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TECHNICAL
REPORT

High-Technology Manufacturing and U.S. Competitiveness

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Summary

The charter of the President's Council of Advisors on Science and Technology (PCAST) subcommittee on Information Technology Manufacturing and Competitiveness is to examine issues surrounding the migration of high-technology manufacturing from the United States to foreign countries. There is a concern that an increasing share of manufacturing—especially high-tech manufacturing—formerly performed in the United States is being done overseas with potentially harmful consequences to the U.S. economy. In particular, the rise of the semiconductor industry in Asia has been at the heart of a public debate: Should the U.S. government undertake steps to stem the migration of an industry that has meant so much to the U.S. economy from moving offshore?

The hypothesis that the nation's long-term economic security could be adversely affected by a migration of U.S. high-tech manufacturing to overseas locations is based in part on the belief that a high-tech industrial base provides the financial support and intellectual catalyst for innovative research and development (R&D). If that base stagnates, or in a worse case, declines, support for R&D may diminish. With a less vigorous R&D base, it is feared that the United States may not be able to maintain its leadership position in cutting-edge, high-tech industries. As a result, fewer students might pursue higher-education degrees in the science and engineering (S&E) fields because of reduced employment opportunities. A reduction in the number of scientists and engineers could lead to the development of fewer innovative products with a seemingly inevitable downward spiral of U.S. technological leadership and economic well-being.

PCAST submitted a report in late 2003 to the President of the United States on the relationship between high-technology manufacturing and the nation's long-term economic security. The Science and Technology Policy Institute (S&TPI) at RAND was asked to provide analytic support to the PCAST subcommittee. We focused on providing answers to the following questions:

- What are the current trends in U.S. high-tech manufacturing?
- Is there empirical evidence that the United States is in danger of losing its overall manufacturing capabilities due to foreign competition?
- Has the United States lost part of its high-tech manufacturing base in the past, and what lessons can we learn?
- How has U.S. industrial R&D changed over time? How does U.S. federal R&D compare with that of other industrial countries?
- What are the trends in the choices of academic disciplines? What fractions of advanced S&E degrees are awarded to foreign students?

- How are some other countries dealing with the migration of manufacturing to offshore locations?

This report presents the data and analyses that S&TPI provided to the PCAST subcommittee. Given the interests of PCAST, we focus on the information technology (IT) sector generally and on computer hardware (including components) and semiconductor manufacturing specifically.

The State of U.S. High-Tech Manufacturing

To place high-tech manufacturing in context, it is worth examining the overall trends in manufacturing. The January 2003 U.S. Census Bureau's Annual Survey of Manufacturers reports that the number of U.S. manufacturing jobs has stayed relatively constant over the past 50 years, with production workers varying between 11 million and 15 million. However, the *percentage* of manufacturing jobs in the total U.S. workforce has been halved over the same period because the U.S. workforce has roughly doubled in that same time frame. After 1998, when there were 12.2 million production workers, there began a gradual decrease to 12.0 million in 1999 and 11.9 million in 2000. A sharp drop was reported in 2001 during the current U.S. economic slowdown to 11.2 million production workers, or an 8 percent drop from 1998. Data from the Bureau of Labor Statistics show this trend continuing in 2002 to 14.7 million manufacturing employees total and 10.3 million production workers.

Increased productivity is a major reason for the decreased manufacturing employment numbers. Also, the World Trade Organization's Information Technology Agreement (ITA) has increased U.S. exports of such items as semiconductor manufacturing equipment overseas and has also furthered global production networks for IT firms. The difficult issue—as yet unresolved—is separating what proportion of this decrease in manufacturing jobs is due to the U.S. recession, ITA implementation, increasing productivity, or the loss of jobs due to foreign competition.

Data segmenting the U.S. gross domestic product (GDP) by industry is available from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). Both manufacturing value added and overall GDP have increased in current dollars over past decades. Manufacturing's percentage of GDP has declined because GDP has grown faster than manufacturing value added. Manufacturing's percentage of GDP dropped from 18.7 percent in 1987 to 14.1 percent in 2001. In contrast, the services industry, which includes health, business, and legal services, grew over the same period, increasing from 16.7 percent to 22.1 percent. Other industries that increased from 1987 are the finance, insurance, and real-estate sectors, which combined rose from 17.5 percent to 20.6 percent.

With regard to high-tech manufacturing trends, there is more concern about such trends than with the overall manufacturing statistics, since the high-tech industries are in much greater flux. Many indicators, such as employment and value added per employee, showed signs of a decline in 1997–2000 before the economic slowdown in 2001. Causes for this decline included the maturing of high-tech industries and the increasing price sensitivities of its products. Decline in employment in itself is not necessarily an indication of a problem, since industrial production in semiconductors, computers, and communications equipment all skyrocketed during that same period. However, high-tech manufacturing value added per employee also dropped fast, suggesting that many of its products were rapidly becoming routine or lower-margin and hence more attractive targets for foreign manufacturing development. Falling prices in the IT sector have resulted in part from the increases in U.S. total multifactor productivity since 1995 as well as the globalization of the industry. These issues also factor directly into decreased value added for manufacturing and, correspondingly, decreased value added per employee.

Computer and electronics product manufacturing includes the subcategories of semiconductor, peripheral, terminal, and storage equipment manufacturing. Computer and electronics manufacturing is a major U.S. industry, ranking third in employment, third in manufacturing value added, and fourth in shipment value. Of the 15.9 million U.S. manufacturing employees,[1] only the fabricated metals and transportation industries employ more people than the computer and electronics industries. From 1997 to 2001, both production workers and all employment positions in the U.S. computer manufacturing industry dropped. The magnitude of the decrease in the computer manufacturing industry is larger than that for overall manufacturing. Whereas overall manufacturing employment dropped by 6 percent from 1997 to 2001, computer manufacturing employees decreased by 20 percent. The decrease of computer manufacturing production workers was even sharper, dropping by 35 percent over the same period.

The Federal Reserve Bank releases an industrial production index every year that measures the real output of the manufacturing, mining, and electric and gas utility industries. The latest released statistical data show that computers and semiconductor industrial production have rebounded since the slowdown in 2001. There was a fivefold increase in semiconductor production and a threefold increase in computer production from 1997 to 2003. Communications equipment production, however, peaked in 2000 and has continued to drop through 2003. The Federal Reserve Bank also reports on the capacity utilization of industries in an attempt to capture sustainable maximum output—the greatest level of output a plant can maintain within the framework of a realistic work schedule, after factoring in normal downtime and assuming sufficient availability of inputs. For high-tech industries, capacity utilization dropped sharply after the dot-com boom of the late 1990s, which suggests some overcapacity in high-tech industries. Since May 2002, computer and electronics manufacturing has made the largest percentage change of industries reported by the Federal Reserve Bank. Computer and electronics manufacturing and nonmetallic mineral products were the only industries to improve industrial production from May 2002 to May 2003.

The rise of foreign high-tech manufacturing industries is unmistakable. Prior to 2000, programmers in India and elsewhere were sought after because there were not enough U.S. programmers to patch Y2K software problems. With labor rates in China and India a fraction of those in the United States, labor-intensive industries, such as software development, continue to move overseas. Highly automated manufacturing processes for semiconductor and other high-tech components have a much smaller labor component than software development, but their production has also grown overseas, lured by foreign government incentives—notably from Taiwan and China. With some products like computer peripherals and monitor displays, Asia-based manufacturers are already the leaders. Peripherals and monitors are the lower value-added-per-employee end of the production scale. However,

[1] Manufacturing employees include production workers plus those in related support and management positions.

higher value-added-per-employee industries, such as semiconductor, computer, and storage devices, are increasingly moving overseas as well.

The ownership of overseas manufacturing can take different forms, from overseas operations of U.S.-owned companies, to U.S. joint ventures with foreign firms, to foreign companies that have grown through contract manufacturing relationships with U.S. and other foreign companies. Policymakers must consider that U.S. companies may be moving production facilities overseas to gain market access abroad or to find ways to provide lower-cost products to U.S. consumers. Those U.S. manufacturing activities that have remained in the United States tend to be the most advanced, complex manufacturing, typically requiring close coordination with engineering or design staff. But routine manufacturing, in which every efficiency must be vigorously pursued, is tending to locate overseas. Advances in supply chain IT and other business technologies increasingly make possible asset visibility and operational control of remote operations, further enabling overseas manufacturing for U.S. companies.

Is the High-Tech Manufacturing Glass Half Empty or Half Full?

When measured as a percentage of GDP, the decline in U.S. manufacturing since the mid-20th century has been so pronounced that it seems to support the idea that the United States is becoming a "postindustrial" society. This theory, made famous by sociologist Daniel Bell, posits that, as national economies develop, workers move out of relatively low-skill and low-value-added agricultural production into low-skill and then high-skill manufacturing and, at the highest stage, into high-skill, knowledge-based service production. Although Bell himself didn't put it this way, "low skill" and "high skill" are often translated to mean "low tech" and "high tech," where technological intensity is measured as an increasing function of R&D expenditures as a share of total expenditures.[2]

Most of the concerns about a possible U.S. economic shift away from manufacturing have focused on the overseas migration of manufacturing industries. Pointing to the growing U.S. deficit in manufactured goods trade, critics of the U.S. government's generally hands-off industrial and trade policies have argued that foreign governments have deliberately and successfully subsidized and promoted their own manufacturing industries at the expense of U.S. industry. In the long run, the argument goes, it is not just U.S. manufacturing firms and workers who will be hurt, but all Americans will suffer a decline in their standard of living if manufacturing is lost because of the nearsighted or simply nonexistent U.S. government policies. We label this the "deindustrialization-due-to-globalization" hypothesis.

Have apparent declines in total U.S. manufacturing output and employment since the late 1970s been caused by competition from foreign manufacturers? A closer examination of the data suggests another explanation. Data show that between 1977 and 2001, manufacturing output came close to doubling when measured in constant 1996 dollars.[3] These data suggest that, with respect to the absolute volume of production, foreign manufactured goods

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[2] Technological intensity is also sometimes measured in terms of the proportion of scientists and engineers in the workforce.

[3] When calculated for the period 1977–2000 (before the sharp economic downturn of 2001), output slightly more than doubled.

have not replaced American manufactured goods on U.S. and world markets. In fact, over this period, U.S. manufacturers churned out more textiles, chemicals, automobiles, electronic equipment, etc., than they ever had before.[4]

Further, manufacturing's share of U.S. GDP in constant dollar terms over the 1977–2001 period declined only slightly compared with the steep decline when measured in current dollar terms. The difference between the current and constant dollar measures occurs largely because the prices of manufactured goods increased more slowly than the prices of many services. For example, construction; transportation and public utilities; health care; and financial, insurance, and real-estate service prices all rose faster than manufactured goods prices in that time frame.

Both the rising volume of output and the falling price of U.S. manufactured goods are consistent with an increase in the productivity of American workers in the manufacturing sector. The conceptual connection is as follows: As workers become more productive, fewer are needed to produce the same volume of output for a particular industry. The result is some combination of increased output and a reduced workforce. The workers who remain receive higher wages, but total costs of production fall. Therefore, as long as the industry is competitive, prices of outputs also fall. Real output per full-time equivalent manufacturing worker more than doubled between 1977 and 2001, from just under $41,000 to over $86,000 in constant 1996 dollars. In comparison, real output per service worker actually fell slightly, from $55,000 to $48,000. Thus, increases in manufacturing productivity offer an alternative explanation for observed declines in U.S. manufacturing employment and output as a share of GDP since the late 1970s.

The argument presented above has been confirmed by more sophisticated analyses using carefully constructed data and econometric techniques. Krugman and Lawrence (1994), for example, conclude that "competition from abroad has played a minor role in the contraction of U.S. manufacturing . . . . In fact, the shrinkage is largely the result of high productivity growth, at least as compared with the service sector." As they note, this is somewhat ironic because inadequate productivity growth is often blamed for the presumed loss of U.S. manufacturing competitiveness.

In a study prepared for the International Monetary Fund, Rowthorn and Ramaswamy (1997) found strong evidence that Bell's hypothesis is, in some ways, right. Most developed economies have experienced declines in manufacturing employment that, as a share of nominal GDP, are on the scale of those experienced by the United States. These declines in manufacturing employment appear to be features of successful economic development worldwide—not excepting the East Asian economies of Hong Kong, Taiwan, Singapore, and South Korea. Far from being a crisis, the so-called loss of manufacturing "is, in general, associated with rising living standards." Further, Rowthorn and Ramaswamy find that the deindustrialization in the United States and other developed economies has little to do with competition from low-wage economies; rather, it is associated with high productivity growth in manufacturing industries.

There is no empirical case to be made that the United States is in danger of losing its overall manufacturing capabilities due to foreign competition. Declines in U.S. manufactur-

[4] Of course, certain types of foreign manufactured goods may have replaced certain types of American manufactured goods, and there may well have been even more American manufactured goods on world markets in the absence of foreign competition.

ing employment can be directly attributed to increased manufacturing productivity, which has continued to grow since the late 1970s, when large U.S. trade deficits in manufactured goods first began to appear. Thus, more Americans than ever now find their employment in the service sector, and their numbers are continuing to grow. But it is not the case that American manufacturing per se is declining; to the contrary, American manufactured goods are more plentiful, and cheaper, than they have ever been before.

Further, we have not found empirical evidence that either supports or contradicts the notion that American high-tech industries should receive particular government support or protection. We note, however, that even when theoretically there may be economic justifications for supporting certain industries at the expense of others, the development and implementation of sound industrial policies may be difficult if not impossible. This is because, as argued by Krugman (1996a, p. 111) "you have to base interventionist proposals on detailed predictions about how firms will change their strategies in response to hypothetical policy changes, how these strategic moves will affect profits, wages, R&D, and so on, and finally, how all of these changes will affect the economy at large."

Lessons from the 1980s: The Competition Between U.S. and Japanese Semiconductor Firms

The United States has faced challenges in high-tech manufacturing before. We examine one important case and whether the policy responses of the U.S. government were effective. Between 1979 and 1986, the U.S. percentage of the world market for DRAM (dynamic random access memory, the most common type of semiconductor memory) products fell from over 70 percent to under 20 percent and has never recovered. Japanese semiconductor manufacturers had mounted a sustained campaign to capture the market, which they successfully controlled until the emergence of South Korean competition in the 1990s. The Japanese introduced 256K DRAM chips before any U.S. firm did. As the Japanese gained market share with the 256K chip, U.S. firms filed complaints against the Japanese actions. In June 1985, the Semiconductor Industry Association filed a petition with the U.S. Trade Representative (USTR) under Section 301 of the Trade Act of 1974, alleging that there were barriers to U.S. entry into the Japanese market, that the barriers were a structural aspect of the Japanese market, that the Japanese government condoned them, and that Japanese government policy condoned overseas dumping. The USTR, in turn, decided to pursue an antidumping case by December 1985.

Under mounting pressure, Japan acceded to most of the USTR demands, in a deal designed to settle both the entry barriers and antidumping claims. The agreement had two basic conditions. First was that Japanese firms would cease dumping in all world markets, which was a substantial precedent in that a bilateral agreement dictated behavior in other markets. Related to this condition, Japanese firms had to develop detailed cost records in order to establish a price floor. The second condition addressed the market access issue in two ways. In the official agreement, Japan agreed to encourage foreign firms to achieve increased market share in the Japanese market, and, in a side letter, the Japanese government stated that it "understood, welcomed, and would make efforts to assist foreign companies in reaching their goal of a 20 percent market share within five years." Eventually, the foreign share of the Japanese market hit 20 percent in the fourth quarter of 1992. The year 1991 also marked the beginning of a sustained five-year industry boom that saw total sales revenue grow to nearly three times the 1990 level. The boom, along with greater R&D and product development associated with it, led the U.S. industry to recapture the worldwide semiconductor market leadership position in 1993 for the first time since 1985. The U.S. industry has since maintained that position.

It is important to note that industries evolve both structurally and technologically over time. Industries and product lines that once met the definition of "high tech" might not stay that way. For example, DRAM chips once involved extremely advanced technological processes and highly skilled, specialized labor. In the 1980s, the U.S. government failed to protect its industry against powerhouse Japanese firms; as a result, U.S. firms were forced to move on to products in which they were more competitive, such as microprocessors. Now DRAM technology is well known and DRAM chips have become commodity products produced competitively and at low cost across Southeast Asia. The many Japanese firms that continued to produce DRAMs are no longer earning rents—in fact, they are now operating at a large competitive disadvantage. The lesson for the U.S. government may be that the "loss" of certain industries to foreign competitors does not necessarily lead to adverse economic or national security outcomes. Further, in the long run, such losses may not be avoidable.

While unfair Japanese trade practices, specifically with regard to the manufacture of DRAMs, should have been challenged and were, those practices may have had only a transitory effect on the U.S. semiconductor industry. While the Japanese concentrated their efforts on producing what was essentially a commodity—i.e., DRAMS—the U.S. semiconductor industry focused on where its comparative advantage lies, namely, on the design and production of the more technologically advanced and innovative logic and microcontroller products.

Providing the Foundation for a Robust U.S. High-Tech Manufacturing Base

Past or present performance of the high-tech sector is no guarantee of future health. To get a glimpse into the future of the high-tech sector, we examined two essential enablers for the United States continuing to be a source of advanced technology: a robust R&D base and an adequate number of S&E graduates.

U.S. Research and Development Funding

The excellence of U.S. research universities, national laboratories, and technology industries depends critically on R&D funding for the development of emerging technologies and cutting-edge innovations. Industrial R&D funding has remained fairly steady over the past three decades relative to GDP and has increased recently.[5] This has occurred despite the fact that federal support for industrial R&D has fallen and is continuing to fall. In 1970, federal industrial R&D funding was slightly more than 1 percent of GDP. In contrast, by 2000, federal funding had fallen to about 0.25 percent of GDP. Industry has more than made up for the decline in federal support.

[5] Industrial R&D is performed by for-profit companies and paid for by those companies, the federal government, or other organizations and institutions.

Over the past decade, total federal R&D funding has remained fairly constant—both in terms of constant dollars and as a percentage of GDP. In 2003, total federal R&D was split nearly evenly between defense and nondefense activities. The major change has been the strong growth in the health R&D component, in which funding has increased about 150 percent since 1990. Over the same period, while federal R&D funding for industrial R&D purposes has declined, federal R&D funds to academic institutions has increased by 57 percent. The emphasis on health-related activities is reinforced when examining federal obligations for research. While the funding for all fields has generally increased over time, there has been a dramatic increase in funding in life science research, tripling in constant dollars from 1990 to 2002.

Of course, the federal R&D portfolio could be shifted back toward providing more support for industrial R&D either at the expense of other R&D activities or with an increase in the overall federal R&D budget. If such a change were contemplated, it would lead to posing the following questions: Would additional federal R&D investment help ensure the future of the high-tech industry? Or might it lead to a reduction in industry-sponsored R&D?

In aggregate measures, U.S. total R&D support is comparable to the support of other major industrial nations when measured as a percentage of GDP. In 1981, the United States spent, in constant dollars, nearly as much for R&D as that spent by all the other G-7 nations combined. By 2000, the U.S. share of total R&D had grown slightly relative to the total of those same countries. However, the United States spends its R&D funds differently than the other industrial nations. As a percentage, the United States spends considerably more on defense-related activities and considerably less on advancement-of-knowledge activities. However, there may be spillover effects from defense-related R&D activities to advancement of knowledge activities that this simple categorization does not capture. The best allocation of R&D funds for maintaining a healthy high-tech manufacturing base within the context of overall national priorities remains an open issue. However, the data do not support the thesis that difficulties that may have been experienced by high-tech manufacturing have led to a decline in support for R&D.

U.S. Science and Engineering Degrees

Ensuring a skilled workforce, one that can work and thrive in an increasingly technological and rapidly changing environment, is a U.S. priority. Of particular importance are university and college graduates with technical degrees, whose training may allow them to contribute directly to the latest innovations and technological industries. The published National Science Foundation (NSF) data on degrees granted extends only up to 1998–1999. From then until the present time, the global high-tech manufacturing situation has arguably changed more than during any other recent four-to-five-year period. It would be useful to extend the examination of data on degrees granted from 1998–1999 to the present time. However, such data were not available during the course of this study. Within the data limitations just described, we found that:

- Both the number of degrees for all disciplines and the number of S&E degrees grew at rates that are larger than the rate of growth in the U.S. workforce over the 1985–1998 period. Thus, if degrees granted per workforce member measures the need for graduates with technical degrees, the United States, it appears, would continue to produce an adequate supply of such people.

- The numbers of S&E bachelor's, master's, and doctorate degrees as a percentage of all degrees granted at the bachelor's, master's, and doctorate levels, respectively, remained remarkably constant from 1985 to 1998.
- The number of bachelor's degrees in computer science, mathematics, and electrical engineering—fields closely associated with the information technology area—as a percentage of all S&E bachelor's degrees declined from 1985 to 1998, but the percentage of graduate degrees in the three fields increased over the same period.
- Examining a limited sample of industrial countries, we found that the United States educates a larger percentage of foreign graduate students in the fields of computer science and mathematics than do other countries. At the bachelor's degree level, only a small fraction of degrees were awarded to foreign-born students. But at the graduate degree level, a significant portion of master's and doctorate degrees in the fields of computer science and mathematics awarded at U.S. academic institutions—63 percent and 71 percent, respectively—went to foreign students. While educating foreign-born students has benefits for the United States, these percentages seem to be undesirably high. The United States would appear to be very dependent on foreign-born graduates for providing the technological know-how in the computer science field—a key component of IT. The United States should consider policies for stimulating the interest of U.S. citizens in this and associated fields.
- The good news is that, in 1999, more than 80 percent of Asian students who were awarded doctorate degrees planned to stay and seek employment in the United States. Whether that trend will hold for IT fields, particularly in light of the global changes in the IT industry, is uncertain. The United States should consider balancing its desire to have foreign graduate students return to their countries, and the potential of rising to leadership positions there, with the benefit of having those same students stay in the United States—especially those who have attained advanced S&E degrees—to contribute to U.S. technological leadership.

The Taiwan–Mainland China Experience

Taiwan is experiencing an outflow of IT production to mainland China. In some respects, the situation that Taiwan is facing mirrors what many say the United States is experiencing, namely, the migration of high-tech manufacturing to overseas locations. Yet other aspects of the Taiwanese experience are unique and evolve around the particular security situation that Taiwan faces vis-à-vis mainland China. What steps has the Taiwan government taken to stem the flow of its high-tech manufacturing base to China? Have these steps yielded concrete results?

Taiwan plays a significant role in global IT production. Taiwanese companies produce approximately 60 percent of the world's notebook computers, 90 percent of its motherboards, 60 percent of its liquid crystal displays (LCDs), 50 percent of its computer display terminals (CDTs), 30 percent of its optical disk drives, and 25 percent of its servers. Until recently, Taiwan ranked third in the world in IT hardware production value, trailing only the United States and Japan. As more Taiwanese manufacturing has relocated to the mainland, however, China has surpassed Taiwan, becoming the third leading producer of IT hardware, while the island has fallen to fourth.

Prior to 1979, there was virtually no economic interaction between China and Taiwan. At the beginning of the 1980s, Taipei enforced a nearly complete ban on exports to the mainland and permitted only certain Chinese foods and medicines to be imported from China via Hong Kong. Despite these prohibitions, Taiwanese businessmen rushed to take advantage of increasing opportunities on the mainland, and cross-Strait trade reached nearly $1 billion by 1985. Perhaps recognizing the futility of enforcing the ban on trade and investment, the Taiwanese government in 1985 adopted a noninterference policy on indirect exports to and investment in China.

Yet the economy on Taiwan was undergoing important changes that would lead to an accelerated transfer of production to the mainland. Rising wages and the appreciation of the currency reduced the competitiveness of Taiwan's labor-intensive industries and forced these industries to find low-wage production bases, like China. In October 1989, Taiwan issued regulations sanctioning indirect trade with and investment in China. This mix of restrictions and tolerance allowed steady increases in trade between Taiwan and China. In 1978, Taiwanese exports to the mainland totaled a mere $51,000; however, by 1991, they had exceeded $4.6 billion.

In the early 1990s, Taiwanese investment began to move up the manufacturing chain. Migration of IT hardware manufacturing capacity across the Strait was propelled in large part by the requirement to lower production costs. In 1993, Taiwan companies producing PC-related products on the mainland were already benefiting from significant savings over the cost of production on the island, exceeding the savings available in Southeast Asian countries like Malaysia. By 1999, according to one estimate, about one-third of Taiwan's IT products were being manufactured in China.

The Taiwanese government has been playing catch-up in terms of its policies on cross-Strait economic relations. For the most part, Taiwan's policies have lagged behind economic trends, often by several years or more.[6] Nowhere has this tendency to fall behind the business curve been more evident than in Taipei's attempts to regulate the flow of investment from the island's companies into the emerging information technology sector on the mainland. Taiwan companies have found innumerable ways over the years to circumvent the restrictions imposed by the Taiwanese government, such as incorporating overseas or channeling funds through Hong Kong, the Cayman Islands, and the British Virgin Islands. In recent years, the pattern has continued, with Taiwan modifying regulations to accommodate—and to attempt to shape to the extent possible—emerging trends in the increasingly dynamic China-Taiwan economic relationship.

In many ways, the Taiwanese experience mirrors the situation that some fear is already happening to the United States. It is important to note how ineffective Taiwan's policies appear to be at stemming the tide of relocation of lower-end manufacturing to lower-cost locations and to China in particular. If Taiwan, with all its political and security concerns, cannot effectively curb the location of manufacturing to China, the U.S. government could face even more difficulty and, perhaps, less effectiveness.

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[6] Two examples illustrate the reactive nature of Taipei's approach to economic integration with the mainland. First, Taipei did not lift its ban on private-sector cross-Strait exchanges until 1987. Second, the Taiwanese government waited until the early 1990s to legalize investment in the mainland by Taiwanese businesses.

Both China and Taiwan have a substantial array of incentives to attract foreign companies to locate in their respective territories.

China

In China, preferential policies offered by the central government and local authorities in various cities—along with the allure of a fast-growing domestic market, which stands out even more when compared with the sluggish global IT industry as a whole—have proven a potent combination, attracting large foreign investments that are fueling the growth of a nascent domestic semiconductor industry. Tax subsidies and the desire for market access are the principal draws for many companies planning to invest in semiconductor manufacturing facilities in China. The most controversial incentive is a value-added tax (VAT) rebate on chips made in China that is offered by the central government. Foreign-made chips are subject to a 17 percent VAT, while chips produced in China receive an 11 percent rebate, effectively lowering the VAT on domestically produced chips to 6 percent. The Chinese government has also offered free land use and other incentives such as tax holidays and reductions to companies building advanced semiconductor manufacturing facilities. For example, under the "2+3" incentive plan, which applies to integrated circuit manufacturers and software firms, the central government offers a two-year exemption from corporate taxes followed by a 50 percent reduction for the next three years. Local governments in China are offering their own incentives, frequently attempting to one-up each other in a fierce competition to attract foreign investment in high-tech industries. Nowhere is this regional competition more intense than in the semiconductor industry.

Taiwan

Taiwan essentially established the foundry industry, which today is dominated by two of the island's leading high-tech companies, the Taiwan Semiconductor Manufacturing Corporation (TSMC) and the United Microelectronics Corporation (UMC). In 2002, the two foundry giants combined to account for more than 70 percent of the global market for made-to-order chips. Both TSMC and UMC were spun off from a government-funded high-tech research institute. When TSMC built its first facility in 1986, the government of Taiwan contributed nearly half of the initial $200 million investment. In addition, the government reportedly offers substantial tax incentives to TSMC and UMC. Incentives designed to encourage foreign companies to establish regional headquarters and R&D centers in Taiwan include two years of free rent on land in designated industrial districts, followed by another four years of reduced rental rates, and a variety of corporate income tax breaks.

Conclusions

We revisit the questions posed earlier and summarize our conclusions:

- What are the current trends in U.S. high-tech manufacturing?
  - U.S. high-tech exports still lead the world by a large margin, and U.S. high-tech companies are expected to maintain leading market shares for some time. The latest 2003 data from the Federal Reserve Bank show that industrial production of semiconductors and computers has rebounded since the economic slowdown in

2001. However, industrial production of communications equipment has continued to drop through 2003.
  - U.S. manufacturing activities that have remained in the United States tend to be the most advanced and complex manufacturing, typically requiring close coordination with engineering and design staff. But more routine manufacturing, in which every efficiency must be pursued, tends to locate overseas for economic advantages.
  - However, challenges remain. For example, there has been a decrease in computer manufacturing employment that actually began several years prior to the dot-com crash. In fact, the data indicate that the United States is not facing a manufacturing crisis but rather an employment problem. While there are some linkages between the current state of U.S. manufacturing and the current unemployment situation, U.S. government policies may be better focused on employment issues, not assuming that the solution necessarily lies with the manufacturing sector.
- Is there empirical evidence that the United States is in danger of losing its overall manufacturing capabilities due to foreign competition?
  - There is no empirical case to be made for this. Declines in U.S. manufacturing employment can be directly attributed to increased manufacturing productivity. The key problem is not the U.S. capability in high-tech manufacturing but rather the employment issues that have resulted from strong productivity growth.
  - More Americans than ever now find their employment in the service sector, and their numbers are continuing to grow. But it is not the case that American manufacturing per se is declining. To the contrary, American manufactured goods are more plentiful, and cheaper, than they have ever been before.
  - We have not found empirical evidence that either supports or contradicts the notion that American high-tech industries should receive particular government support or protection.
- Has the United States lost part of its high-tech manufacturing base in the past, and what lessons can we learn?
  - Japanese semiconductor manufacturers mounted a sustained campaign to capture the DRAM market. Between 1979 and 1986 the U.S. percentage of the world market fell from over 70 percent to under 20 percent and has never recovered.
  - Part of the Japanese success was due to unfair trade practices. Through a series of U.S.-Japan agreements, the United States was able to stop the dumping of Japanese semiconductors on the world market and to open the Japanese market to U.S. semiconductor firms.
  - In the final analysis, Japanese practices had only a transitory effect on the U.S. semiconductor industry. While the Japanese concentrated their efforts on producing what was essentially a commodity—i.e., DRAMs—the U.S. semiconductor industry focused on where its comparative advantage lay, namely, on the design and production of more technologically advanced microprocessors and other innovative semiconductor-related products.
- How has U.S. industrial R&D changed over time? How does U.S. federal R&D compare with that of other industrial countries?
  - There is no evidence that there has been a decline in industrial R&D funded or in federal funding of R&D. While federal funding of industrial R&D has declined, the shortfall has been more than made up by industry.

  - Over the past decade, federal R&D funding has remained nearly the same in constant dollars, while federal R&D support to academic institutions has increased by 57 percent.
  - There has been a shift in the ways federal R&D funds have been allocated over the past decade with increased emphasis on health and life sciences.
- What are the trends in the choices of academic disciplines? What fractions of advanced S&E degrees are awarded to foreign students?
  - The numbers of college graduates are more than keeping pace with the growth in the U.S. workforce.
  - There is no evidence that interest in attaining S&E degrees, compared with interest in non-S&E degrees, is waning.
  - There is a potential problem with a large percentage of advanced IT degrees being earned by foreign students.
- How are some other countries dealing with the migration of manufacturing to offshore locations?
  - Our analysis focused on investment flows between Taiwan and mainland China. Taiwan, with all its political and security concerns, has not been able to curb effectively the location of manufacturing to China.
  - The U.S. government could face even more difficulty and perhaps less effectiveness if it attempts to influence investment flows.

Elements for Improving U.S. High-Technology Manufacturing

Let us set aside the debate over whether foreign economies and industries are luring away and trouncing American high-tech firms or if U.S. high-tech firms are thriving both overseas and domestically. While the debate is important, and how it is resolved will have implications for the health of the U.S. high-tech industry and for U.S. government policy, there are a number of steps that, if taken, may provide for the foundations of a consistent industrial strategy. The following strategic steps may be taken regardless of how high technology or any another manufacturing industry faces foreign competition.

The summary and findings above highlight three principal elements for improving U.S. high-tech manufacturing prospects:

- Level the Playing Field: Trade Practices
  - Enforce existing trade agreements by investigating allegations of trade infractions—e.g., many consider China's VAT policy discriminatory—taking action as appropriate.
  - Aggressively monitor and enforce intellectual property rights.
- Level the Playing Field: Incentives
  - Determine what role, if any, the federal government should play in assisting the various U.S. states in developing incentive packages to attract high-tech industry—either U.S. or foreign.
  - Consider an appropriate agreement governing such practices—e.g., the Doha round of trade talks.
- Strengthen the Innovation Infrastructure Base

- Determine if the overall magnitude of federal R&D funding is at a level appropriate for a nation that desires to remain the most technologically advanced.
- Reexamine the allocation of federal R&D funding in terms of both the types of organizations that are performing R&D and the disciplines that are being funded.
- Strengthen high school science programs so that more students will become interested in the sciences, and encourage high school students to go into S&E programs at the college level.
- Encourage S&E college graduates to continue their higher education by earning graduate degrees in S&E fields.
- Make it easier for foreign students who earn advanced S&E degrees in the United States to stay and contribute to U.S. economic growth.