineering workforce, available capital, a large internal market, and a growing university and research infrastructure.

- China has more plans for new wafer fabrication capacity than any other country. Most of the new fabs are foundries. China is also relying on artificial market barriers, standards, and financial incentives to speed up technology transfer from foreign industry to its domestic industry.
- Semiconductor customers (i.e., electronics companies) have migrated to China from the United States at the same time that China's domestic market for electronics is booming. The U.S. share of semiconductor consumption dropped from 31 percent in 2000 to 19 percent in 2003, and is expected to fall to 17 percent in 2007. China, on the other hand, has already exceeded this year's projections by consuming 15 percent of the world semiconductor production.
- China is weak in design skills, but design centers are expanding quickly and wages are about 20 percent of U.S. wages. In addition to domestic firms, multinationals are opening design firms to design for the large local market and service the global electronics firms. China's design houses number in the hundreds and expect about 22 percent growth in revenues this year.
- While China's industry is not world class now, there are potential opportunities for attracting talent, investments in infrastructure, and resources for cutting-edge R&D. China uses talent from overseas, especially Taiwanese and overseas Chinese, to manage and train its industry and workers.

• India is gearing up in hopes of becoming a major semiconductor design center. Indian policy makers have established an export target of $1 billion in silicon design services by 2005.

- Although employment in India by U.S. companies is only 4.4 percent of non-production employees in the United States, it is growing. U.S. semiconductor companies employ 4,000-5,000 workers in semiconductor design in India. Rather than designing for the local market, most of them are designing for main product lines of the companies.
- While the productivity and quality of the workers at these design centers is lower than that of workers at U.S. design centers, their level of experience and work quality is rapidly improving.
- Salaries are about a fifth of U.S. salaries. The savings for U.S. companies drop to 40 percent, however, factoring in additional costs for travel, management, and infrastructure. Large salary increases are expected each year for semiconductor designers, while the cost differential between the United States and India for experienced managers is much less.
- U.S. companies also actively recruit in the United States for U.S.-educated and trained Indian nationals to manage and staff the design centers in India.

- India's main barriers are a lack of schools, trainers, and tools to graduate and train chip designers. Currently, it produces about 350 new design workers a year, but expects to need about 3000.

- Long-term trends in the structure of the industry suggest that employment in manufacturing by U.S. semiconductor companies will decline, both in the United States and abroad, and employment in R&D and design work will increase at a faster rate outside the United States. The most immediate effect of outsourcing and offshoring is positive for U.S. company competitiveness, but outsourcing and offshoring have the potential to affect U.S. market share and jobs in semiconductor manufacturing, design, and R&D in the long term.

- Despite this, the U.S. semiconductor industry retains much unique strength to address these challenges.
  - It has a dynamic economy, capital market, and business friendly environment allowing entrepreneurs to bring new ideas and companies to market quickly and exploit new structures and niches in the industry.
  - The industry is very diverse, competing in every part of the value chain. It has a particularly creative design sector, with around 500 fabless companies, including the only fabless company ranked among the top 20 semiconductor companies worldwide.
  - It has top-notch research universities and university-industry-government lab interaction with the ability to invest in cutting-edge technologies that can transform industry processes and serve to cultivate top talent.
  - It has a large educated, skilled, and experienced workforce. Even though workers in some lower-wage countries can match U.S. workers in technical skills and sometimes education, they lag behind U.S. workers in experience and management skills.
  - It maintains a historical advantage in intellectual property and dominates the lucrative microprocessor market.
  - It has survived previous competitive challenges from Japanese and Korean industries, and prospered and regained leading world market share.
  - Even though many U.S. companies are becoming fab-lite or fabless, it appears that the United States will maintain a core of cutting-edge manufacturing and process R&D in some of its larger semiconductor companies.

Knowledge-Based Industry
Pharmaceuticals

Increasingly sophisticated and powerful pharmaceuticals are the precursors for innovative breakthroughs in therapeutic options for human diseases and disabilities. Considerable scientific advances over the last several decades have revolutionized our ability to understand human diseases and disabilities at the molecular biological level, which has opened the door to taking on more complex diseases and disabilities through more effective molecular therapies. Pharmaceuticals are also widely regarded as one of the Nation's most important high technology sectors for the future – as a source of new healthcare technologies able to improve the nation's well being and living standards, as a realm of business opportunities with significant growth prospects, and as a source of new jobs in high valued-added components of the global pharmaceuticals supply chain.

The United States has long been a global leader in pharmaceuticals. Yet, many U.S. international trading partners – in Europe, Asia, and Latin America – have indicated strong future aspirations in the biosciences, biotechnology, and associated industries and markets. These aspirations are both to meet the growing healthcare needs of their domestic populations and to eventually compete in the larger global marketplace. This raises questions about how this global marketplace might evolve over the balance of the current decade, and what the implications will be for the existing pharmaceutical infrastructure and workforce in the United States.

- The pharmaceuticals industry is a significant sector of the U.S. economy.
  - Pharmaceuticals accounted for 3.3 percent of all manufacturing shipments in the United States in 2001 and 4.9 percent of all manufacturing value added.
  - It is also one of the most R&D intensive of any major U.S. industry. In 2003, U.S-owned pharmaceutical companies and U.S. divisions of foreign-owned companies invested $33 billion in R&D in the U.S. and abroad. Of this, about $27 billion was spent in the United States.
  - The global market for pharmaceuticals is estimated to have totaled about $492 billion in 2003, with annual growth rates over the last three years of 8-9 percent. North America (dominated by the United States) accounts for about 49 percent of this global market, with annual growth rates of approximately 11-17 percent.

- The U.S. workforce for the pharmaceuticals industry totals around 294,000. Of this about 48 percent are involved in production and about 27 percent engaged in scientific, professional, or technical activities.
  - The Bureau of Labor Statistics projects an increase of almost 68,000 occupations in the 2002 to 2012 timeframe.
  - However, these employment figures do not account for services provided by contract research organizations or for universities and non-profit R&D organizations working in collaboration with pharmaceutical companies. Neither of these important ancillary components of the pharmaceuticals industry is comprehensively documented by industry or government statistics. Preliminary research indicates that they may be a sizable fraction of the employment of the core industry cited above.

- Specific information on the distribution of the company's workforce by function (e.g., R&D, marketing and sales, manufacturing) and geographic location is not clear from information provided in the companies' annual reports and other financial filings.
  - It is apparent, however, that among the globally integrated companies, U.S.-headquartered companies have substantial number of employees in facilities abroad and foreign headquartered companies have substantial number of employees in facilities in the United States. Few of the industry's largest companies provide disaggregated statistics on relevant characteristics of their employees (by function and geographic location) in their regular financial reports.

- Corresponding information for the other smaller companies in the pharmaceuticals industry is also not readily available. However business press articles suggest that even the industry's smallest companies are aware of opportunities for collaborative work and are sourcing on a global basis.
- The industry's considerable dynamism at present also adds to the complexity of the analysis – including numerous larger company buyouts of smaller firms to acquire cutting-edge science and technology, larger company mergers and acquisitions at a global level for efficiency and market expansion reasons, and the growing attention to outsourcing generally (whether with domestic companies or those abroad) as a strategic response to emerging business needs.

• Both the industry and markets for pharmaceuticals are considerably global in nature.
- The industry's production chains for research, development, manufacturing, marketing, and sales exist around the globe. The industry's most successful companies perceive the markets for their products to exist beyond the shores on which they are headquartered.
- The industry's top ten companies currently account for about 46 percent of global sales, none with greater than an 8 percent share overall. Five of these companies are headquartered in the United States and the other five abroad – in the United Kingdom, Switzerland, France, and Germany. The rest of the industry is composed of a large number of companies with varying product mixes, market geography, and production activities.
- It is expected that both the economic fundamentals of the industry, particularly the high cost and risk of research and product development, and the increasingly global matrix of life sciences research will drive further global consolidation in the years ahead.

• The United States is widely recognized as the global center for pharmaceutical research and innovation. This leadership has increased over the last decade and reflects a constellation of favorable circumstances for innovation, the result of U.S. policies and initiatives. They include:
- Abundant support for pre-competitive research (notably, the basic research funded by the National Institutes of Health (NIH), which provided $26.4 billion in funding for life sciences research by NIH intramural laboratories, universities, and other extramural research performers in fiscal year 2003);
- The strong pool of U.S. world-class scientific talent and continuing stream of scientific achievements;
- The strong interests of U.S. businesses and capital markets in aggressive development and commercialization of potential new therapeutic drugs. In addition to NIH-funded research, the major pharmaceutical companies spent $27.4 billion on R&D in the United States in 2003;
- An attractive U.S. marketplace both from a demographics perspective and from a drug pricing perspective; and
- A well-established government regulatory regime, such as the Food and Drug Administration, for approving the market entry of new pharmaceuticals.

• With continued scientific strength and incentive for industry to take on and invest in the task of new pharmaceutical development, the United States should retain its role as world leader in pharmaceutical innovation with effective responses to emerging challenges and issues.

- Healthcare and demographic fundamentals suggest that the vigorous pace of growth in global demand for pharmaceuticals should continue for some time to come. The United States should also remain the world's leading market for pharmaceuticals.
- The basic science frontier is likely to continue to advance at a fast pace (building particularly on the recent progress in genomics and related molecular biology fields), and this will open many new opportunities for pharmaceutical innovation.

• Some emerging issues with the potential to erode U.S. advantage could work to noticeably shift some of the investment and innovation engine abroad.

- One important consideration is the aggressive efforts underway in Europe, Asia, and elsewhere to develop a globally competitive life sciences industry. These initiatives are building support and momentum.
- Also, national policy debates in the United States related to healthcare cost containment and cost effectiveness, and to the boundaries of acceptable life sciences research, have the potential to influence the risk and return expectations pharmaceutical companies will have in considering the what and where of their future investments in research and new drug development.
- Increasingly, the capabilities for strong science and technology in the life sciences arena – including human talent, resources, and infrastructure – also exist abroad. Workforce seems not so much a problem for the United States in terms of level of supply. The issue is much more whether the United States will develop workers with the right skill sets. The increasing synergy between fields, such as computer simulation and biological systems requires an inter-disciplinary approach to education and training. Other countries appear to recognize these opportunities and are working hard to target them.

Education and Training in Other Countries

Success in today's global economy is not only dependent upon access to natural resources or physical labor, but also is increasingly being determined by how well an economy or a company can develop and harness the skills and creative talents of people. In that sense, education and training become indispensable to ensuring appropriate levels of talent necessary to sustain innovation and economic growth.

The United States has historically been a leader in higher education and training, but other countries are attempting to provide comparable quality of and access to education. Although the ratio of Bachelors degrees to the college-age population in the United States remains among the world's highest, other nations are quickly catching up in terms of sheer numbers of graduates. For example, in both China and India there has been a dramatic increase in the number of students entering higher education systems.

This availability of highly educated graduates has allowed countries like India and China to produce, develop, and even design products or services that historically were the purview of the more technologically developed nations. Other economies receiving media attention for their ability to develop and supply local and foreign companies with workers possessing higher science and technical education and skills include Taiwan, Ireland, and the Philippines.

There are four caveats regarding this review of education and training programs. First, the review focused on two leading countries – China and India – primarily because they have become leading destinations for outsourcing and offshoring from the United States, and because both China and India graduate comparable numbers of scientists and engineers to that of the United States. Second, the analysis examined only the post-secondary or secondary education programs in the two countries, mainly because a larger proportion of graduates from the post-secondary phase enter the national or international job market. A more complete future review could include all stages of the education system. Third, it was difficult to conduct a thorough analysis of the national training or vocational programs within these countries during the period of this study. Therefore, only anecdotal evidence on training is offered here. Finally, it was also difficult to reconcile the various sources of statistical information. For example, enrollment or graduation data obtained or derived from one source might vary significantly from similar data from another source. In such cases, both sets of statistics are cited.

The following sections cover key aspects of post-secondary education, government involvement in education, and recruitment of highly-educated workers for China and India; and to a lesser extent, Taiwan, the Philippines, and Ireland.

- The proportion of the college-age population that earned degrees in science and engineering fields was significantly larger in several countries in Asia and Europe than in the United States during the same periods.
  - Science and engineering degrees have consistently made up about one-third of U.S. undergraduate degrees over the past 30 years. However, in 2001, the percentage of bachelor degrees awarded in science and engineering in China, Korea, and Japan was 59 percent, 46 percent, and 66 percent, respectively.
  - In 2000, U.S. students earned about 15 percent of their Bachelors degrees in engineering, while students in Asia and Europe earned about 40 percent of their Bachelors degrees in engineering.
  - South Korea and Taiwan have increased their ratio of Bachelors degrees in science and engineering as a percentage of the 24 year-old population from just over 2 per 100 in 1975 to about 11 per 100 in 2001.

- While China and India have low overall enrollments as a percentage of their population they are closing the gap with the United States in terms of absolute number of degrees earned.
  - In China and India, 2.9 and 4.2 per hundred people, respectively, earned science and engineering degrees in 2001.
  - In 2000, China awarded 337,000 science and engineering degrees compared to 398,622 for the United States.
  - Recent estimates indicate that India may surpass the United States in terms of the numbers of science and engineering degrees produced annually. Indian government data indicates

that India granted 232,000 science degrees and 160,000 engineering degrees and diplomas in 1997; the National Association of Software and Service Companies (NASSCOM) reported that India granted 630,000 science and engineering degrees in 2001.

China's rapid economic growth is increasingly driven by its evolving capability to compete in international markets with knowledge-intensive high-value products. Education and training in science and technology are at the forefront of China's economic development policy and in support of this the government is attempting to develop a university system based on recognized international standards of research and instruction.

- The proportion of students in China enrolled in science and engineering programs is greater than in the United States.
  - In 2001, more than 59 percent of students enrolled in university undergraduate education in China major in natural science or engineering, compared to 31 percent in the United States.
  - At the graduate education level, the proportion of students enrolled in natural science or engineering the same year in China was at 57 percent, in comparison to about 20 percent in the United States.

- In recent years, there have been large increases in the number of Chinese students studying abroad.
  - From 1978 to 2001, about 458,000 Chinese students went to more than 103 countries and regions for overseas study, with over half of them traveling to the United States.
  - The number of Chinese students in American universities grew from about 2,500 in 1980 to about 65,000 in 2003.

- The Chinese government has taken concerted steps to ensure that it becomes a viable destination for international research and has the university and industry structure to nurture highly skilled talent.
  - The Chinese government seeks to develop its higher education system to provide greater access for all its citizens.
    - From 1998 to 2002, enrollments in the China's higher education system grew from 2.15 million to 15.1 million (approaching U.S. enrollment of about 15.3 million in 2000).
    - The Chinese plan to raise secondary education enrollment to 16 million by 2005, again close to the U.S. projected enrollment of 16.8 million.
    - The government has also developed plans to create up to 100 new world-class universities.
  - The government's 5-year plan emphasizes the need to take advantage of commercializing technologies and improve the nation's capacity for innovation.
    - There is increased emphasis on competition in research, particularly in promoting intensified competition and higher levels of achievement in research.
    - Reform policies include placing all research faculty members on contracts and conducting formal project evaluations every three years at the research institutes.
    - Reform is also directed towards restructuring China's science and technology workforce through retirement, staffing cutbacks, and the recruitment of younger,

better-educated scientists.
- Research institutes are also encouraged to launch commercial spin-offs based on successful research applications. To expedite this, the government has facilitated the development of almost 44 national and 124 local university science parks.

- Reform of China's science and technology base is heavily dependent on the government's ability to continue to attract foreign direct investment and talent.
  - The Chinese government continues to offer incentives to attract foreign research laboratories and has pushed for the establishment of high-tech research parks with high-quality infrastructure.
  - The government has reduced funding for state-funded R&D organizations and encouraged them to privatize. Universities and related research institutes are beginning to actively seek funding from private companies.
  - As China continues to reform its economic structure and increase its investments in scientific and technological infrastructure, local demand for high-level specialized personnel is also increasing.

- There appear to be increases in return-rates of Chinese graduates of U.S. universities.
- China has made great efforts to bring back U.S-educated Chinese scientists and engineers to work on or start new businesses. The returning Chinese play an important role in knowledge transfer that is critical to the Chinese drive to modernize.
- From 1985 to 2000, about 95 percent of U.S. science and engineering doctoral degree recipients from China reported that they had plans to remain in the United States for further study and employment. Seventy percent in 2001 reported accepting firm offers for employment or postdoctoral research in the United States.
- A different survey of 1,045 Chinese graduates employed in the United States (2001) reported higher rates of return. For example, 21 percent had plans to go home within 5 years, 36 percent had plans to go home within 5-10 years, 23 percent had plans to go home after 10 years, and about 19 percent had no plans to return. The relatively high percentage of those with plans to return may be correlated to the respondents' immigration status: many of those participating in the survey had plans to obtain dual citizenship (U.S. and Chinese).

The burgeoning demand for IT and related skills has given India unprecedented opportunities to participate in the global marketplace for knowledge-intensive and high value products and services. Using its extensive system of public universities, institutes, and private colleges, India is attempting to develop its talent pool and offer multinational companies a source of talent for increasingly sophisticated IT work.

India appears to have a large pool of workers that can be tapped for IT industries. Thousands of engineers graduate each year from India's elite engineering schools and institutes. Many U.S. and international businesses moved to India to take advantage of lower labor costs, and focused on lower-level technical tasks like call centers and bookkeeping and accounting functions. However, given its large pool of technical talent, India has the potential to move into more sophisticated work areas such as software development and hardware design. In response to industry needs, especially in the IT sector, the Indian education and training system is growing rapidly. The following findings summarize the current output and challenges of the Indian system.

- Higher education in sciences, historically the purview of India's national (government-funded) universities, institutes, and colleges, is coming under increasing pressure to change and respond to market forces for technical skills.
  - As of March 2002, there were almost 10 million students enrolled in India's 253 universities and 13,150 colleges.
  - The demand for courses in information technology, biotechnology, and digital electronics is both high and increasing.
  - The government's reductions on duties and restrictions on license regulations for imported software and equipment has benefited universities and teaching institutions.

- The seven Indian Institutes of Technology (IITs) are the country's premier technical institutions. They are internationally recognized for the quality of graduates they produce, despite not being highly regarded for their research capabilities.
  - Upon graduation, a large percentage of IIT graduates immigrate to other countries for employment opportunities.
  - IITs are exclusively staffed by faculty with doctorates. In computer science programs, a significant proportion of the faculty earned PhD degrees from the United States, and also has U.S. industry experience.
  - IITs face serious challenges: non-competitive compensation packages, alternative opportunities abroad, lengthy recruitment procedures, outdated facilities, and an excessively rigid academic program structure make it difficult to attract and retain qualified faculty.

- India is also trying to emulate its successful IIT model for IT education.
  - In 1998, the Indian government with industry assistance set up the Institute of Information Technology (IIIT) in Hyderabad and Bangalore. Both schools are designed to grant computer software and computer engineering degrees at the Bachelors, Masters, and PhD levels.
  - The IIITs have formed alliances with private IT companies, many of them U.S.-based, to deliver courses ranging from 6 weeks to 6 months to train IT professionals. They estimate that by 2008 the annual output from the two IIITs will be 2,000 engineering graduates and 25,000 professionals with short-term training.

- Graduates of the Indian educational system, both students and professionals, have been going abroad for advanced study or work, and the Indian government has had little success in stemming the flow of talent out of the country or enticing Indian nationals, particularly those with advanced degrees, to return to India for teaching or research.
  - As of March 2001, more than a million Indian-born individuals were resident in the United States – a doubling of this population since 1990. Of the Indians who came after 1990 and were in the United States at the end of the decade, an estimated 78 percent had Bachelors degrees.
  - In the past two academic years (2001 and 2002), India surpassed China as the leading country of origin for international students in the United States.

- Almost 94 percent of the Indian science and engineering doctoral students expressed their intent to remain in the United States after completion of their studies.

- The demand for IT professionals in India has spurred the growth of private training institutes providing short and long term training, both in India and abroad. These training institutes claim to offer an alternative to university IT education.
  - Many of the computer training programs are targeted towards students with backgrounds in engineering who have the foundational skills for software programming and towards those in college desiring parallel computer education. Students from other disciplines such as science and arts typically require much more intensive training in programming, web development, coding, and designing before they are considered to have the requisite skills for software development.
  - Private institutes (such as Aptech and NIIT) offer an alternative to university IT education, and have opened hundreds of franchised training centers in India and around the world. Aptech states that it has trained almost 3.5 million students from 3208 training centers spread across 52 countries. Aptech, which operates in China through a local joint venture, claims to have 100 centers in 57 Chinese cities providing IT and multimedia training. NIIT claims that it places about 10,000 students per year in recognized organizations and companies.
  - These private institutes partner with U.S. companies including Microsoft, IBM, and Sun Microsystems, among others, to offer both short-term courses and advanced training for IT professionals desiring to upgrade their IT knowledge.
  - Typically, they offer three-year programs (four semesters of course work followed by one year of professional practice) in software engineering, systems engineering and networking, information systems management, and business processing management.

- India, like China, faces many challenges in improving its higher level education system.
  - Institutions have suffered declines in quality, exacerbated by greatly expanded enrollments, declining state expenditures, and an inadequate policy framework for private financing. Philanthropy and private sector investment in higher education is still very limited.
  - Much of the scientific research and development activity in India is conducted by the national research laboratories, which have minimal links with academic institutions. Many Indian universities also lack the funding to engage in research.
  - Due to inadequate exposure to practical (versus academic) training in science and limited job opportunities, many Indian graduates in science do not pursue science as a career.
  - Although there has been a tremendous expansion in engineering programs offered by private schools since 1996, most of these privately financed colleges are not yet of high quality.

- The government of Taiwan has plans to make the country a center for the engineering and design of more innovative products than those manufactured in China.
  - Taiwanese government officials estimate that Taiwan will need 10,000 more engineers if the country is to realize its goal of becoming a larger center for the design and engineering of sophisticated products like semi-conductors.
  - The Taiwanese government has successfully used incentives such as tax breaks and direct

subsidies to recruit foreign companies to set up R&D operations in Taiwan. The government plans to use the presence of the multinationals at R&D centers to spur local companies to start developing their own products rather than making equipment for foreign companies.

- Due to its cultural affinities with the United States, including American-style English, the Philippines is a popular location for offshoring.
  - Colleges in the Philippines annually graduate 380,000 students, many with backgrounds in U.S.-style accounting.
  - The country at present has a relatively small base of IT workers, and the government is attempting to create a local base of IT work by stimulating the development of domestic IT companies.

- Despite a small population, Ireland has become a large information and communications technology (ICT) outsourcing destination, and is second to the United States in software exports.
  - Ireland exceeds the United States in its production of science and engineering graduates as a percent of its college age population: 8.5 percent compared to 5.7 percent.
  - Of particular concern to the Irish government are recent projections that show a shortage of electronic engineers and a surplus of other engineers in 2006. The government plans to bridge this gap through a proposed series of initiatives.
    - Allocation of extra funds to support in-company training for bridging existing knowledge or skill gaps and permitting worker advancement to the next level of qualifications.
    - Encouraging the universities to take a more inter-disciplinary approach to prepare graduates for employment in the technology sector.
    - Increasing educational opportunities for women and disadvantaged groups.
    - Implementing a revised immigration policy allowing colleges to recruit overseas students to fill unused slots in technology programs.

Appendix

List of Figures and Tables

Industry	Employment						
	Number				Compound Annual Growth Rate		
	1990	1994	2001	2003	1990-1994	1994-2001	2001-2003
Software Publishers	98.2	136.8	268.9	239.2	8.6%	10.1%	-5.7%
Data Processing, Hosting and Related Services	211.4	226.9	316.8	283.7	1.8%	4.9%	-5.4%
Internet Service Providers and Web Search Portals	40.8	41.2	176.8	123.8	0.2%	23.1%	-16.3%
Computer Systems Design and Related Services	409.7	531.4	1,298.4	1,108.4	6.7%	13.6%	-7.6%
Total IT Services and Software	760.1	936.3	2,060.9	1,755.1	5.4%	11.9%	-7.7%

Table 1 – IT Services and Software Employment

Professional IT Occupational Employment—Occupational Employment Survey
(in thousands)

	1999	2000	2001	2002
Computer and Information Scientists, Research	26,280	25,800	25,620	24,410
Computer Programmers	528,600	530,730	501,550	457,320
Computer Software Engineers, Applications	287,600	374,640	361,690	356,760
Computer Software Engineers, Systems Software	209,030	264,610	261,520	255,040
Computer Support Specialists	462,840	522,570	493,240	478,560
Computer Systems Analysts	428,210	463,300	448,270	467,750
Database Administrators	101,460	108,000	104,250	102,090
Network and Computer Systems Administrators	204,680	234,040	227,840	232,560
Network Systems and Data Communications Analysts	98,330	119,220	126,060	133,460
Computer and Information Systems Managers	280,820	283,480	267,310	264,790
TOTAL	2,347,030	2,642,910	2,550,040	2,507,950
Source: Occupational Employment Survey, U.S. Department of Labor, Bureau of Labor Statistics				

Table 2 – Professional IT Occupational Employment

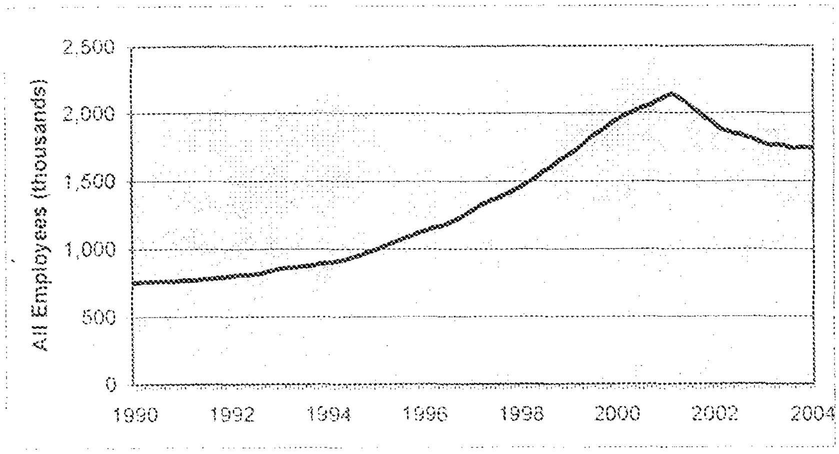

Figure 1 – Professional IT Occupational Employment across All Industries

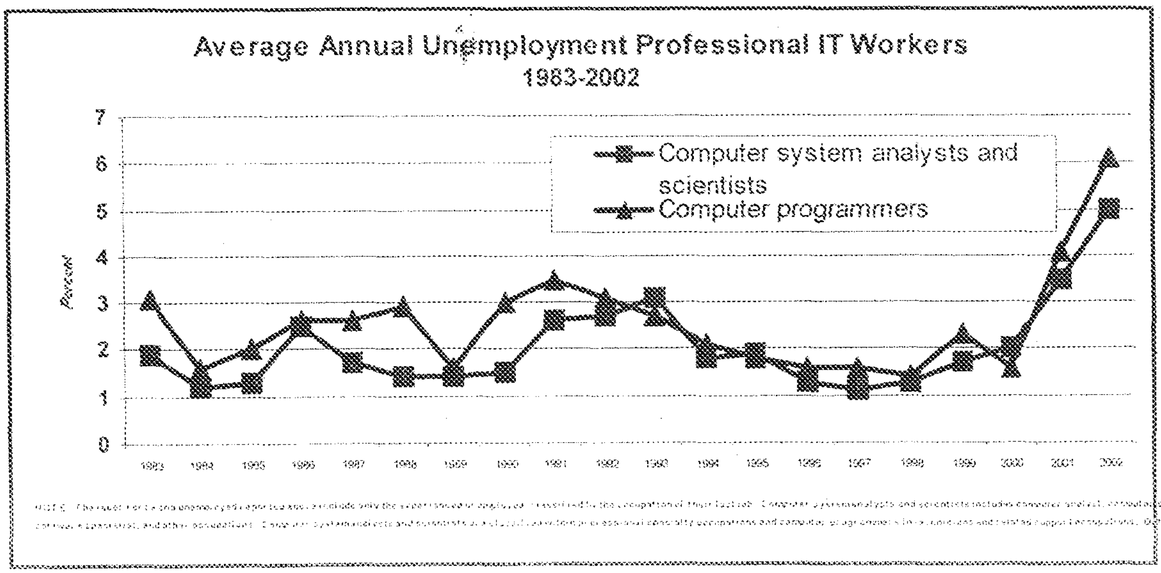

Figure 2 – Average Annual Unemployment for Professional IT Workers

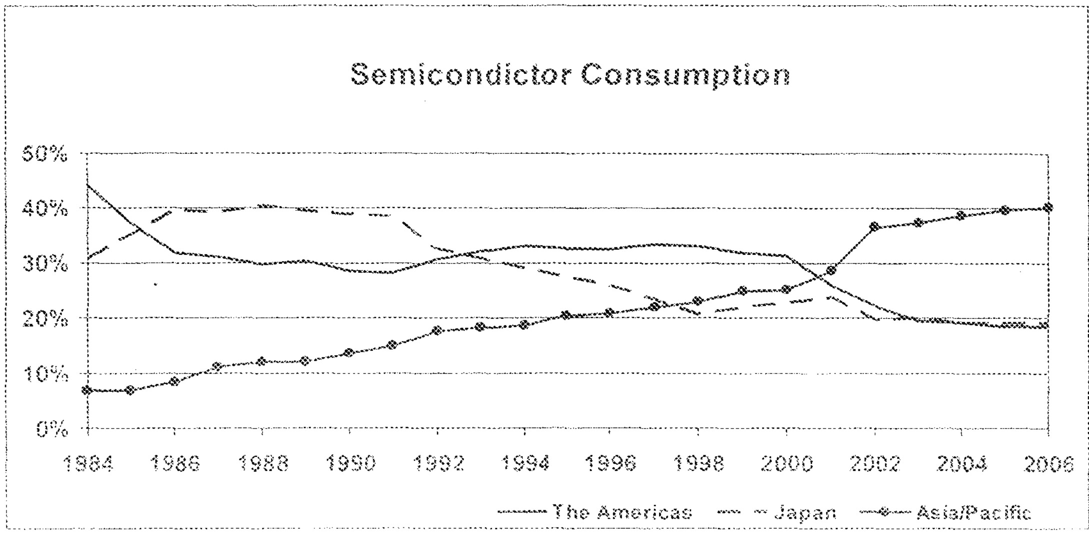

Figure 3 – Percent Share of Global Semiconductor Consumption

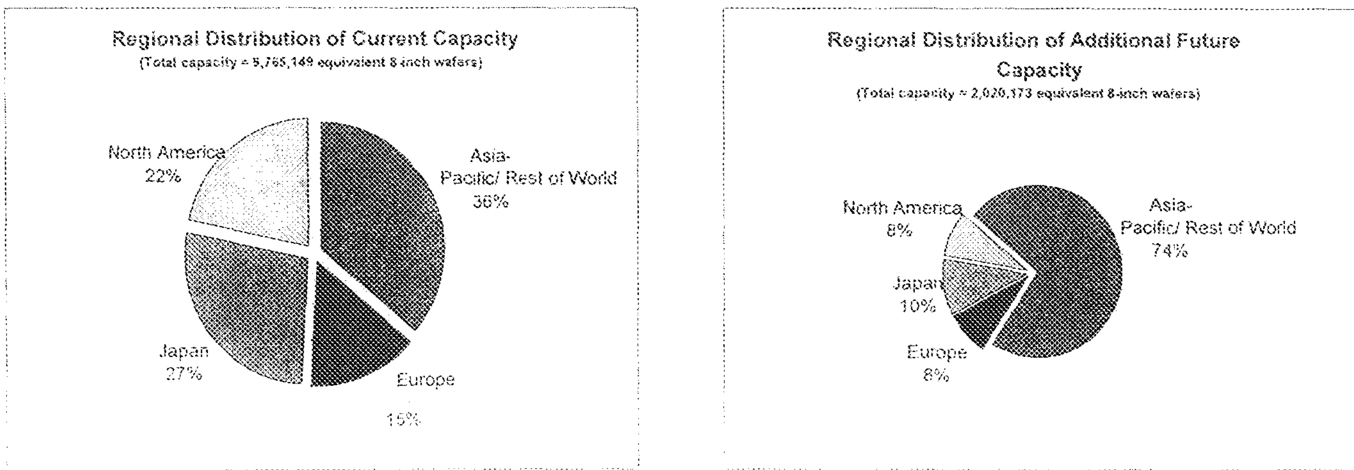

Figure 4 – World Semiconductor Production Capacity and Growth

Location	2002 Average annual cost (US$)
Silicon Valley	300,000
Canada	150,000
Ireland	75,000
Taiwan	< 60,000
South Korea	< 65,000
China	28,000 (Shanghai), 24,000 (Suzhou)
India	30,000

Table 3: Cost Comparison of Semiconductor Design Engineers

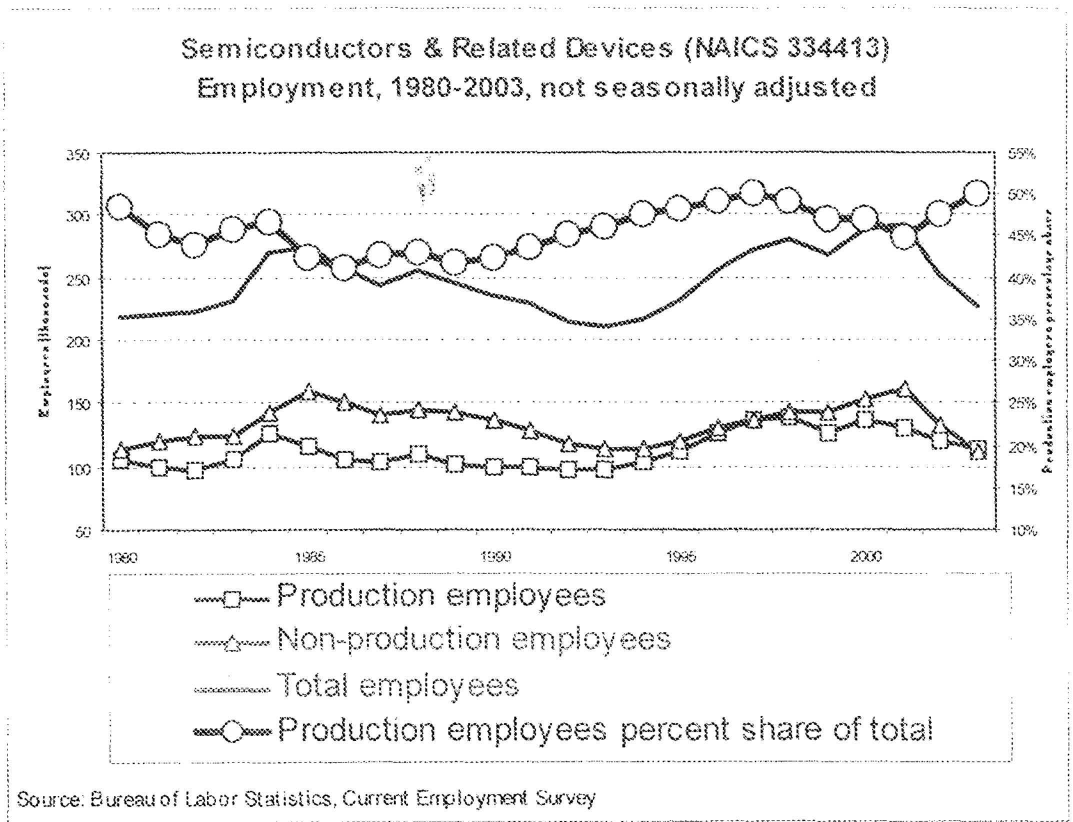

Figure 5 – Semiconductor and Related Devices Sector Employment

Occupational Classifications	Employees 2002		Employees 2012		Increase 2002-2012 (% of 2002)
	Number	Percent of Total	Number	Percent of Total	
Professional information technology occupations	11,877	4.0%	16,069	4.5%	4,192 (35%)
Engineers	10,491	3.6%	13,442	3.7%	2,951 (28%)
Technologists, technicians, drafters	23,750	8.1%	29,887	8.3%	6,130 (26%)
Life/physical science and mathematical occupations	24,299	8.3%	32,131	8.9%	7,833 (32%)
Medical professions	2,794	1.0%	3,511	1.0%	715 (26%)
Production and distribution	134,255	45.8%	160,856	44.5%	26,604 (20%)
All other occupations	68,638	23.4%	82,220	22.7%	13,580 (20%)
Total, all occupations	293,300	100.0%	361,300	100.0%	68,000 (23%)

Table 4 – Pharmaceutical Industry (NAICS 3254) Occupational Outlook

Region	All First University Degrees	All Science and Engineering	Natural Sciences	Mathematics, Computer Sciences	Engineering	24-year olds	First University Degrees	Natural Sciences, Engineering
	Number						*Ratio to 24-year old population*	
China (2001)	567,839	337,352	63,517	NA	219,563	19,639,000	2.9	1.5
India (1990)	750,000	176,036	147,036	NA	29,000	17,700,800	4.2	1.0
Japan (2001)	542,314	359,019	14,192	4,965	104,478	1,719,400	31.5	8.0
Taiwan (2001)	117,430	48,624	3,684	9,391	26,587	385,894	30.4	11.1
South Korea (2000)	209,747	96,859	13,427	9,299	56,508	783,600	26.8	10.9
European Union (2000)	1,330,025	477,973	112,79	70,003	338,139	9,844,745	23.9	6.7
Ireland (2000)	18,669	6,636	2,231	1,405	2,014	69,000	27.1	8.5
U.S. (2000)	1,253,121	398,622	83,531	49,123	59,536	3,703,000	33.8	5.7

Table 5: Secondary Education, 24-year old population, by region.

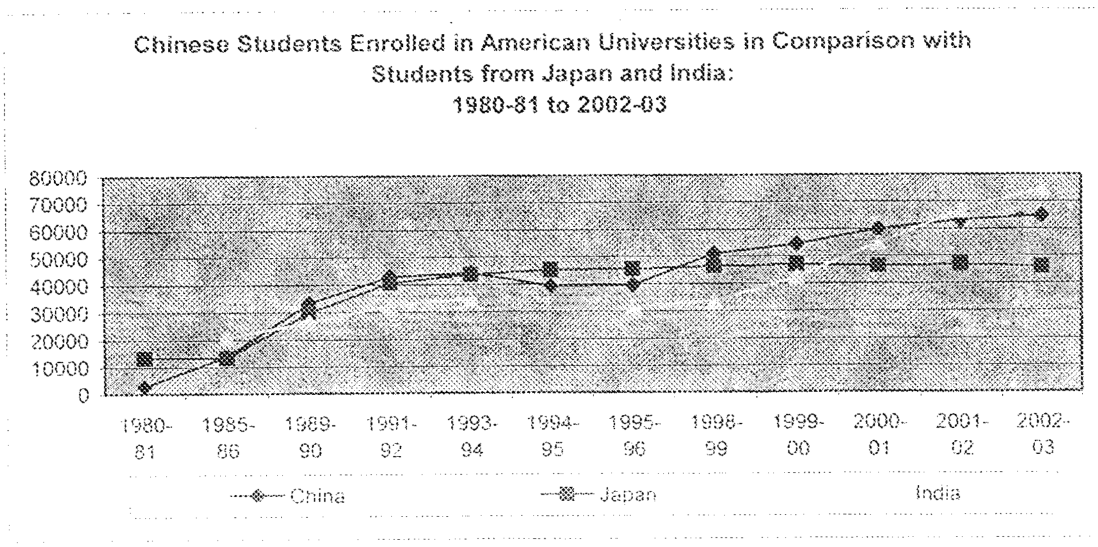

Figure 6: Select Foreign Student Enrollments in U.S. Universities

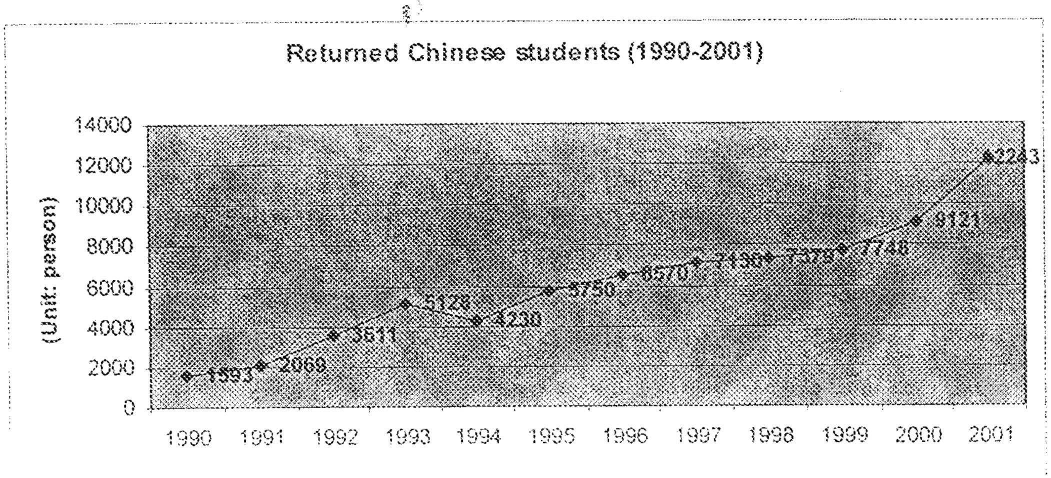

Figure 7: Return Rate for all Chinese Students