4. The Globalization of Research, Development and Innovation

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The narrative that is repeated constantly by the experts and pundits promoting the current flavor of globalization, whether they are ideologically on the left or the right, is that it is inevitable that low-skill, low-wage, labor-intensive jobs will move to low-cost countries. But that is fine, because the United States will specialize in technology sectors that create highly skilled, well-paid jobs that depend on creativity and innovation.

The narrative and its prescriptions rest on a division-of-labor hypothesis: The U.S. response to increased offshoring should be to "move up" the innovation and skill ladder. Countries like the United States need to specialize more intensely in sectors and jobs where they hold a comparative advantage, and in the case of the United States, it's in innovation. The story acknowledges that low-skill, low-wage workers will face increased competition from workers abroad and some may lose their jobs, but it offers a solution for them too. They can be easily retrained for higher skill and higher wage jobs, and end up better off.

Economic theory, the story says, holds that the overall gains from offshoring will be so great that theoretically the "winners" (firms and consumers) could easily pay off the "losers" (workers and smaller firms) for the costs they incur, and still have a lot of money left over. The fact that the winners historically have never paid off the losers seems to be of little importance. A similar story is told about specific industries. If certain industrial sectors, like textiles or computer manufacturing, are lost, that's all right since they will be replaced by "better" industries. In this ideal tale, everyone goes home happy, because everyone is either the same or better off than they were before offshoring.

But what happens to the narrative if in reality, the tasks and jobs moving to low-cost countries are in the very same high-skill innovation and high-tech sectors in which the United States is supposed to hold an advantage? What if the sectors that are lost are the "better" industries?

A variety of indicators show that some high-tech jobs and sectors have already moved to low-cost countries like India and China, and there is even more evidence that this migration will increase. The growth could be substantial. Princeton economist Alan Blinder estimated the vulnerability to offshoring of all 838 Department of Labor job categories, and found absolutely no correlation with skill level. This means that many occupations requiring advanced skills are vulnerable to offshoring, including nearly all science and engineering job categories.

In response to these facts, another narrative supporting status-quo globalization has been constructed. In this muddled tale, the rise of India and China is seen as both a challenge and a boon. In response to the challenge, American workers and industries that cannot take advantage of offshoring must "run faster and jump higher" or "adjust" by moving to new functions or sectors. The experts argue that innovation is a panacea, and that more public money should be directed to increase U.S. technological capacity. They offer a simple three-ingredient cocktail: increase R&D spending (and R&D tax breaks); produce more scientists and engineers; and improve K-12 science and math education.

Of course, all of these put the onus on taxpayers to pick up the bill.

These investments are seen as providing the "infrastructure" for creating new firms and high-wage jobs. As this line of thinking goes, doubling public investments in science and technology will encourage or complement private investments in science and technology and a new wave of high-wage, high-technology jobs and companies will be created in the United States. The path to redemption is clear, so don't change the flavor of globalization just speed up innovation.

This story is boosted by the media and other institutions, like higher education. These days, every university president in the nation seems to be only able to utter one slogan out of his or her mouth: innovation. It is couched in terms of the need to be globally competitive.

But it doesn't stop there since the proponents wisely chose a multi-pronged approach. To reassure people, they again bring up the division of labor hypothesis, claiming that while some "R&D" might be going offshore, it isn't really the important stuff. The noncritical, noncore R&D might be moving offshore, but it is work that is either "last generation" or is geared toward localization — customizing products for local needs. The really high-tech, cutting-edge research is staying in the United States.

But what happens to this new narrative if private R&D spending and the highest skilled jobs move to low-cost countries? If those countries are also investing in their public technological research infrastructure, what happens when these countries start capturing more of the core R&D and leading-edge innovation?

That's where the "boon" part of the new, muddled tale comes into play. Here the story goes that any new discoveries abroad from research and development will add to overall human welfare. As some have put it, who would or could complain if a cure for cancer was discovered in China? So the promoters get to have their cake, eat it too, and stick U.S. taxpayers with the bill.

This chapter explores how much offshoring of research and development and technological innovation is taking place, some of the discussion about its implications and what the United States has chosen to do about it.

The Political, Economic and Policy Context

India and China have attained the ability to produce world-class science- and engineering-based goods and services. This is a very new and surprising phenomenon, and various American institutions are responding to it. Congress has been holding hearings; businesses are responding to new competitors and opportunities; management consultants are promoting high-end offshoring to businesses as a way to save money; site selection consultants are promoting new geographies for new R&D facilities; academics and experts are studying it; top business schools are setting up centers of excellence to teach their MBA students how to manage innovation offshoring; U.S. universities are going global, setting up outposts in low-cost countries to train the workers for the businesses that are offshoring; foreign governments and business groups are marketing their low-cost R&D capabilities; experts are offering various prognostications about it; and the business press has been reporting on it.

Simply put, this is the beginning of a fundamental shift in the global production of innovation and R&D, and it will have a profound impact on the U.S. economy, including the types of jobs available for millions of Americans, sectoral specialization, military position, and competition and opportunities for businesses.

Yet even with all of the attention it receives, the state of knowledge about the magnitude and direction of Indian and Chinese technological capability remains meager, at best. There are a variety of reasons driving this state of affairs. First, the data available is limited, stale and narrow, and is of poor quality.[1] The federal government has devoted virtually no resources to improve this data situation. Second, the businesses benefiting from sourcing high-technology products and services from China and India have strong incentives to understate, misstate or simply not disclose their activities there, making data collection and forecasting especially difficult even in ideal circumstances. But the challenge is exacerbated by the fact that science- and engineering-based production are characterized by long lag times, risk, prolonged learning curves, learning by doing, positive feedback loops, network effects, specialized and expensive human capital development and path dependencies. Today's investments will not appear in actual products and innovations until some time in the future, if they do at all. Coupled together, these factors make predicting the trajectory and nature of the globalization of R&D and innovation especially difficult.

Putting the data and forecasting issues aside, there is another important factor muddying the public discussion of the offshoring of innovation: It is difficult to precisely identify the future impact of R&D on the U.S. economy and its workers. Even in an ideal scenario, where the government could document the offshoring of high technology for the next 20 years, economic theory doesn't provide guidance on how it could impact the United States.

Technological innovation is neither measured well nor modeled formally. It is generally treated as a residual or, as Stanford University economic historian Nathan Rosenberg calls it, a black box.[2] Much of the important literature on innovation comes from the evolutionary branch of economics, which is more like storytelling than formal modeling. It describes a nation's capacity to innovate in terms of ecosystems and other such metaphors. Linkages between and behaviors of various actors are often more important than the sheer size of resource inputs. And predicting specific economic outcomes is especially difficult.

Second, the traditional neoclassical models of trade have not factored in much about offshoring, despite claims of the proponents of globalization. Offshoring isn't simply trade in the narrow sense that political economist David Ricardo or the theory of comparative advantage that is usually invoked, but instead shifts in productive capabilities across countries. Contrary to many pundits' popular beliefs, economic theory does not say this will automatically be good for the United States. In fact, rhetorical claims by prominent economists that it is guaranteed that the United States would be better off were rebuked by Nobel Laureate Paul Samuelson, who accused pro-globalization economists like Columbia University professor Jagdish Bhagwati and Dartmouth's Douglas Irwin of engaging in "polemical untruths" by misrepresenting what comparative advantage says and doesn't say.[3] Samuelson's arguments rest on the fact that offshoring results in shifts of relative productivity. So if China gets more productive at the things the United States does well, the United States may actually become a net loser.[4]

Samuelson has covered the economic implications of offshoring in general, but not specifically the offshoring of innovation. If offshoring of everyday jobs can shift relative productivity, it's likely that offshoring of science- and engineering-based production to other countries will also shift relative productivity. Ralph Gomory, renowned mathematician and former head of research at IBM, has done groundbreaking work in this area of economics pointing out the common fallacies made about how trade theory is invoked even by sophisticated economists. His testimony before Congress summed up what economic theory can and cannot offer about offshoring:

> "Conclusions about trade in the narrow sense with fixed capabilities should not be confused with conclusions about the effect of productivity shifts. There is nothing in either common sense or economic theory which says that improvement in the productivity capabilities of other countries is necessarily good for your country. This observation holds true even if these productivity shifts are brought about by the free and unfettered actions of corporations. When the U.S. trades semiconductors for Asian T-shirts, for example, that is trade in the narrow sense. And the conclusion of the most basic economic theories is that this exchange clearly benefits both countries. But when U.S. companies build semiconductor plants and R&D facilities in Asia rather than in the U.S., then that is a shift

> in productive capability, and neither economic theory nor common sense asserts that shift is automatically good for the U.S. even in the long run."

In light of these facts, some advocates draw on history to argue that even if this occurs the United States won't suffer. They argue that this movie has been shown before with the rise of the Japanese industry in the 1980s and early 1990s. Even with the Japanese rise, the United States economy boomed in the 1990s while Japan's economy stagnated. They argue that this history should be the guide.

But one of the most important and least understood differences today versus the experience with the rise of Japan is the change in business behavior. The ties of corporations to a specific country and its workers have broken down. As Craig Barrett, CEO of Intel Corp., one of the quintessential success stories of the new economy of the 1990s, put it, "Intel can succeed without ever hiring another American."[5] Companies are no longer rooted in a specific country.

In a 2006 article in *Foreign Affairs* magazine, IBM CEO Sam Palmisano gave the eulogy for the multinational corporation, and introduced in its place the globally integrated enterprise.[6] Palmisano said: "Many parties to the globalization debate mistakenly project into the future a picture of corporations that is unchanged from that of today or yesterday....But businesses are changing in fundamental ways — structurally, operationally, culturally — in response to the imperatives of globalization and new technology." The multinational corporation model in which firms replicated their organization in each country where they sold goods, is now giving way to the globally integrated enterprise model, where firms geographically separate their production from the markets in which they sell.

When discussing his firm's aggressive moves to shift its share of workers to low-cost countries, Ron Rittenmeyer, CEO of EDS, the largest U.S.-based IT services firm, said he "is agnostic specifically about where" EDS locates its workers, choosing the place that reaps the best economic efficiency. By 2008, EDS had 43 percent of its workforce in low-cost countries, up from virtually zero in 2002.[7] The public policy discussion has not included this change in the behavior of businesses.

During the 2004 election, presidential candidate John Kerry repeatedly called CEOs who offshore jobs "Benedict Arnolds." He was roundly lambasted by the press for making the statement and eventually capitulated. His comment was silly indeed, but not for the reasons given by the press. What people didn't understand, including Kerry, is that the business world had radically changed. CEOs of globally integrated enterprises are neither "patriots" nor "traitors." They are business executives with clear incentives.

Corporate boards tie CEO compensation to earnings and share prices. Many CEOs receive bonuses and outsized pay packages even while running their company into bankruptcy. One thing is clear: Their compensation is never tied to whether the United States economy grows or how many American jobs they create. The old Charlie Wilson quote of what's good for GM is good for America needs to be updated to. "What's good for IBM may not be good for the U.S., and what's good for the U.S. may not be good for IBM."

Yet the public discussion is still moored in the 1950s Charlie Wilson economy. A notable exception to this rule is Ralph Gomory, who says, "In this new era of globalization the interests of companies and countries have diverged. In contrast with the past, what is good for America's global corporations is no longer necessarily good for the American people." Whether Congress is listening or understanding this is unclear. What is clear is that Congress has acted as though this profound shift hasn't happened. It is also clear that large multinational firms have inordinate influence over the U.S. policy process and will pursue their own political interests regardless of the impacts on the nation.

This change has special ramifications for science- and engineering-based jobs and innovation policy. Before the advent of the globally integrated enterprise, firms had the bulk of their science and engineering workers in their home country and would provide them with the latest scientific tools and technologies. Nowadays, it would be silly for globally integrated companies to give preferential access to tools and technologies to workers in any one country. Instead, they are providing the latest tools and technologies to the engineers in low-cost countries.

This is a critical change since one of the primary outputs of public investment in research and technological innovation is embodied in new and better tools and technologies. They are adopted by a wide range of firms and are then used to benefit the entire economy and workers. One of the traditional spillover benefits of public investment in research and development — new tools and technologies — are now much more footloose and "leaky" across borders. Coupled with improvements in communications technologies, the Internet and low-cost telecommunications, the global diffusion of tools and technologies has already been occurring much faster, even without firms stepping on the accelerator pedal by taking them to their overseas workers.

Some have argued that there are factors that will keep jobs in the United States. They argue that product development needs to be co-located with the end customer, and since the United States is the most sophisticated market, it will retain a substantial number of high-end jobs. The problem with this observation is that it is too simplistic. The largest growth markets are in India and China, so that's where significant job creation will be and, contrary to popular wisdom, many of the markets are quite sophisticated. India's wireless market is larger and more technologically sophisticated than the one in the United States. Is it any surprise that Motorola does 40 percent of its software development there?[8]

Even for technology work that must be done in the United States, firms are increasingly relying on foreign workers. The largest and most sophisticated IT services customers are in the United States, but Indian offshore outsourcing firms have been gaining market share and are the market leaders in this space. How do they do it? They don't hire Americans. Instead, they send foreign workers to the United States to do the jobs on-site by exploiting loopholes in U.S. immigration laws. It is simply a matter of time before this business model spreads to many other sectors.

Many observers, like Alan Blinder, have pointed out that America's superior higher education system is a source of strength and comparative advantage in technology. But universities have caught the globalization bug too. A transformation similar to the multinational corporation to the globally integrated enterprise is happening in elite universities, even if it is still in its infancy. Elite universities are "venturing abroad," tapping new markets of students in low-cost countries. Cornell, the largest Ivy, declares in its mission statement that it is the first "transnational university."

Never mind that it's a land grant university that gets large amounts of funding from both New York state and the federal government. Dozens of other elite universities are establishing — or are exploring the possibility of establishing — science and engineering programs in low-cost countries. Those schools include Rice, Purdue, Georgia Tech and Virginia Tech.[9] Various programs have already been initiated by major engineering colleges. Carnegie-Mellon offers its technology degrees in India in partnership with a small private college there. Students take most of the courses in India because it is less expensive, and then they spend six months in Pittsburgh to complete the Carnegie-Mellon degree.[10] Call it the globally integrated university (GIU) approach.

No one has good information about how many overseas university programs are being negotiated and the terms of their commitments. More important though, is why universities are behaving this way, and what the implications are for America. Surprisingly enough, no one within the university community even bothered to reflect on whether these actions are good for America or American workers. Cornell University President David Skorton defended his courtship of India with language straight out of IBM's globally integrated enterprise playbook, saying: "American higher education doesn't need protectionism."[11] But universities are not the same as for-profit corporations working in the free market. Most universities have tax exempt status and get a large share of their funding from governments, whether through research and other grants or through tuition subsidies and subsidized loans for students.

As a result of these significant changes to corporate and university behavior, it is unlikely that the traditional policy levers will work as expected since the U.S. innovation system itself has morphed into a fundamentally different enterprise. Yet the policy discussion has largely acted as though the U.S. innovation system is the same.

Another shortcoming of the discussion is the belief that the technological challenge is solely from China and India. Many other developed countries are betting on technological innovation as the appropriate way to respond to the increasing competitiveness of low-cost countries, leading to an increasingly crowded field. Singapore can no longer compete in low-cost manufacturing so it is targeting opto-electronics and biotechnology. It is funding the so-called "Biopolis" to attract biotechnology firms and pharmaceutical research. Ireland is trying to diversify away from its specialization in software services. Other developed countries are ratcheting up their investments in innovation and R&D.

Why Offshoring of R&D and Innovation Matters

Science- and engineering-based production receives special attention by policymakers because of its ramifications on economic growth, job creation, health care and military capability. The federal government will spend about $150 billion on R&D in fiscal year 2009. While much of this money is spent on specific missions, such as national defense, competitiveness is often a rationale for government investment. For example, the Bush administration's effort to boost R&D spending was called the American Competitiveness Initiative (ACI), and Congress recently passed the America COMPETES Act.[12]

Regardless of where one's sensibilities may lie, there is near consensus among both proponents and detractors of this flavor of globalization that innovation is an important advantage for the United States. America's capacity to stay on the edge of technological frontiers is a significant economic advantage, and there is consensus that policies should be put in place to maintain and expand those advantages. If R&D begins to be offshored some wonder if innovation will follow. Others, like Amar Bhide and Christopher Hill, argue that the location of R&D doesn't matter because wealth and jobs are really created by the downstream innovation, technology adoption and commercialization activities rather than technology creation.[13] If this is true, then states like New York are foolish to be pouring hundreds of millions of dollars into nanotechnology research in Albany because, after all, the goal is to create geographically localized spillover benefits from the research in the form of firm and job creation.

Perhaps more important is the drive by India and China to create their own innovations, so-called "indigenous innovation." In China's case, this is driven by the state, in India's case, by the private sector. Even if these efforts meet with limited success in creating breakthrough technologies, they indicate the ability to work with advanced technologies and attract advanced design, development and production work.

Data on the Offshoring of R&D and Innovation

The larger problem faced by policy makers is that policy proposals are being made and adopted with limited knowledge about how much innovation and R&D is actually being done in low-cost countries. The indicators of India's and China's innovation and research capabilities offer a decidedly mixed picture. The data is sometimes conflicting, with some showing an unmistakable rise in their technological prowess, while other data show these countries terribly lagging. For example, in 2006 China was by far the leading exporter of advanced technology products to the United States, surpassing all of the European Union combined. While it was also a significant importer, China is running a large and increasing trade surplus in these types of products with the United States.[14] Yet not a single publicly traded Chinese company is a top 100 spender on R&D.[15] And the number of triadic patents —those filed in Europe, the United States and Japan — awarded to Chinese inventors in 2002 was a mere 177 versus more than 18,000 for American and more than 13,000 for Japanese inventors.[16]

India's indigenous information technology services companies, like Infosys and Wipro, have become the market leaders in their sector, forcing U.S.-based competitors like IBM and HP to adopt their offshore outsourcing business model. But, in 2003, India only produced 779 engineering doctorates compared to the 5,265 produced in the United States.[17]

How Much Offshoring of Innovation and R&D Is Happening?

Since innovation cannot be directly measured, proxies are used to identify common elements of — and inputs to — innovation. Some of these metrics include high-technology trade, R&D spending and human capital.

Traditional leaders in science and technology are the United States, the European Union, Japan and more recently Taiwan, Israel, Ireland, Singapore and South Korea. The rise of India and China seem to be reported widely in the press, but many of the common R&D and innovation metrics provide a more nuanced picture. Some of those common indicators are examined below.

R&D Services Trade

The research, development and testing (RD&T) services sector is a relatively small and specialized industry sector comprising firms that complete contract research and other activities, such as environmental lab testing.[18] In 2003, RD&T accounted for $12.5 billion (around 6 percent) of the $204 billion of R&D performed by industry in the United States.[19] (The Bureau of Economic Analysis has only been capturing trade data for RD&T since 1999.)

The United States ran a trade surplus in RD&T of $3.4 billion, exporting $10.1 billion while importing $6.7 billion worth of these services in 2005.[20] The surplus in 2005 was the lowest recorded level in the 2001-2005 timeframe. While exports increased by 33 percent between 2001 and 2005, imports increased at almost double the rate: 64 percent.

RD&T trade data is further broken down by "affiliated" cross-border transactions within a multinational corporation, and "unaffiliated" cross-border transactions between independent firms. Most RD&T trade, 79 percent, is between affiliates — that is, within multinational corporations. In this category, the United States ran a trade surplus in 2005, but imports were rising much faster than exports. Trade between affiliates is not reported by country, so the sources of the shifts in trade are unknown.

For "unaffiliated" trade in RD&T, there was a small surplus in 2001 of $321 million that shifted to a deficit of $1 billion in 2005, most of which was attributable to trade with Europe. For unaffiliated trade with India, the balance went from a modest $15-million surplus in 2001 to a deficit of $43 million in 2005. Similarly, unaffiliated trade with China went from a $5-million surplus to a $15-million deficit. While the numbers are moving in a direction indicating a shift toward offshoring, the scale of the RD&T trade with India and China is puny. The two countries combined only account for 3 percent of unaffiliated trade in RD&T.

But RD&T trade with many other locations with high levels of research and innovation production are also quite small. For example, Japan, which is the third largest R&D spending country, accounts for only 7.6 percent of unaffiliated RD&T trade, and other countries well-known for their innovation — Taiwan, South Korea, Israel — each account for about 1 percent.[21] Even in well-established countries, RD&T may be a poor indicator of shifts in R&D across borders. If R&D and innovation is increasingly produced in, and shifted to, India and China, then RD&T may not reveal it.

It is also possible that cross-border RD&T is undercounted. In 2005, unaffiliated imports from India were reportedly worth $61 million. HCL Technologies, a major India-based engineering firm, claims to have sold $512 million worth of R&D services in 2008.[22] It is possible that significant shares of cross-border technology activities, especially in services, are simply not being picked up in the official data. As Timothy Sturgeon has pointed out, measures of the services sector, particularly with respect to trade, are woefully inadequate.[23] And the numbers that are reported by different government sources can vary quite dramatically. The U.S. Government Accountability Office found that India reported exporting 20 times more business, professional and technical services to the United States than the United States reported as imports of those services from India.[24]

Advanced (High-Technology) Trade Balance

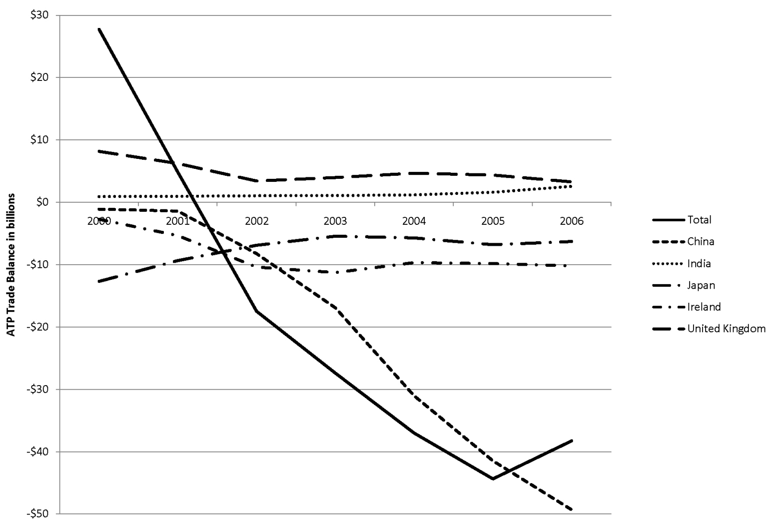
Other trade measures provide insight into the kinds of skills and capabilities required to produce tradable products. Again, there is widespread belief that high-skill, high-technology products are made in high-cost countries, and that low-skill, low-technology products are made in low-cost countries. But that is not the case.

The United States is running large and growing trade deficits with China in the "advanced technology products" (ATP) category. The advanced technology products category, defined by the Foreign Trade Statistics division of the Census Bureau, captures trade in goods (services are excluded) that require a high amount of research and development to produce. The ATP series was created in the late 1980s to easily identify the U.S. trade position in high technology.

The United States began running a trade deficit in advanced technology products in 2002, and that deficit increased to $38 billion in 2006 as shown in Figure A. Much of the deficit can be attributed to the rapidly declining trade position with China, dating to its accession to the World Trade Organization in 2001.

Looking at exports and imports separately, China ranks number one for both exports and imports. The United States exported more ATP — $24 billion — to China than any other country in 2006, up more than two-fold from $11 billion and 8th place in 2000. But the

Figure A: U.S. ATP Trade Balance 2000 - 2006

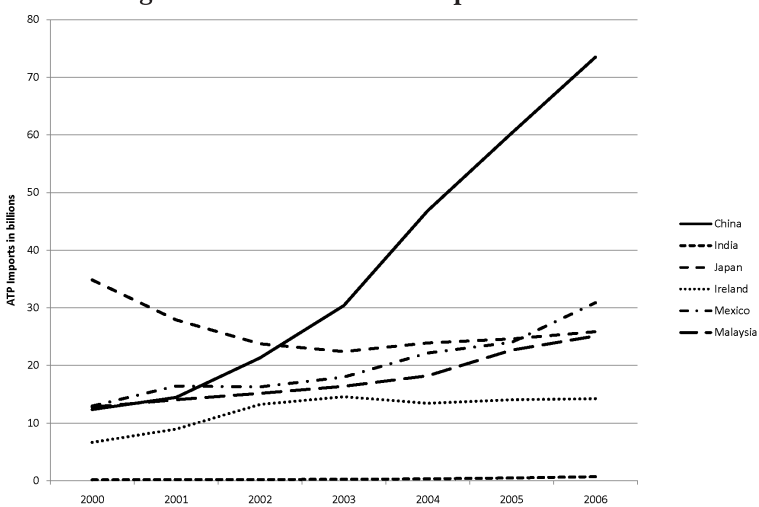


Source: National Science Foundation, Science & Engineering Indicators 2008, Table at06-21 remarkable story, as shown in Figure B, is the massive five-fold increase in ATP imports from China between 2000 and 2006, going from $12 billion and 7th place to $73 billion and a dominant 1st place (Mexico is a distant second at $31 billion), accounting for one-quarter of all U.S. ATP imports.

The importance of China's rapid rise in ATP trade is in dispute. Some believe it shows rapid technological advances and, coupled with China's plan to spur indigenous innovation, poses a significant threat to U.S. competitiveness.[25] Others believe it exaggerates China's high-technology capabilities, explaining that it simply reflects global production networks, where production is increasingly fragmented across countries, and the rise in Chinese ATP exports is the result of export processing.[26] While the end product might indeed be high technology (i.e., China has content that requires R&D and high-skilled labor), the portion produced in China only required relatively low-skilled workers.

Others explain that the increase in Chinese ATP exports is due mostly to foreign multinational investments, either wholly foreign owned or joint ventures, and that indigenous Chinese firms account for less than 10 percent of ATP exports. Furthermore, those exports are mostly in two sectors, information and communications technology and optoelectronics.[27]

Figure B: U.S. ATP Trade Imports 2000 - 2006



Source: National Science Foundation, Science & Engineering Indicators, 2008, table at06-21

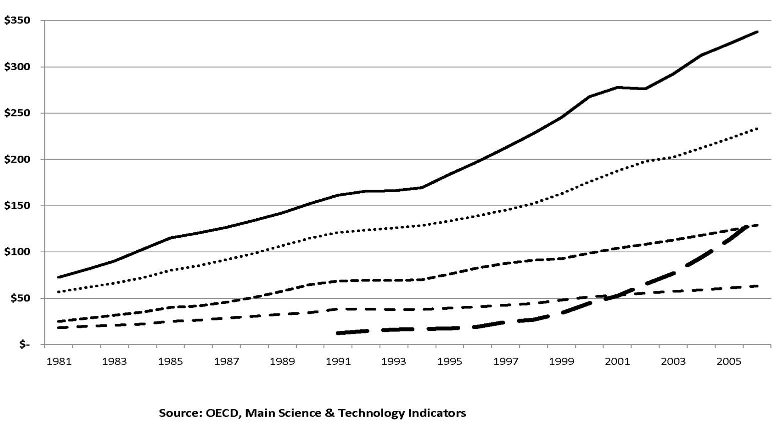
In the case of India, the United States ran a slight surplus of $2.6 billion in 2006, up from $913 million in 2000. Exports to India increased from $1 billion and a rank of 28th in 2000 to $3 billion and a rank of 20th in 2006. Many predicted that India would become a large market for U.S. ATP exports, as the offshoring of IT services and "business process outsourcing" exploded. The expectation was that Indian workers would be buying Dell computers and telecommunications equipment from Americans, but it simply hasn't materialized. Information and communications ATP exports to India increased $470 million between 2003 and 2007, from $650 million to $1.12 billion, while the Indian offshoring industry exploded.[28] Aerospace is the one sector where U.S. ATP exports have increased significantly.

R&D Spending

When the OECD released data estimating that China overtook Japan as the number two country in R&D spending, it raised a lot of eyebrows. As Figure C shows, China overtook Germany in 2002 and Japan in 2006 in R&D spending. While China remains below the United States, at $136 billion versus $338 billion in 2006, its recent (1999-2003) R&D spending growth has averaged 23 percent in comparison to 5 percent for the United States.[29]

China's spending on R&D is substantial and growing. A number of analysts have argued that, by using purchasing power parity (PPP) exchange rates, the OECD is overstating China's real R&D spending.

Figure C: Domestic R&D Expenditures 1981- 2006 *(in billions of current PPP $s)*



Source: OECD, Main Science & Technology Indicators

While wage rates for researchers may be lower in China compared to the United States, the market prices for lab equipment are likely equivalent. So absent an R&D-specific PPP, obtaining an apples-to-apples comparison is difficult. China's spending is heavily weighted towards the development side of R&D.[30] (India's R&D spending is not reported.)

Multinational R&D Investments and Linkages

U.S. multinational corporations performed about 85 percent of their R&D ($152 billion) at the parent company in the United States in 2004. About 15 percent ($28 billion) was performed by majority-owned foreign affiliates, most of which was in Europe. The foreign-affiliate share has risen slightly from 12 percent in 1994.[31] China's share was a modest 2 percent of the foreign affiliate R&D spending, accounting for just $622 million. India's share was even less at 0.6 percent, or $163 million.[32]

Foreign multinational corporations performed $30 billion of R&D at their affiliates in the United States. The amounts from Chinese and Indian multinational corporations are so small that they don't appear in the data. About three-quarters of the R&D performed in the United States by foreign firms comes from European companies. While foreign multinational R&D spending in the United States is higher than U.S. multinational spending abroad ($30 billion versus $28 billion), the difference is small. The United States does not appear to be a major magnet for R&D.[33]

Low-Cost Countries Attract R&D Sites

Another new phenomenon is competition by low-cost countries for R&D site selection. Defying the product life cycle pattern of technological investments proposed by Raymond Vernon, India and China have successfully attracted R&D and innovation facilities.[34,35] Vernon argued that newly invented products were initially produced in developed countries and only after they matured did production move to developing countries. Any R&D done in developing countries would be limited to customizing the product for the domestic market.[36] The criteria used for placing R&D facilities are multifaceted, including lower labor and capital costs, proximity to markets, specialized talent, as well as government subsidies and incentives. Experts have also pointed out that some governments, especially China, are requiring companies to place R&D facilities and transfer technologies as a condition of access to the Chinese market.[37,38]

Recent surveys of corporate R&D managers indicate that India and China have become much more attractive as destinations for R&D investments. A survey by the U.N. Conference on Trade and Development of the top 300 worldwide R&D spenders found that China was the top destination for future R&D expansion, followed by the United States, India, Japan, the U.K. and Russia.[39] A survey of 248 R&D managers of U.S. and European multinational companies, conducted by Thursby and Thursby for the National Academies' Government University Industry Research Roundtable, found more firms had new or planned facilities "central to overall R&D strategy" to be located in China than in the United States, and a large number are slated for India.[40] The study also found that the managers expected R&D employment growth in India and China, and that more respondents expected U.S. R&D employment to decline than those who expected it to increase. Their findings also point to a division of labor between R&D, where "new science" tended to be located in developed countries, whereas "familiar science" tended to be located in emerging economies. In 2007, *The Economist* magazine surveyed 300 executives about R&D site selection. They asked them to name the best overall location for R&D excluding their home country. India was the top choice, followed by the United States and China (Canada followed as a distant fourth).[41] Eight of the top 10 R&D spending companies have R&D facilities in China or India, (Microsoft, Pfizer, Chrysler, General Motors, Siemens, Matsushita Electric, IBM and Johnson & Johnson).[42]

It appears that the emerging economies of India and China have leap-frogged certain stages of economic development by attracting private-sector R&D production. This may result in greater competition between regions for attracting R&D investments. An important rationale for public sector investment in R&D is that it helps to attract private-sector R&D investment in the same location. Public sector investments, often accompanied by tax and other subsidies, may become less effective at attracting those private investments.

Patents

Patents are another common proxy for research and innovation output. By this measure, the inventive activity of developing countries like India and China is quite low. In 2003, inventors from China were granted only 573 (0.3 percent of the total) U.S. patents. Inventors from India received only 341 (0.2 percent of the total). That same year, U.S. inventors received 87,901 patents (52 percent of the total), and Japanese inventors were awarded 35,517 (21 percent).[43]

Some have argued that because many patents have limited economic value, analysts should use so-called triadic patents — those patents that are granted in Japan, Europe and the United States, the three major markets — to try to identify high-value patents for products with global markets. By this measure, in 2002 Chinese inventors received 177 triadic patents (0.3 percent of the total), and Indian inventors were awarded 78 (0.2 percent). U.S. inventors were granted 18,324 (35.6 percent), and Japanese inventors received 13,195 (26 percent) of the worldwide total of triadic patents.[44]

By patent measures, inventors in China and India are not inventing many products for the United States or global markets. But it may be just a matter of time before this activity increases. If we look at patent activity from South Korea and Taiwan, often referred to as the East Asian Tigers, we see that patents granted have increased markedly from 1990 to 2003. In the case of South Korea, the number of U.S. patents granted grew from 225 to 3,944, and in Taiwan's case from 732 to 5,298.[45]

Yet even the Council of Competitiveness claims that patents are not a good indicator of innovation. In its 2007 "Competitiveness Index" it notes that Apple Computer is considered to be the world's most innovative company, yet it ranked 187th in receipt of U.S. patents in 2005 with 84. "Apple actually spends less on R&D as a percentage of sales than the average for its industry," the council says. Google, which was in second place in the global innovation rankings, did not even muster 40 patents in 2005, ranking it below the top 400 companies receiving U.S. patents. Yet Google is ranked as the second most innovative company in the world. IBM, which has for years been the top recipient of U.S. patents, is ranked only in 10th place among the world's most innovative companies. The second largest recipient of U.S. patents, Canon, doesn't even make the list of top 25 global innovators. Hewlett Packard, in third place among patent recipients, isn't considered to be a top global innovator, either. The same is true of Matsushita, Hitachi, Toshiba and Fujitsu, all of which are on the top 10 list of U.S. patents but don't make the top 25 list of global innovators.

So what is true of companies might also be true of countries:

patents might not be a good indication of innovation. China and India have innovation systems that are quite immature. It may be simply a matter of time before there are increases in patenting activity. Weak intellectual property regimes, however, may continue to hinder inventive activity in those countries.

Royalties from Intellectual Property

Royalties from intellectual property are another indicator of cross border flows of technology. The size of the flows is relatively small, with the United States receiving $4.8 billion from other countries and paying them $2.2 billion in 2003. The two-way royalty flow for the United States with both India and China is very small. The U.S. receipts from China were $100 million, and from India they were $22 million. U.S. payouts were even smaller, $3 million and $1 million, respectively.[46]

While these values may begin to rise, they are unlikely to ever be very substantial. U.S. royalties from Japan were $1.3 billion, and payments to it were $524 million in 2003.[47]

Science and Engineering Articles

A significant output of research activity, especially academic research, is the publication of scientific articles. China's article output increased more than four-fold between 1995 and 2005, moving it from being ranked 14th to 5th in just a decade. The 2005 Chinese output of around 42,000 articles still significantly lags the United States and European Union, each of which accounted for over 200,000 articles, but China's scholarly article contribution is now three-fourths the size of Japan's. India's output, which was nearly equal to China's in 1995, has increased at a much slower rate, with about 15,000 articles published by its scientists and engineers in 2005. It began 1995 and ended 2005 as the 12th ranked country.

A potentially more significant figure is how China has focused its efforts on particular technical fields. The data cited above include social sciences as well as natural and physical sciences. China appears to be primarily investing in the physical sciences (engineering and mathematics). In engineering and chemistry, China became the second leading publisher of articles, supplanting Japan. And in physics and mathematics, it moved into third place (behind Japan and France, respectively).[48]

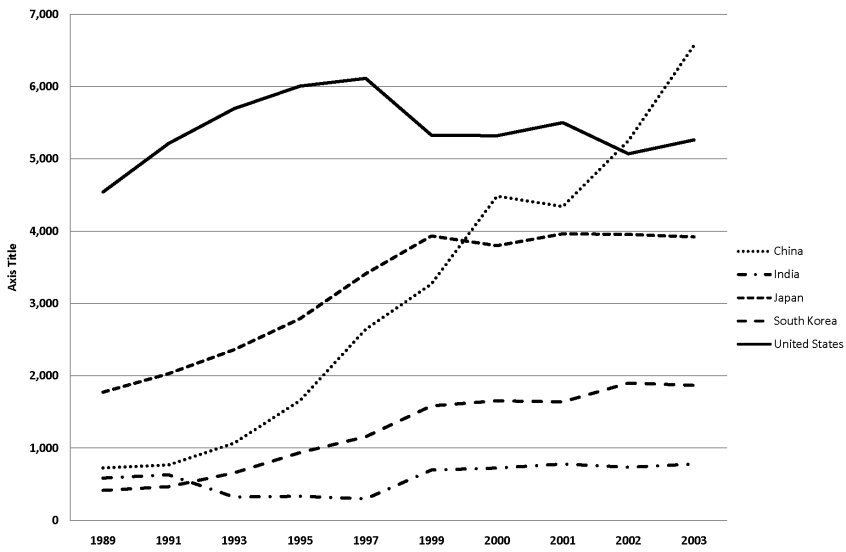
In the leading-edge field of nanotechnology, China is now ranked number two, behind the United States, in the number of nanotechnology papers published.[49] By contrast, India was only in the top 10 in chemistry (7th) and physics (10th), maintaining the same country ranking it had in 1995.

Like patents, articles vary in quality, so citation counts are often used as a proxy for quality. Chinese and Indian citation numbers still lag the United States, European Union and Japan significantly. In the case of China, the citation counts are increasing, indicating improved quality, and this increase in citations has occurred at the same time as the overall quantity of articles has increased.[50]

Human Capital Measures

Chinese and Indians are responding to the increased opportunities in science, technology and engineering occupations, from offshoring as well as overall growth. In India, the response has been mostly in the private sector through a proliferation of private colleges and training academies. In China, the state has played a bigger role in expanding the talent pool at all levels, with a dramatic difference especially at the doctorate level.

Figure D: Engineering Doctorate Production by Country 1989- 2003



Source: NSF 2007a, Table 3

As Figure D on the previous page shows, India's engineering doctorate production hardly budged from 1989 to 2003, but China's production increased nine-fold, surpassing Japan in 1999 and America in 2002, moving to first place.[51]

Explaining the Competitive Advantage of the Indian IT Services Industry

One of the most important technology stories of the past decade has been the swift rise of the Indian IT services industry. This sector includes India-based firms like Wipro, Infosys, TCS, Satyam, as well as U.S.-based firms like Cognizant and iGate that use the same business model. There is no need to speculate about whether the Indian firms will eventually take the lead in the sector sometime in the future; they already have. By introducing an innovative, disruptive, operational business model, the Indian firms have turned the whole industry upside down in the matter of four short years. It caught U.S. IT services firms like IBM, EDS, CSC and ACS flat-footed. Not a single one of those firms would have considered Infosys, Wipro or TCS as direct competitors as recently as 2003.

The U.S. firms are now moving as fast as possible to adopt the Indian business model, moving as much work to low-cost countries as possible. The speed and size of the shift is breathtaking.

IBM held a historic meeting with Wall Street analysts in Bangalore in June 2006, where the whole IBM executive team pitched their strategy to adopt the Indian offshore outsourcing business model. During the two-day event, punctuated by more than 300 PowerPoint slides, the IBM executive team explained why it believed the talent pool in India and other low-cost countries will continue to deepen, and that IBM would be investing $6 billion to expand its Indian operations.[52]

IBM's headcount in India has grown from 6,000 in 2003 to 73,000 in 2007, and it is projected to be 110,000 by 2010.[53] This compares to a headcount in the United States of about 120,000. Accenture passed a historic milestone in August 2007, when its Indian headcount of 35,000 surpassed any of its other country headcounts, including the United States, where it had 30,000 workers.[54]

In a 2008 interview with an IT trade publication, EDS chief executive Ron Rittenmeyer extolled the profitability of shifting tens-of-thousands of the company's workers from the United States to low-cost countries like India, and he outlined plans to continue the process through 2008. He said that outsourcing is "not just a passing fancy. It is a pretty major change that is going to continue. If you can find high-quality talent at a third of the price, it's not too hard to see why you'd do this."[55]

ACS recently told Wall Street analysts that it plans its largest increase in offshoring for 2009, when nearly 35 percent of its workforce will be in low-cost countries. The 2009 offshoring efforts will involve more complex and higher-wage jobs than in prior offshoring efforts, including jobs in application development and project management.[56]

So why have the American firms so aggressively increased their low-cost country headcounts? The answer is that the Indian offshore outsourcing business model is significantly more profitable. Table 1 compares financial performance of four companies, two offshore outsourcing firms (Infosys and Wipro) against two of the largest U.S.-based IT service firms (EDS and CSC). The data is from 2005 because this was when U.S.-based IT services firms began to seriously ramp up their offshore presence. As can be readily discerned, the market capitalizations of Infosys and Wipro were much higher than EDS and CSC even though their sales were a small fraction.

In other words, Wall Street was saying loud and clear that Infosys and Wipro were market leaders. The reason for the extraordinary val-

Table 1: Comparative Financial Data for Traditional IT Services Versus Offshore Outsourcing Firms

Company Name	Headquarters	Market Cap (mill)	Latest FY Sales (mill)	Profit Margin (5 yr Avg)
Infosys	India	$19,877	$1,592	27.93%
Wipro	India	$15,268	$1,627	20.59%
Electronic Data Systems	US	$12,517	$25,865	2.74%
Computer Sciences Corp	US	$10,015	$14,059	3.23%
Dollar figures in millions; Retrieved from Reuters, www.reuters.com on November 13, 2005				

uations of Infosys and Wipro was their net profit margins (based on sales) were multiple times those of EDS and CSC. Infosys averages a remarkable 28 percent profit margin in an industry where 6 percent to 8 percent is considered a good year. Infosys maintained these margins while growing its revenues and headcount by 40 percent per year, so it comes as little surprise that the CEOs of EDS and CSC began to slash U.S. and European workforces and ramped up hiring in India and other low-cost countries.

The success of the Indian software service business model is built on a company's ability to maximize the amount of work that can be done in a low-cost country with rock-bottom wages. Firms can hire fresh computer science graduates from good universities at $5,000 per year.

The Indian government grants tax holidays on software and business process outsourcing exports. This advantage translates into much lower effective tax rates for Infosys and Wipro (between 13 and 14 percent) than for their U.S. rivals, which had effective tax rates of approximately 35 percent.

The upshot is that the Indian IT firms have been wildly successful in selling high-technology services to the world's most sophisticated market — the United States — without hiring or employing Americans. This is even more remarkable since most economists long considered that most high-tech services were nontradable.

The offshore outsourcing industry is now targeting higher-end innovation and other engineering services work and jobs. Considering the pace and depth of their success in software services it may not be long before they pick off more of the highest-skilled American sectors and jobs.

The software services industry is a key example of the new era of globalization that has not been fully appreciated by millions of Americans. The industry pays high wages and hires workers with advanced degrees and training in engineering and other technology fields. Industry firms are innovators and spread advanced technical abilities to their customers. Yet the sector does hardly any formal R&D. In fact, EDS doesn't even report any R&D spending in its financial statements.

Anyone who focuses solely on R&D spending or patents is blind to this major loss of American innovation jobs. Second, and more important, is how the U.S.-based firms reacted to the competitiveness challenge from Indian offshore outsourcing. Instead of investing in their American workers with tools, technologies and training that would make them more competitive, they jettisoned them in favor of low-cost workers. The era of the globally integrated enterprise is upon us. The IBM and EDS strategy of shifting workforces to low-cost countries may well succeed, but for whom?

India's success is not lost on the Chinese government, which has created a state-owned joint venture with Microsoft for the express purpose of helping China develop a world class IT services offshoring capability. IBM is also playing its part. The company is training 100,000 IT services professionals in Jinagxi.

Rapid growth has also enabled offshore outsourcing firms to raise extraordinary sums from public offerings on stock markets. At the same time in 2003 that Google was raising $1 billion in an initial public offering (IPO) on Wall Street, Tata Consultancy Services, the largest Indian IT firm, raised a similar amount with an IPO on the Indian stock exchanges.

R&D Activities in China and India

Trends in R&D site selection are simply not tracked by the U.S. government. Recent announcements show that many are being placed in low-cost countries. For example, Applied Materials announced the opening of a major R&D complex in China in March 2007. According to *Site Selection* magazine, 22 of the 25 largest facility investments in semiconductor plants since January 2006 have occurred in Asia, including nine of the top 10. A University of Texas study recently found that of the 57 major global telecommunications R&D announcements in the past year, more than 60 percent (35 announcements) were located in Asia, whereas a meager 9 percent (five) were located in the United States.

According to the China's Ministry of Commerce, foreign multinational corporations have established 1,160 research institutions. There were 30 such institutions in 1999, approximately 200 by 2001 and 700 by 2005. These research institutions have to meet government standards to be counted.

Major corporations are using many tactics to ensure that these investments pay off. For example, the leading professional group representing R&D managers from U.S. multinational companies is the Industrial Research Institute (IRI). A major initiative of the group, and "one of IRI's fastest growing programs," is what is called the China Forum for Senior Technology Executives. IRI has a program specifically targeted at foreign multinational companies setting up shop in China and wanting to take advantage of indigenous innovation there. This is not an isolated effort. For example, Oracle Corp. underwrote a 2007 R&D meeting in China called "China and R&D Globalization: Integration and Mutual Benefits." The goals of the meeting were to explore:

- How foreign R&D can further contribute to the Chinese national innovation system.
- How China can better contribute to the global knowledge pool through further integration into the global knowledge system, outward investments, exchanges of highly skilled human resources and increasing international trade in knowledge.
- The unfulfilled potential for international cooperation between Chinese and foreign players in R&D and innovation.
- How to nurture a more fruitful interface between foreign R&D activities and Chinese domestic innovation capabilities.
- How the design of China's future National Innovation System could better integrate the role of foreign R&D activities with outgoing R&D investment by Chinese firms.

There is no comprehensive list of R&D investments by U.S. multinational corporations being made in China, and American companies are not required to disclose foreign R&D activities in financial filings. Below are some of the R&D activities from which two patterns seem to emerge: the R&D activities and investments in India and China are relatively new, and they are growing. Figures in the parentheses show the firm's R&D spending rank (for U.S.-based firms only) and its spending for fiscal year 2007.

General Motors (No. 1, $8.1 billion)

• GM in India: The India Science Lab, one of eight General Motors research labs, is located in Bangalore and was established in 2003. More than 70 percent of its researchers hold a Ph.D.[57] Also, GM has created collaborative research laboratories with two Indian universities to focus on specific R&D topics. GM has nine such labs with universities, and two of the three outside the United States are in India.[58]

• GM in China: In October 2007 General Motors announced it would build a wholly owned advanced research center in Shanghai to develop hybrid technology and other advanced designs. GM already has a 1,300-employee research center in Shanghai through a joint venture with Shanghai Automotive Industry Corporation.[59]

Pfizer (No. 2, $8.1 billion)

• Pfizer in India: Pfizer has been outsourcing significant drug development services to India. Forty-four new drugs are under clinical trials involving 143 medical institutions and at least 1,800 patients. The company is now looking to expand into drug research in India through collaborations.[60]

• Pfizer in China: Pfizer has approximately 200 employees at its Shanghai R&D center, which supports global clinical development. It also uses a number of contract research firms for R&D there. It plans significant expansion of its R&D in China.[61]

Microsoft (No. 5, $7.1 billion)

• Microsoft in India: Microsoft employs more than 4,000 workers in India. The Microsoft India Development Center was established in 1998. It has grown more than 10-fold since 2003, when it had 120 people.[62] With 1,500-plus workers, it is the company's largest development center outside the United States.[63]

• Microsoft in China: The Microsoft China R&D Group is more than 10 years old and currently employs 1,500 workers. Activities are for both localization and global markets. The Microsoft China R&D Group focuses on five areas: mobile and embedded technology; Web technology products and services; digital entertainment; server and tools; and emerging markets.[64] Microsoft broke ground on a new $280-million R&D campus in Beijing in May 2008.[65] In November 2008, Microsoft announced it is significantly expanding its R&D operations in China by investing an additional $1 billion over the next three years, thus making it the largest R&D center behind the United States.[66]

Intel (No. 6, $5.8 billion)

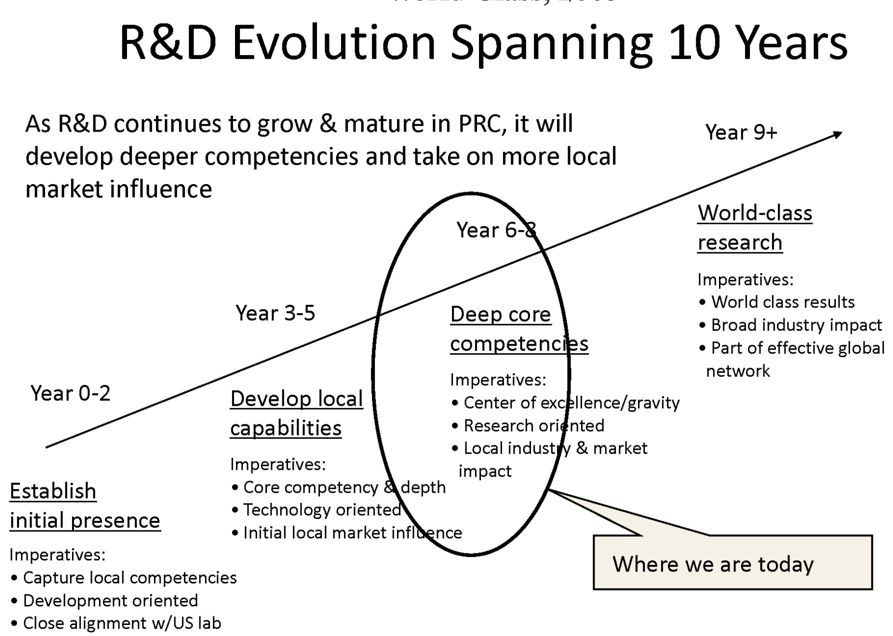
• Intel in India: Intel began with a sales office in 1988 and established an R&D center in 1998. It now has about 2,500 R&D workers in India, and it has invested approximately $1.7 billion in its Indian operations.[67] In 2007, Intel's Bangalore Development center contributed about half the work towards its "teraflop research chip."[68] In September 2008, Intel unveiled its first microprocessor designed entirely in India, and the first time that 45 nanometer technology was designed outside of the United States. The Xeon 7400 microprocessor is used for high-end servers.[69,70] In 2005, Intel announced a planned investment of $800 million in India to expand research operations and an additional $250 million to launch a venture capital fund targeted at Indian start-ups.[71]

• Intel in China: Intel is building a $2.5-billion, 300mm semiconductor fabrication facility in Dalian, China, its first fab in Asia.[72] In April 2008, Intel announced that its $500-million Intel Capital China Technology Fund II will be used for investments in wireless broadband, technology, media, telecommunications and "clean" technology. The first fund's size was $200 million.

Examples of Intel's first China fund company investments include Neusoft Group, Supcon Group, A8 Music, Chinacache International, Chipsbank Microelectronics, DAC, HiSoft Technology International, Kingsoft, Legend Silicon, Montage Technology and Palm Commerce. Notable liquidity events involving portfolio companies from Intel's first fund include Actions Semiconductor, Kingsoft and Neusoft Group.[73]

Figure E reproduces a slide from a May 2005 presentation by Peter Liou, former director of Intel's China Research Center, on Intel's R&D strategy in China.[74] The slide indicates that Intel's China Research operations are expected to achieve world-class status before 2010.

Figure E: Intel Plans to Make Its China Research Center World Class, 2005



Why the Stats Don't Match the Business Reality

If one reads only the typical science and engineering indicators, as reported by the National Science Foundation, a particular image seems to appear. China is investing large sums in building up its R&D and innovation infrastructure, but the innovation outputs have been mixed, with healthy increases in publications and production of Ph.D.s, but a very limited number of patents. The huge increases in advanced technology products trade seem almost independent of these actions. One view of China is that it's just a matter of time before it becomes home to indigenous innovation. On the other hand, India appears to be significantly backward when it comes to the traditional innovation indicators. The government isn't investing in R&D and innovation, and its research outputs, publications and Ph.D. production have been stagnant for the past 20 years, yet it is able to attract foreign investments in R&D.

Contrast the official statistics with the buzz by management consultants and business school professors who promote Indian and Chinese research capability right now. Why does the large gap exist? For one thing, the official data is stale. Table 2 shows that much of the data

Table 2: Data Availability for Innovation Indicators

Innovation Indicators - Year Most Recent Data Available	
Category	**Most Recent Data Available**
Patents	2003
Triadic Patents	2002
MNC R&D Investments	2004
R&D Spending	2006
PhD Production	2003
Royalties from Intellectual Property	2003
RDT Services Trade	2005
Advanced Technology Products Trade	2008
Science & Engineering Articles	2005

Sources: NSF 2007a; ATP Trade data available from Foreign Trade Statistics, U.S. Census Bureau is three or even five years old. High-end offshoring is relatively new and growing fast. For example, IBM has increased its headcount in India more than 10-fold, from 6,000 in 2003 to 73,000 in 2007. Contrast that with the most recently available data.

Conclusions

China and India are both defying Raymond Vernon's traditional product life cycle model for international investments in technology. Businesses are making increasing investments in R&D and innovation in emerging countries like China and India. However, the scale and scope of these investments is still not clear. China and India are likely on very different technological development trajectories.

China, whose export prowess is based on manufacturing, appears to be building its innovation system through major investments in R&D spending, attracting foreign firms and advancing education. While it has major initiatives to spur indigenous innovation, it is still too early to tell how fruitful those efforts will be. India, on the other hand, has created a specialization in white-collar services exports. These sectors generally do little formal research or patenting even though they are innovative and create large numbers of high-wage, high-technology jobs. India's indigenous firms are market leaders in key sectors like IT services, but India does not appear to be investing heavily in building its innovation system, instead relying on the private sector to take the lead.

The rise of India and China in these sectors will affect how the United States benefits from its investments in innovation. There are significant structural changes including shifts in employment relations, private sector management strategies, university internationalization and a more uncertain and volatile domestic science, technology and engineering labor market. These structural changes mean that the system will react differently to policy changes.

Will government R&D investments result in the same kind of domestic production payoffs as in the past? Or do the downstream benefits of the development and production jobs leak out rapidly to countries that have lower costs, the technological capacity (human and infrastructure) to absorb those jobs, and the globally integrated enterprises that are able to transfer the technologies and knowledge more rapidly? The economic and national security outcomes of increased investments into the innovation process are going to be different than they have been in the past. The United States needs fresh thinking about policies that reflect this new reality.

Most forward-looking indicators point to a rapid increase in the offshoring of R&D and innovation, yet there is poor information on the nature of the work moving overseas. Is it advanced or mundane? Is there indigenous innovation, or is it mostly being done by U.S.-based multinationals? The private sector has strong incentives to withhold making public information on the offshoring of innovation, and the U.S. trade data on services is woeful. If, as many experts believe, leadership in innovation is key to America's future competitiveness, the government needs to immediately collect detailed information on offshoring, including new data series that capture the realities of trade, investment and job distribution in the age of globally integrated enterprises.

What is known and not known about the offshoring of research, development and innovation — and its likely long-term economic impacts — have been analyzed here. The stakes are high but little action has taken place. Limited data and the need for more analysis are no longer valid excuses to continue the current state of policy paralysis. There are clear indications that America's standing as a technological leader is threatened by the offshoring of research, development and innovation. It will take more than just additional federal funds thrown at training and education to ameliorate the trends. The time to act is now because of the significant lag before current policies manifest themselves in long-term economic decline. The U.S. has overestimated its technological lead throughout history, whether it was with the Soviet Union and Sputnik or the rise of Japanese manufacturing. It appears the country is under the same illusion now.

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