Testimony of
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Mr. Chairman and members of the Committee thank you for the opportunity to take part in this important hearing. I was asked to speak about the criteria firms use for locating their R&D sites in a globalizing world. For the past five years, with Rafiq Dossani of Stanford University and funded by Alfred P. Sloan Foundation Industry Studies grants, I have been studying services offshoring to lower wage economies. Today, my remarks will focus on R&D offshoring to India and China.

R&D globalization is not new. For example, IBM and many large pharmaceutical firms have had laboratories in high labor-cost foreign nations for decades. Nearly every major European or Japanese firm has R&D operations in the U.S. (see, e.g., Serapio et al. 2004). Recently, though, a new phenomenon has emerged, namely the rapid expansion of R&D facilities operated by firms from high labor cost nations in lower labor cost developing nations, in particular, China and India, along with Russia, Eastern Europe, and Brazil. My testimony focuses upon China and India because they have been the most important lower-wage nation recipients of R&D investment.

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During the last two decades the work of what Robert Reich termed "symbolic analysts" has been digitized. With the advent of digitization the information has been freed from its physical media, and, as a result, can be shipped anywhere in the world (or, more correctly, workers from anywhere in the world can log into a database housing this information). The implications are profound. Not only might personnel in disparate locations collaborate on the same database or software programs, but R&D personnel might collaborate on designing the same artifact, be it an aircraft wing or an insulin pump.

R&D is a broad category of business activities including everything from relatively mundane product improvement and product localization work to the most sophisticated Ph.D.-level research conducted at the cutting edge of science or engineering. As a generalization, most R&D offshored to India and China is mundane, but some cutting edge work is being done, particularly in the research laboratories of firms such as Google, IBM, Microsoft, and Yahoo!. I was asked to limit my remarks to the R&D operations of MNC firms, though I will extend this mandate to encompass the Indian IT service providers that are now providing development work to global firms on an outsourcing basis. I would suggest that there is one other important missing variable in this discussion and that is the pattern of venture capital investing in these two emerging economic giants, but I shall not discuss this important phenomenon.

To answer the questions posed by the Subcommittee, my testimony is structured in the following manner. First, I discuss the different reasons for offshoring R&D and provide real world examples throughout. I suggest that, in many cases, as, for example, product localization and developing new products for the foreign market creates only minimal competition for U.S. workers. Other types of R&D globalization may create greater competition and thereby have more significant implications for the U.S. In the second section, I discuss the trends in R&D

offshoring with respect to India and, to a lesser degree, China. The third section briefly discusses governmental policies adopted by India and China to attract MNC R&D. In the conclusion, I suggest some policies that might help bolster U.S. leadership in commercializing the fruits of R&D.

Factors Influencing Site Selection for Offshore R&D Facilities

There is an ample literature on R&D globalization, in general. It can provide some insight into the site selection decision, but, generally it has not dealt with situations where there are very large wage differentials. Table One is a list of some of the more important reasons for offshoring. Prior to discussing the various reasons for site selection, it is important to state that only in cases of extreme compulsion will a private firm place an R&D site in a location that does not have at least some suitable personnel that can be employed.[2] In other words, the statement that firms are locating somewhere to access the local "talent" is trivial.

In Table One, each reason is presented as separate and dichotomous; despite the fact that almost always the decision to establish an R&D facility either domestically or abroad is due to a combination of factors. To illustrate, a cell phone manufacturer with large market share in China might experience significant pressure to undertake R&D in China. The manufacturer might also feel that future success is dependent upon customizing its phones for the Chinese market. Here, having a design and development team in China would be desirable in and of itself. So the pressure combined with the opportunity would be sufficient to overcome opposition for other reasons, such as concern about intellectual property (IP). Another example would be a firm with a significant manufacturing operation in a nation, it might find it helpful to have a small

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[2] An example of this is the difficulty the Chinese government has had despite many schemes and subsidies in getting Chinese or foreign firms to locate in Western China.

laboratory in proximity to its factory. These decisions would be even easier if the R&D personnel were less expensive than in the firm's home nation, all other things being equal.

Academic research suggests that understanding R&D facilities through observations at single points in time is hazardous, because there are almost always changes, as a firm's strategy, market position, and the external market evolve. An assumption that the evolution of an R&D facility moves unilinearly from say a government-mandated investment to one based on access to skilled personnel is unfounded. R&D facilities may evolve from having one objective to having multiple objectives or vice versa. Finally, firms may completely abandon an R&D facility if market conditions change dramatically.

Government Compulsion

Government compulsion, as a motivation for offshoring, comes in a wide variety of forms. For example, it can be mandated that foreign firms selling in the domestic market must invest a certain percentage of profits and sales in local R&D. More subtly, there may be a informal "pressure" applied by local officials. These forms of attracting R&D are unlikely to be captured through firm surveys. Anecdotally, it is widely reported that Chinese government officials apply considerable pressure to MNCs to upgrade their sales or manufacturing operations to include R&D. For example, the Danish firm Novo Nordisk, which has 70 percent of the Chinese diabetes market, established its first R&D laboratory outside of Denmark in Beijing, in part due to informal pressure from the Chinese government (Kjersem 2006). Firms such as Cisco, Intel, and IBM having significant market shares in China are almost certain to experience significant informal pressure from government officials to establish local R&D operations.

In the case of India, Boeing, as part of a deal to sell aircraft to Air India, agreed to $1.8 billion in offsets that had to be invested in India. To fulfill its offset obligations, Boeing is purchasing engineering services from Indian firms and considering establishing its own engineering subsidiary in India (*The Economic Times* 2007). In this case, the Indian government is, in effect, forcing Boeing to open facilities, which will include engineering, in India. In this case, it is simply quid pro quo. These illustrations show that sovereign governments can impact the decision to establish an R&D facility abroad.

Localization and Access to Dynamic Markets

Very often foreign markets differ in substantial ways from a firm's home markets. Market entry may require localization, a process that may necessitate product reengineering or other substantial revisions. For example, to sell software in China, code must be rewritten to ensure that software is usable for Chinese-language speakers. This is considered development and is done in an R&D facility, very often in the country where the sales will take place. Similarly, foreign cell phone manufacturers must either transfer the specifications and schematics of their phone models to a Chinese development facility or do localization in some other usually higher cost location. Employing local engineers lowers costs. The local engineers can go a step further, redesigning and de-featuring the model to further lower cost and make the phone accessible to even more consumers. Sometimes this lower cost phone can then be exported to other markets.

In the case of localization, the establishment of an offshore R&D facility may relocate employment from the developed nation to a developing nation, but it also allows the model developed in the home nation to have a longer life and be more profitable. In effect, it creates a division of labor. For the MNC, the ability to localize effectively may be critical to capturing new markets. In the case of India, the market is smaller and since the language problem is not as prominent, there is less localization of R&D. But there are examples, such as Texas Instruments India that designed a single chip that combines all the functions of the multiple chips in a cell phone, thereby dramatically reducing the cost of cell phones and thus allowing market expansion to lower-income groups (Mitra 2006).

Proximity to Key Customers

For suppliers, proximity to a key customer's facilities may be an important marketing advantage. So, for example, Intel has an enormous and increasing number of customers in China and proximity to their operations is important both in terms of a show of commitment, but also to be able to rapidly respond to their needs/issues. Similarly, the Chinese telecommunications equipment market is growing rapidly, therefore firms such as Cisco and Juniper Networks require an R&D presence to satisfy their customer's desires. The establishment of such R&D facilities is driven by a headquarters' estimation of the current and future importance of its customers, and is not directly driven by a desire to access qualified personnel or cost concerns.

Access to Highly Qualified Personnel

For certain types of R&D, access to qualified personnel can be the most important factor governing R&D location. For example, nearly every major information technology firm in the world has some sort of R&D operation in Silicon Valley. In the past many saw this as a problem. Their reasoning was that foreign firms were accessing technology to transfer it abroad. What was not understood was that having these firms in Silicon Valley REINFORCED its primacy in the global IT economy. By being in the region and communicating, while accessing information, these firms transmitted information into the ecosystem and, of course, hired or transferred skilled persons into the ecosystem, thereby increasing Silicon Valley's global salience. In this case, despite wage rates, which many consider exorbitant, the specialized personnel and unique information dominate cost considerations. The U.S. has been an enormous beneficiary of these investments.

Around the Clock Engineering

Having global R&D operations allows a firm to take advantage of the fact that normal operating hours differ by time zones. Here, the savings is in development time. Such a strategy does not imply that lower-cost offshore personnel should be used. However, the ability to use lower-cost personnel would, of course, be an attractive added bonus. There are a variety of ways in which this natural phenomenon can be utilized.

The most obvious, but often relatively difficult to manage, strategy is to undertake work in say, North America, and then electronically transfer the project to another location, say India or Europe, where they continue the work. Though simple in concept, this can become unmanageable when there are difficulties requiring immediate communication with the offshore team that has already gone home. Another strategy entails having the lower-cost foreign engineers do the less desirable debugging and testing for the U.S. programmers overnight. Here, the foreign engineers are given the low-skill, more routinized tasks while the U.S. programmers do the more challenging work. Over time, this strategy can have problems as the most skilled engineers in any nation want to work on the hottest projects.

Another strategy has been to take a development project and divide the work into various modules, allowing autonomous progress until various benchmarks are met then the modules are integrated. Here, there is the advantage of a division of labor, but it need not be hierarchical. The foreign modules may be just as sophisticated as those done in the U.S. In this case, there is no explicit time-saving, as the foreign team could just as easily sit in the U.S. The motivation is cost-saving, as the work could be done in the home nation, but for a much higher price.

Access to a Lower-Cost Labor Force

In market economies lower cost labor forces have always held an attraction, particularly if the quality of their production is roughly comparable to that of an existing work force. This is at the heart of Richard Freeman's (2005) observation about the doubling of the world's workforce through increased access. For firms of all sorts, the ability to access adequately trained, college-educated personnel at a cost of between 40-60 percent less than those in their developed home nations is an ample attraction. It is, of course, not easy managing across borders, but for many U.S. firms efficiently utilizing their offshore and, particularly, Indian work force is of vital importance in ensuring their profitability. In the last month, EDS, which has in the past two years hired and acquired in excess of 20,000 Indian employees for its global operations, announced that 12,000 U.S. employees will be terminated. Unless these 12,000 were unskilled, cost must have been a consideration. Thus, in the same ways manufacturing was offshored in the past, certain service and R&D functions are being offshored today.

Consider the cost differences. The VC-financed Indian firm Tejas Networks designs sophisticated telecommunications switches (i.e., its products compete with those of Cisco, Huawei, and Alcatel/Lucent). Were the firm to have been established in Silicon Valley, it would have cost between $100-150 million, whereas Tejas, which is now on the verge of positive cash flow, cost between $30-50 million – a dramatic difference (Tejas Network executive 2006). In the case of a software/ASIC design firm, the cost comparison for 50 engineers in India, with an average cost of $40,000 per year in Bangalore, yields a burn rate of $2 million per year versus in Silicon Valley where the average salary would be $180,000 per year for a burn rate, in wages alone, of $9 million per year (Indian startup firm executive 2006). There are, of course, many disadvantages to locating in India rather than Silicon Valley, but the cost equation is quite compelling. Similar cost advantages would be true for any other firms locating R&D operations in India.

Nearly all firms are under cost pressure from rivals or stockholders intent upon increasing their returns. The existence of an accessible lower cost labor force is a natural attractant. For commodity-style work it may be difficult to resist the “India price” for a service. Today, U.S. service workers are being introduced to offshore competition from lower-wage workers from around the world, but especially from India.

Section Summary

This section has briefly summarized a variety of reasons that a firm might want to offshore its R&D to a low-cost nation. Cost emphatically is not the only reason for offshoring. For many operations in China, some combination of product localization, government pressure, and proximity to key customers help explain the corporate decisions. Low-cost engineering personnel are also significant. There is also an elite strata of brilliant global-class science and technology talent that MNCs will pursue where ever they are located – and with their huge numbers of people it is not surprising that some of them are located in India and China. R&D

facilities are established in various locations to access different qualities in the labor force. The next section examines offshore R&D operations and provides illustrations of MNC strategies in globalizing their R&D operations to India and China.

Trends in R&D Offshoring

Measurement of R&D offshoring is difficult for the following reasons: First, firms are not required to report on their R&D in any uniform manner. Second, it is difficult to precisely define R&D. Many activities, such as porting a software platform from say the Microsoft operating system to Linux, are relatively routine and are considered development. On the other hand, upgrading a proprietary banking software application is usually not considered development.

Today, the dominant destination nations for R&D offshoring are India and China. Their importance is, perhaps, best illustrated by a survey of 300 executives conducted by the *Economist* (2007) asking which nations were the best overall overseas location for R&D investment (excluding their home nation). Approximately twenty-eight percent answered India, approximately twenty-three percent answered the U.S., and another fourteen percent answered China. The remaining answers were scattered among various nations with Canada a distant fourth place (7 percent). Many non-U.S. executives saw the U.S. as the most important location. If we believe that U.S. executives consider the U.S. the most important location, India is still the second most important location. In 2007, it is not an exaggeration to suggest that for U.S. R&D managers, the three most important nations are the U.S., India, and China (the European Union as a whole would be of similar importance).

The Indian and Chinese R&D work forces are still smaller than that of the U.S. The latest NSF data suggests that in 2003 approximately 1.16 million U.S. workers were engaged in private sector R&D (NSF 2005; 2007) and that 4 million U.S. workers with bachelor's degrees were employed in science and technology occupations. Despite the rapid and continuing annual growth rates of 20 percent per year, the 140,000 private sector R&D workers in India is small when compared to the U.S. The OECD (2007), using Chinese government statistics, estimates that China has 1.1 million science and technology researchers of all types. By the U.S. standard, India and China are still laggards.

India[3]

The Indian GDP of $805 billion in 2006 is significantly smaller than the $2,527 billion Chinese economy. However, India exported $31.9 billion of services (Nasscom 2007), there are no comparable statistics for China, but its service exports are significantly less. Of particular importance is the increase of the R&D, engineering services, and software products category to $6.5 billion. It is estimated that this will increase by a further 22 percent to approximately $8 billion in 2008. In 2006 total employment in the services export sector was approximately 1.25 million. Employment growth is expected to continue at in excess of 20 percent per year. As a gauge of the importance of the entire industry to India, in 2007 the IT service industry generated 5.2 percent of national GDP (Nasscom 2007).

Indian wages are indicative of the cost savings that can be achieved. According to one source, for fresh bachelor degrees there are roughly three tiers with different wages. In the first tier, Google, Yahoo, Microsoft, and eBay will pay $30,000 to $35,000 for IIT's best graduates.

[3] This section draws heavily upon Dossani and Kenney (2007a, 2007b).

The second tier of firms are Cisco, TI, and the Silicon Valley startups that pay between $15,000 to $20,000 and primarily recruit from the top tier of the best regional colleges and the middle rung of the IITs. The Indian outsourcers such as TCS and Infosys employ the third tier and pay approximately $10,000 per year.

To understand the growth in Indian service provision and the rise of significant R&D potential, illustrations from various MNCs are useful. Table Two provides the employment in India by various non-Indian software and software services firms. What is most remarkable is the scale of the operations. In India an increasing number of U.S. software firms have their largest foreign workforce. To illustrate, as of 2007, Adobe had 1,000 employees in India and had already filed for 50 patents developed by its Indian employees (Gupta 2007). Adobe India has been given global responsibility for producing software upgrades for two key products, PageMaker and FrameMaker.

Among the software services firms, growth has been organic through hiring and inorganic through the purchase of Indian firms (see Table Two). It is important to note that the vast majority of this employment is NOT in R&D, but rather more mundane service provision. The largest of these MNCs, IBM, only reestablished its operation in India in 1992, but the preponderance of its growth has been since 1999. Today, IBM has approximately 60,000 Indian employees and expects this to grow to 100,000 by 2010. To speed its growth, in 1994 IBM acquired a leading Indian business process firm, Daksh, with 6,000 employees. In 2004, it acquired the 1,400-employee Network Solutions, which specialized in IT infrastructure services. In terms of R&D, IBM has research laboratories in both Delhi and Bangalore and, according to a recent *New York Times* article, employed 100 Ph.D. researchers in India in 2006 (Rai 2006).

With IBM setting the pace, other U.S. IT service providers are also rapidly expanding. For example, EDS, which entered India in 1996 as a GM subsidiary, began its expansion even later, and as of 2005 it had only 3,000 employees in India. In 2006, EDS management decided that it had to rapidly build its offshore operations, so it acquired the 11,000 person Indian business process firm MphasiS, and in 2007 acquired the 700-person firm RelQ. Simultaneously, it accelerated hiring at its existing Indian facilities. To be sure, it is not only U.S. domiciled organizations that are responding, as Table Two shows, the largest European outsourcing firms are rapidly increasing their presence in India.[4]

The reason these MNC service providers are expanding their presence is not surprising, since competition with the Indian service providers, with their far lower cost basis, is heated. In the 2006 EDS Annual Report, its Chairman and CEO reporting improved results observed, “We continued to realign our work force with strong offshore capabilities, making us more price competitive and responsive to client needs. We more than doubled our presence in high-quality, lower cost locations to 32,000 employees. While India was the primary beneficiary, we also are migrating our work force to other regions such as Latin America, China, Hungary and Poland.” Each of the major MNC service providers faces a similar conundrum, namely a cost structure that is difficult to sustain in a globally competitive environment.

The MNC service providers establishing facilities in India have been joined by firms from a wide variety of other industries. For example, major retailers, such as Target Corporation, have large Indian subsidiaries. According to Robert Kupbens, the Vice President for Technology in Technology at Target Corporation (2007), in August 2006 Target Corporation opened its Bangalore subsidiary, and in mid 2007 employed 500 persons, but expected the Indian operation

[4] In fact, in recent months there have been a spate of articles in the industry press suggesting that the relative tardiness on the part of European software services firms to offshore to India has put them at significant

to grow to 3,000 by 2009. The types of work to be performed in India are indicative of the evolution of these offshore subsidiaries. By the end of 2007, operational responsibility for Target.com will be in India. The spectrum of work will also expand, as a financial team is being formed to do analysis. The India team even does photo retouching and newspaper circular layouts for the U.S.

In traditional manufacturing sectors such as automobiles, the McKinsey Global Institute (2005) identified R&D and engineering as most vulnerable to offshoring and found that 44 to 45 percent could theoretically be relocated. Moreover, this included not only simple low skilled engineering. For example, General Motors (GM) is a leader in relocating R&D and certain elements of design. Its offshore centerpiece is a laboratory in Bangalore employing approximately 240 professionals in 2004, 400 in 2006, and has announced that it is expanding employment to 800 persons by 2008. The skills being recruited are fascinating. In July 2005, the laboratory advertised jobs for individuals with Master's degrees or, preferably, Ph.D.s, in aerospace, computer, industrial, mechanical, and software engineering and computer and materials science. In the materials laboratory, GM sought candidates with Master's degrees and Ph.D.s in metallurgy, polymer science, materials science, materials processing, and math-based analysis of materials. In the material process modeling group, the work included validating microstructural models, designing high-performance materials, and molecular modeling of nanocomposite/TPO exfoliation and fuel cell membranes (General Motors 2005). These job descriptions illustrate the engineering activities being offshored by industrial corporations. Moreover, GM is not alone, as Caterpillar, Delphi, and others build their Indian R&D operations.

The case of Agilent Technologies India (AGI) illustrates the rapidity with which an Indian operation can mature. AGI was established in 2001 to undertake both back office and

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disadvantage when compared to their U.S. and Indian rivals.

engineering services. Its initial engineering services work was simple data entry. However, the operation rapidly matured and began doing CAD support the next year. The next task it undertook was QA for product development. In 2003, electronic design automation software development commenced in India. Success in these initial projects encouraged the addition of an ASIC design center in India, only the fourth one that Agilent operated globally (Dossani and Manwani, 2005). In April 2006, AGI announced that it had purchased 10 acres of land in the Delhi area to build its own campus. Employment growth was rapid, as it had no employees prior to November 2001, and by November 2004 had 1,200 employees with plans to increase to 2,000 by 2006. Agilent India is expanding in three ways: First, its engineering capabilities are growing rapidly. Second, more of the firm's global back office operations are being relocated to India. Finally, the Indian market for its test and measurement equipment is burgeoning.

Yahoo! has rapidly expanded its Indian operation. In 2003 Yahoo! established its Indian Development Center (IDC) and hired 150 engineers (Seth 2006). It has since grown to nearly 1,000 employees in December 2006. But, from our perspective, what is more interesting is how its work has evolved. Initially, the IDC operated as a low-end engineering back office for Yahoo! Palo Alto. In general, the work transferred to India was low value-added and mundane. One result was high rates of attrition sapping the cost savings. To address this problem, in 2004 Yahoo! moved first-level project management to India, a step that gave the Indian operation greater ownership, but created conflicts with U.S.-based managers. The solution was relocating complete responsibility for major activities such as datamining. Now the Indian functional manager reports directly to a SVP in Palo Alto. With the increasing success of the Indian operation, functional responsibility not only for datamining, but also for mobile applications and iPod broadcasting, has been transferred to India (Seth 2006).

These are indicators of learning and maturation. These anecdotes indicate that at certain MNCs, their Indian operations have matured sufficiently to receive global mandates – a powerful indication of an ability to mobilize talented persons and ascend the value ladder. Possibly the most interesting case is General Electric (2007), which has only four research locations globally. Its New York Research Center headquarters employs approximately 1,900 persons, at the new Munich center approximately 150 persons are employed, and in the Shanghai center another 150 persons are employed. The Bangalore center employs nearly 3,000 researchers, i.e., more than the other three centers combined (General Electric 2007). When measured by the sheer number of employees, the size of the GE commitment is remarkable.

Despite this growth, the Indian operations are not comparable to those in the U.S. In market understanding and global project management the Indian operations still lag behind those in the U.S. As the manager of a large MNC noted, "It is easy to do cutting-edge work in India and to manage large projects. The difficulty is in launching products from India, especially the last stage between putting it all together and going live. There is also a gap in capability in conceptualizing projects from India." It takes time to build sophisticated capabilities. And yet, these subsidiaries are becoming important.

The final important group of firms are the large Indian service providers such as Infosys, HCL, Satyam, TCS, and Wipro, and smaller service providers such as Sasken. The large Indian service providers are evolving rapidly and a number of them are developing powerful contract engineering/R&D arms. For example, Wipro, with 15,000 professionals, claims to be the largest contract engineering firm in the world. Wipro also does contract semiconductor chip design. Only three years ago, Wipro was largely confined to the two lower value-added steps of Verification and Physical Design and Production and Silicon Production Engineering. Today, overseas customers contract them to provide higher value-added services in digital/analog design and even architecture. The benefit for the Indian vendor is that it can receive improved rates for the project and its Indian employees can develop new capabilities satisfying their desire to improve their skills (Personal interviews 2006).

The Indian service providers are broadening their businesses by offering ever more engineering services. For example, in 2006 TCS announced an alliance with Boeing to work closely with its customers to design the interiors of new aircraft they had purchased. This alliance led to TCS establishing a aircraft interior design "laboratory" in Chennai (Kurup 2006). HCL claims to have 1,500 person-years of experience designing medical devices such as blood glucose meters for foreign customers. Often the role of the Indian firms is linked to their expertise in software systems, which are a rising portion of the cost and value-added in instruments of nearly every sort. There has also been a proliferation of smaller specialty engineering firms. For example, Sasken provides IC design and silicon platform software services to the world's mobile device manufacturers. To improve service to its U.S. customers, it recently established a subsidiary in Monterrey, Mexico.

The proliferation of MNCs and Indian service firms is creating a powerful ecosystem that is proving attractive to yet more firms and also encouraging firms to undertake more ambitious and sophisticated activities there, including R&D (Dossani and Kenney 2007b). Absent an unforeseen event, Indian service and R&D employment can be expected to continue to increase by 20 percent per annum at least for the next three years. By 2010 there will be approximately 175,000 Indians working on R&D and engineering services for the global economy. Firms such as Wipro will be the largest engineering services firms in the world. By then India will be a recognizable force on the world R&D scene.

China

Less is known about the extent and type of MNC R&D in China. For example, a recent OECD report on the Chinese innovation system provides no employment data for the MNC R&D facilities. Even the number of laboratories varies widely by report. For example, in the most comprehensive survey of the Global Business Week 1000 and Fortune 500 MNCs in China through 2004, the OECD (2007) found that 166 firms had R&D facilities. Of which, 26 were in software, 20 were in telecommunications, and 15 were in semiconductors. In contrast, Zedtwitz (2004) found that in 2005 there were 750 R&D laboratories in China.[5] The largest employer was Motorola (2007a), which had 1,600 engineers scattered across a number of cities.[6] In summation, every major MNC IT firm has R&D operations of some sort in China.

Given the wide disparity in counts of the number of MNC R&D laboratories in China, it is not surprising that there is even less known about their operations. In one of the few quantitative studies, the OECD found that the MNCs were most likely to be exploring products for the Chinese market and this was closely followed by modifying existing products for Chinese markets. Somewhat less prevalent was exploring new products for the world market (which would be the politically correct answer). Even less mentioned was exploring unknown science and technology fields, something that would most closely resemble basic research. The final category was R&D to support production and operations in China (more than one answer was

[5] The reasons for this wide discrepancy may be a decision to count each of Motorola's 19 labs in China separately and/or the capture of the R&D operations of smaller firms such as those of smaller Taiwanese firms.
[6] It is worth noting that Motorola India employed 3,000 engineers in 2007 and 40 percent of the software in its phones worldwide was developed in India (Motorola 2007b).

possible).[7] These results suggest that MNC R&D facilities in China tend to be domestically oriented.

There is significant concern on the part of MNCs about the protection of their intellectual property and know-how. The enforceability of IP rules is indicative of a bigger societal issue relating to the laws and social norms about appropriating or transferring the knowledge generated while working for an employer. Since acceptance of IP rules is more than just enforcement-driven, simply passing laws and then trying to enforce them is unlikely to rapidly change the larger social environment. Though there can be little doubt that Indian IP enforcement is superior to China, few would state that it is equal to the U.S. or Western Europe. Despite IP protection weaknesses, MNCs are increasing their research commitment in China. To take advantage of the large and rapidly growing market and low-cost capable workers, MNCs are careful to undertake R&D in areas in which there would be minimal damage from leakage to the external market.

China is rapidly becoming an important location for R&D. Chinese domestic firms such as Huawei, ZTE, Lenovo, and Haier are investing significant sums in R&D and expanding their global R&D reach. They already have some R&D operations in the U.S. that they established or, as in the case of Lenovo, inherited through acquisition. Given the build-up of capital in China, it is only natural that they will buy U.S.assets – and technology is an important attractant. Simultaneously, MNCs will (indeed feel they must) increase their R&D activities in China regardless of the IP environment.

Summary

[7] OECD (2007) found far fewer MNC R&D facilities than other surveys such as Zedtwitz (2004).

There is a global competition for R&D facilities, but today the two most important destinations for R&D offshoring are India and China. And yet, they differ markedly in terms of the character of R&D being offshored to them. The greatest beneficiary, India, outside some areas of offsets, largely in the aerospace sector, has done little beyond providing a free trade zone. The Chinese government has pursued a more aggressive policy of encouraging MNCs to establish R&D facilities. And yet, India is receiving more R&D employment. From their behavior, it appears as though MNCs are less concerned about the potential loss of IP in India and thus undertake R&D there that they might not consider in China.

There are other differences between the types of MNC R&D in the two nations. First, much of the R&D in China is localization work or developing products for the Chinese market. In India, until very recently the domestic market was of minimal interest. Second, in China there is large and increasing, but thus far not well-quantified, R&D production engineering investment by Taiwanese firms.[8] This type of R&D is largely non-existent in India because it has not been an important manufacturing site nor are there leading customers, though this may be changing, particularly in telecommunications as market expansion is torrid.

The salient differences between the two nations is that MNCs are reluctant to undertake R&D in China whose results might be easily copied by domestic rivals. This need not necessarily affect the sophistication of the R&D. For example, Microsoft undertakes extremely sophisticated basic research in both nations. However, firms carefully distinguish the types of work to be done in the two nations. To illustrate, Intel China's R&D is concentrated on research for system-level software and Intel-specific projects whose disclosure would not put it at a disadvantage. It also has its Channel Systems Laboratory whose purpose is to help vendors

[8] For a discussion of the spatial division of labor in the notebook computer industry, see Dedrick and Kraemer (2006).

design PCs for other environments. This laboratory manages five other laboratories outside of China. The strategy for the Chinese laboratories is to undertake projects whose results are either meant for the public or would be of little use to a competitor. In contrast, in Intel's Indian operations 50 percent of the employees are involved in integrated circuit development, the heart of Intel's business. In the future, Intel Bangalore will design server chips. Broadcom, another important U.S. semiconductor firm, designs some of its most important chips in India, where it has over 200 designers. In contrast, its R&D facility in China was established to support Chinese customers, while its major design operations are located in Taiwan. As a generalization, in most cases among MNCs, and in particular IT MNCs, their more globally oriented R&D is located in India. While, as a rule, their Chinese R&D facilities are smaller and have more of a domestic focus.

Types of Facilities Sited in Low Cost Regions

Facilities localizing an MNC's product or developing specialized local products are likely to be located in the low-cost country. The lower cost nations are far more likely to do development work, rather than product conceptualization. Given their superior infrastructure, the conceptualization and architecting of new products is likely to continue to be concentrated in developed nations. Strategic research planning and product road mapping is almost certain to remain in the firm's home country, though as a foreign R&D operation matures it might be given responsibility for designing products for its domestic market or be given full responsibility for product upgrades.

Sectors

The available evidence suggests that R&D globalization is most advanced in the IT sector. Established firms such as IBM, HP, Motorola, and Texas Instruments have long had overseas R&D facilities, and newer firms, such as Intel, Microsoft, and Adobe, began their international R&D expansion in the 1990s. For the younger, but research-intensive VC-financed firms, such as Google and Yahoo!, overseas R&D commenced even earlier in their development. Conversely, all major European and Asian IT firms have made significant investments in U.S. R&D facilities. What is new is the decision by nearly all of these firms to build significant R&D capability in India and China.

In traditional manufacturing firms, R&D globalization is less advanced, but both nations are experiencing an increase in the number of R&D facilities (OECD 2007). For example, according to OECD (2007), seven foreign auto manufacturers have research facilities in China. Unfortunately, there is no information regarding the types of research. This contrasts with the General Motors Indian facility, which describes the advanced research underway. Firms in the traditional manufacturing industries will increase the size and scope of their offshore R&D facilities.

The human healthcare industries, though smaller than IT and traditional manufacturing, encompass many of the most research-intensive firms in the OECD nations. Recent research suggests that there is only limited investment by the major pharmaceutical firms in developing nation R&D facilities (Cockburn 2007). For example, the OECD identified six MNC biotechnology and pharmaceutical R&D operations in China. According to Yuan (2007), of the six pharmaceutical R&D operations in China, only two, Lilly and Pfizer, were U.S. firms. At this time, the pharmaceutical investments in China appear to be complementary rather than substitutes for R&D in the developed nations. Interestingly, none of the large pharmaceutical

MNCs had R&D operations in India. Given the critical importance of intellectual property protection and the extreme secrecy in which human health R&D takes place, it is unlikely that there will be a rapid relocation of R&D operations to low-wage environments. And yet, given the growing pressure to increase profits, a plethora of organic chemists in developing nations, and the rising importance of developing nation markets, particularly, China and increasingly India, it is likely that pharmaceutical MNCs will gradually increase their offshore R&D. As a caveat to this conclusion, a significant amount of clinical trials and data analysis are already conducted offshore and more can be expected to be relocated.

In summation, there are sectoral differences in terms of the globalization of R&D. IT R&D has globalized most rapidly, while pharmaceutical R&D is diffusing more slowly. Traditional manufacturing firms have only recently begun making major R&D investments in the lower-cost nations, but it is likely to increase.

Policies among Foreign Nations to Attract R&D Facilities

R&D facilities are considered desirable by politicians and economic development professionals. Many nations have tax, cash, and in-kind incentive schemes to attract R&D. Some nations, such as Singapore, Ireland, and Israel have utilized policy to upgrade their economies. Of course, many nations offering similar incentives have experienced only minimal success. In the U.S. the Federal government has ceded such recruitment efforts to the state and local governments, and a number of them provide significant incentives to attract R&D investment. And yet, the most successful state in attracting such R&D investment, California, has few incentives, leading to the conclusion that their efficacy is suspect. For R&D investment there can be little doubt that the most effective attractor is the quality and price of the labor force.

For example, Silicon Valley, an extremely expensive business location, has had great success in attracting R&D investment. What is obvious is that absent a capable work force, only enormous incentives will attract R&D investment.

China has various tax incentive schemes to encourage R&D by both domestic firms and MNCs. There are many science parks willing to provide low-cost office space and often they have free trade zone protection providing tax holidays. In its desire to attract foreign R&D operations, some charge that Chinese government officials coerce MNCs into locating in China and then pressure them to share their IP. However, there are also dissenting Chinese voices suggesting that these foreign R&D operations retard the development of technology by domestic firms because the foreign firms charge unduly high license fees for their patents, "crowd out" domestic firms in the market for highly skilled labor, monopolize technology standards, and thwart technology transfer and knowledge spillovers (OECD 2007).[9] Provincial and city policymakers often supplement national government policies. For example, Shanghai has aggressively pursued MNC R&D facility investment. And yet, absent a stronger legal and social environment protecting the fruits of their R&D, it is unlikely that MNCs will move large portions of their R&D to China.

India has no specific incentives to attract foreign R&D investment. The Software and Technology Parks of India regulate R&D, like all other exported services. STPI operates like a free trade zone and all firms registered under it are exempt from corporate income tax until 2010. These are substantial incentives, however, they are not specifically targeted at R&D as opposed to other services, such as call centers and data entry.

[9] Obviously, MNCs have no interest in allowing the know-how and intellectual property that is the key to their competitiveness to leak to local rivals.

China has more actively pursued R&D investment than has India. However, neither of them has gone after R&D investment as single-mindedly as nations such as Singapore, Ireland, and Israel. Interestingly, in China there is some dissent regarding the wisdom of encouraging foreign R&D operations. In contrast, Indian and MNC firms are treated equally by STPI and there has been little dissent by domestic firms. This suggests that other variables, such as a superior IP protection environment, English-language capability, and management skills, are as important as a larger market and more active government involvement.

Conclusion and Policy Opportunities

The current globalization of R&D is an outcome of the increasingly globalized and intertwined sinews of economic activity. It is impossible in the current economic environment to see how this trend could be reversed. The result of the technological, legal, and political lowering of barriers to trade has made R&D globalization a natural outcome. Absent a national consensus, for which none exists or is likely to ever exist, that the import of such services should be outlawed or taxed severely, the current trends in the globalization of services including R&D will continue.

The wage gap between India and China and the U.S. is so great that even with wage increases of 10-15 percent per annum, it will remain substantial for at least the next decade. Moreover, both governments are expanding their higher educational systems in a bid to increase their supply of trained labor. Should the Indian or Chinese labor markets become too expensive, Russia, the Ukraine, and others also have significant supplies of capable engineers. Certain occupations, such as routine engineering, accounting, and finance are being commoditized and globalized. The full import of this movement by firms to access the skills of the global labor force has not yet been felt. The effect is most likely to be experienced in the next recession when firms are faced with the decision as to whether and where to eliminate excess personnel. I believe this will fall most heavily on the high-cost employees who have only globally available skills.

For high-wage nations success in the global economy become ever more dependent on the ability to envision and grow new markets. This means there are enormous opportunities for the U.S. economy, which is the most diverse and creative in the world. It suggests our educational institutions must train young persons regardless of the discipline to be creative and entrepreneurial. The engineering and science disciplines are absolutely crucial as they provide the new knowledge that is an input to the creation of new wants and needs. For example, who would have guessed that Internet search and online auctions would become multibillion-dollar global businesses centered in the U.S.?

The strengths of the U.S. political economy are well known. First, our research universities remain the finest in the world. The U.S. government and Congress have done a remarkable job in providing the research funds that have kept us at the cutting edge. With the America Competes Act, more monies are meant to be allocated to the physical sciences and engineering. Despite this major new initiative, the vitally important areas of computer science and electrical engineering require more targeted investment. To ensure the continuing supremacy of U.S. research universities in the information sciences, Congress might consider whether a National Institute of Information Sciences should be created along the lines of the fabulously successful National Institutes of Health. At this moment, the National Research Council is conducting a study of the health of the U.S. IT R&D ecosystem and the report will be available shortly.

Many of the most important new venture capital-financed firms such as Yahoo! and Google came directly from university graduate students. Unfortunately, the spiraling cost of graduate education is creating an increasing burden on universities and departments wishing to fund these bright young students. Having the finest research universities in the world provides the U.S. with a reservoir of the most highly technically trained persons in the world. To allow this resource to deteriorate would be an incalculable and unforgivable disaster.

A second area that the committee may wish to explore is the operation of the 1980 Bayh-Dole Act, which ceded rights to federally funded inventions to universities. In retrospect, this was important for removing obstacles to the transfer and commercialization of university innovations. In the intervening years, every research university has established a Technology Transfer Office. However, as Robert Litan et al. (2007) conclude, university bureaucracies have arisen that often frustrate technology transfer. Horror stories about university bureaucracies frustrating technology transfer and researcher entrepreneurship are widespread. Well-drafted legislation vesting the patent rights to federally-funded research in the inventor would likely accelerate transfer and encourage entrepreneurship. If there is concern that the meager income the universities derive from licensing would be lost, it could be mandated that they receive a five-percent stake in any revenues from the invention. In cases in which university researchers do not want to commercialize their inventions, they could assign the patent to the university, a third-party, or place it in the public domain. For certain inventions, such as techniques for gene splicing, stem cell creation, software inventions, or improved manufacturing processes, a public domain strategy would increase the public benefit, as adoption is likely to be even faster and more widespread. In other cases, assigning the patent to the university or a third party would be most effective. The inventor is likely to have better insight than any university licensing manager who cannot possibly know the nuances of every technology.

The increasingly restrictive patent regime particularly in software may also be retarding technological development. With the growing emphasis on Open Source software and recombinant innovations,[10] it is vital to establish the right balance between patent protection and increasing the stock of freely accessible knowledge. In an innovation-based economy, in which our nation's success depends upon the value-creating creativity of its citizens,[11] any obstacles to the circulation of information, be it a too restrictive intellectual property regime or unnecessary secrecy, will retard the ability to create new value.

Technology, innovation, entrepreneurship, and science are four keys to the continuing prosperity of the U.S. economy. Success will be based on increasing the capabilities within our workforce even as large numbers of capable foreign workers paid far less than ours enter the global labor market. The U.S. won the Cold War, succeeded in breaking down trade barriers, and opening markets around the world. Now, we must compete in this more open world. Responding to the challenges will require increased investment in our work force, a rethinking of our educational system, and strategies for increasing the creativity of the American people in engineering, manufacturing, design, and the arts.

[10] On recombinant innovation, see Hargadon (2003).
[11] On the importance of creativity to competitiveness, see Florida (2003).

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Table 1. The Motivation for Offshoring and Key Calculation

Motivation for Offshoring	**Key Calculation(s)**
Foreign government requirement	Is market sufficiently large to compel compliance?
Need to localize product or service	Is market sufficiently lucrative to undertake localization. Cost/benefit calculation
Proximity to key customers	Is customer sufficiently significant to warrant the expense
Access to extremely specialized or high-quality talent	How necessary is access? If critical, then costs can be extraordinarily high and the firm must still bear it.
Around the clock engineering	The goal is to shorten development times by having work ongoing in different time zones. Personnel costs are not the key motivation.
Lower cost workers	This is directly driven by the relative cost of undertaking the work in the home market or in the lower-cost market. Of course, the availability of skilled personnel is necessary, as few firms are willing to be shoulder a significant training cost.

Source: Compiled by Martin Kenney

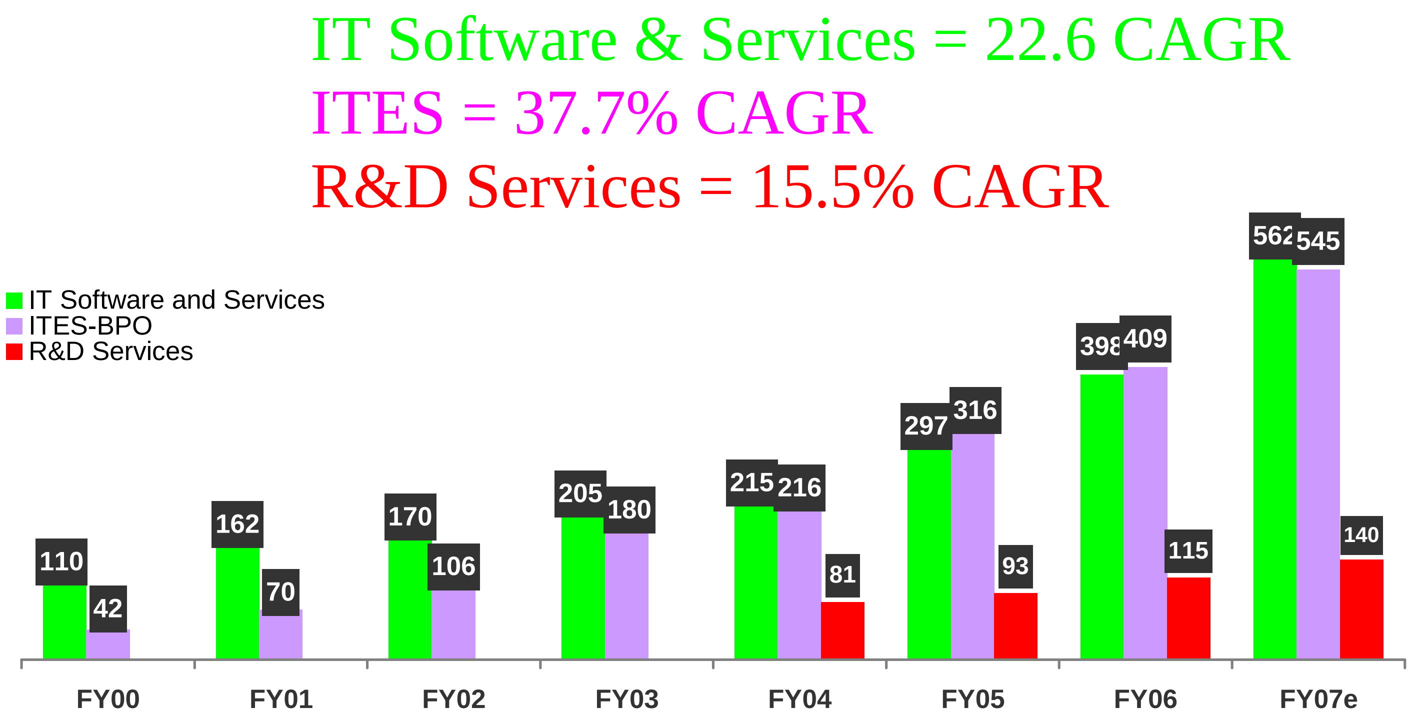
Table Two: Employment in India by Selected Large Non-Indian Systems Integration and Software Firms

Firm	Date of Entry	Nationality	Employment in India (date)	Global Employment 2006	Percent Employed in India	Acquisitions (Name, Date, # of employees
Systems Integrators						
Accenture (2)	1987	U.S.	35,000	129,000	27	
CapGemini	2003	France	12,000 (2006)	75,000	16	Kanbay, 2006, 5,000
CSC		U.S.				
EDS (3)	1996	U.S.	17,000 (2007)	117,000	15	MphasiS, 2006, 11,000 RelQ, 2007, 700
IBM (1)	1992	U.S.	60,000 (2006)	369,277	18	Daksh, 2004, 6,000 Net. Sol., 2005, 1,400
Siemens IT Solutions and Services	1992	Germany	4,000 (2006)	43,000	9	
Software Producers						
Adobe	1997	U.S.	1,000 (2007)	5,879	17	
Microsoft	1998	U.S.	4,000 (2006)	57,000	7	
Oracle	1994	U.S.	8,600 (2006)	55,000	16	I-Flex, 2006
SAP	1996	Germany	3,500 (2006)	38,400	9	
Yahoo!	2000	U.S.	1,000 (2007)	10,000	10	

1. Reentered India 1992 for domestic market and includes total employment not just IBM Global Services.
2. In 2007, Accenture employed more persons in India than anywhere else in the world.
3. In 1996 served GM India from India.

Source: Compiled from various news reports and corporate Securities and Exchange Commission filings.

Figure 1: The Number of Employees in Thousands and Compound Annual Growth Rate (CAGR) for Different Service Sector Employment from 99-00 to 06-07e



Source: Nasscom 2007