CHAPTER 7

# Globalization's Impact on High-Tech Industries in the United States

Jeffrey A. Hart

While globalization has had a major impact on many aspects of the U.S. economy, people have tended to distinguish between its effects on sectors requiring lower levels of technological sophistication and worker skill (detrimental) and those requiring higher levels of both (beneficial). It has generally been understood that U.S.-based firms' temptation to go overseas to gain access to lower labor costs is felt much more strongly in mature, low-tech industries than in emerging, high-tech industries—and thus that high-tech firms and workers in the United States are not as vulnerable to foreign competition as firms and workers in mature industries. But with the rise of China and India, this sanguine assessment has come under question. The U.S. lead in technologically sophisticated production—and the benefits in terms of employment and wealth creation—can no longer be taken for granted.

The wealth and diversity of the U.S. economy is still unmatched by any single national economy (the European Union is a match in size but not yet in market integration), but the advantage that accrues from its "knowledge industries" may be dissipating. Globalization begets knowledge diffusion, and the United States can no longer depend on maintaining domestic technological advantages in a broad range of high-tech industries to guarantee wealth creation and employment. The United States remains a key location for knowledge creation and diffusion, but is increasingly competing with other locations in high-technology industries such as, for example, digital televisions and flat-panel displays. According to Jeffrey Macher and David Mowery:

> The improved capabilities of [foreign] scientists and engineers ... and the changing outlook of demand and growth in the U.S. and foreign markets ... may be causing more rapid shifts in competitive advantage and affecting a

> broader range of activities, including innovation-related activities, than in earlier decades.[1]

:ven in industries in which knowledge has not diffused as widely, as in ıdvanced software and biotechnology, U.S.-based multinational enterprises MNEs) are looking for ways to reduce costs by establishing research ceners in developing countries, outsourcing labor-intensive manufacturing ınd services activities, and contracting out easily codifiable technological vork to lower-cost engineers in the developing world.[2]

This chapter examines the impact of globalization on a variety of highech industries that are important for the U.S. economy. After a brief discusion of the role of MNEs in knowledge diffusion and the rise of India and :hina, the chapter surveys the process of globalization in several high-tech ectors: semiconductors, cellular telephones, software, consumer electronics, ligital television, personal computers, wide-body jet aircraft, and biotechıology. Each section describes the patterns of globalization in the given ndustry and how its distinct industry characteristics affect these patterns. The chapter closes with some conclusions about the impact of globalization on American firms and workers.

## MULTINATIONAL ENTERPRISES IN HIGH-TECH :NDUSTRIES AND THE RISE OF INDIA AND CHINA

*Globalization* is "the increasing integration of input, factor, and final product markets coupled with the increasing salience of multinational enterprises' cross-national value-chain networks."[3] The essence of contemporary :conomic globalization is the greater role of MNEs and foreign direct nvestment (FDI) in the economic flows that increasingly integrate the world :conomy. MNEs engage in FDI for two reasons:

1. To gain access to overseas markets that would otherwise be closed to them
2. To gain access to less-expensive inputs for products and services so that they can compete effectively in world markets

The first is sometimes called *horizontal FDI* and the latter *vertical FDI*.[4] Horizontal FDI tends to go to relatively wealthy regions of the world, vhereas vertical FDI usually goes to developing countries that have low vages or some other price-based advantage such as an abundance of raw naterials or energy.

A major concern in recent years is that vertical FDI by high-technology irms has reduced the international competitiveness of MNEs' home countries including the United States) because it results in the transfer of knowledge to he host countries. Whereas in previous eras scientific and technological :nowledge was created in relatively restricted geographic regions and then pread slowly to others, now the time lag in the transfer of knowledge from egion to region is much shorter than in the past, in part due to the increased ole of MNEs in the globalizing world economy. But there may be other facors contributing to the more rapid diffusion of knowledge in recent decades.

MNEs have a strong interest in creating and diffusing technology internationally, especially when doing so permits them to be more internationally competitive. Ever since the end of World War II, there has been considerable pressure on U.S.-based MNEs to locate not just sales and manufacturing facilities but also research and development (R&D) operations in countries where they operate. Until fairly recently, these pressures were felt primarily in Western Europe and Japan, but recently MNEs have begun to locate R&D facilities in other regions as well, often in search of less expensive scientific and engineering talent.[5]

The reduced time required for knowledge to diffuse globally is a result partly of the actions of MNEs but also of changes in levels of governmental support for knowledge-creating institutions such as universities, science parks, and R&D laboratories (public and private). National governments use a variety of industry-promoting schemes to reduce the risk of investing in new industries for domestic firms. They have undertaken major investments in higher education, sometimes in the form of building new domestic colleges and universities, but also in scholarship programs to enable their citizens to obtain advanced training abroad. The increase in the international flows of scientists and engineers is a result.[6]

MNEs have played a crucial role in diffusing state-of-the-art manufacturing technologies to low-wage countries in the developing world.[7] Not all developing countries have benefited, because of the need to have a local core of skilled personnel to absorb new technologies successfully. But other factors have made it easier for MNEs to transfer new technologies to industrializing countries. Increasingly, MNEs headquartered in middle-income developing countries (such as South Korea and Taiwan) are locating labor-intensive processes in lower-wage countries such as China. Meanwhile, in certain high-tech industries—especially those within the broader service sector—India has emerged as a primary destination for MNE investments.

In addition to their large size, China and India share a number of characteristics that are sometimes linked to economic globalization: rapid growth rates, a new set of policies aimed at improving export performance, and renewed emphasis on entrepreneurialism and private initiative. They differ, however, in the types of export successes they have enjoyed: China excels at manufacturing and exporting goods that have a high labor content; India's forte is providing services internationally via, for example, call centers, business process outsourcing, and contract software engineering. India so far has not done well in manufacturing nor has China made major inroads in services.[8]

Labor costs in China and India are lower than those not only in the industrialized world but also in the emerging countries of Latin America (Mexico and Brazil) and East Asia (Korea, Taiwan, Singapore, and Hong Kong). The same holds for engineering costs. For example, assembly labor costs (including overhead) are less than \$10 per hour in China and India, but more than that in Southeast Asia and Mexico. In the United States, Japan, and Western Europe, assembly labor costs are more than \$30 per hour when overhead is included.[9] Average base salaries for electronic engineers in the United States in 2006 were \$82,000, in Japan \$63,000, in Taiwan \$20,000, and in

China $10,000.[10] When productivity per worker begins to approximate that of the United States, jobs are likely to move.

What follows is a survey of how this movement occurs—that is, how globalization processes diffuse both employment and production—across a number of sectors that broadly qualify as "high-tech." These brief histories provide a sense of how the diffusion of high-technology production and employment has occurred across industries, setting up a comparison of patterns that will help us better understand the implications of globalization processes for the United States.

## SEMICONDUCTORS

Most semiconductor devices now take the form of integrated circuits—small rectangles of silicon upon which electronic components (transistors, capacitors, resistors, etc.) are fabricated and connected by very thin metallic lines to form working electronic circuits. The key fact regarding the globalization of this industry is that the technology for the manufacturing of simpler integrated circuits, such as dynamic random access memories (DRAMs), diffused quickly from the United States to Japan to Korea and Taiwan and now to other industrializing countries, including China.[11] The ability to design and manufacture more complex circuits, such as microprocessors and application-specific integrated circuits, did not diffuse as rapidly. The two U.S. microprocessor giants, Intel and AMD, remain the dominant players in microprocessor markets and account for a large percentage of global semiconductor sales.[12]

In the 1980s, when knowledge about how to manufacture DRAMs began to move from the United States to East Asia, it was feared that all innovation in integrated circuits would follow, because, it was argued, the ability to manufacture DRAMs in high volumes would allow Asian firms to overtake American companies in designing and manufacturing more advanced circuitry. That this succession did not happen is an important reminder that diffusion of knowledge about new process technologies does not necessarily mean diffusion of knowledge about the design of new products.

Another important fact about globalization in the semiconductor industry is that a global division of labor emerged in the 1990s between the firms that designed and those that manufactured circuits.[13] In order for so-called design houses that specialized in circuit design to succeed, there had to be "foundries"—firms that specialized in circuit manufacturing on a contractual basis.

Foundries arose first in Taiwan, as key firms in that country decided that their best strategy for becoming internationally competitive in the industry was to focus on perfecting the process technology and let others do the designs. These firms were founded or run by Taiwanese nationals who had been trained in the United States or who had worked for U.S. semiconductor makers previously. The Taiwanese companies that adopted this strategy did not do so until it was clear that their earlier strategy of doing both design and manufacturing would not succeed. The Koreans, who entered the markets at about the same time, mostly avoided the foundry strategy.[14]

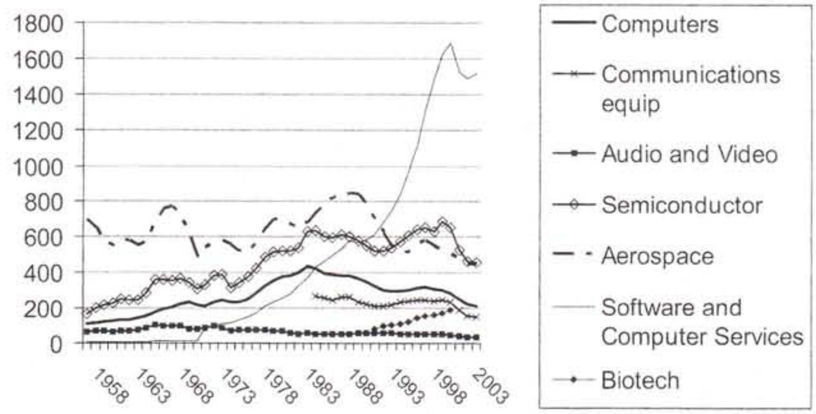


**Figure 7.1. Employment in High Technology Industries in the United States, in Thousands, 1958–2004**

*Source:* U.S. Bureau of Labor Statistics, http://www.bls.gov

Global revenues in the industry exceeded $260 billion in 2006. Intel and AMD were among the top ten firms in terms of revenues in 2006. Intel was the top money earner, accounting for more than 12 percent of world revenues, while Samsung of Korea was second. Intel's and AMD's U.S. operations, especially their R&D operations, were crucial to the overall success of the two firms, but both had invested in foreign fabrication facilities in order to service foreign markets in Europe and Asia.

Employment in the U.S. semiconductor industry grew rapidly from the 1970s until the mid-1980s, when it began to plateau at around 600,000 workers and then declined slightly (see figure 7.1).[15] Manufacturing employment shifted away from simpler devices like DRAMs toward more complex devices like microprocessors. R&D and circuit design remained a source of well-paying jobs, especially for engineers and highly skilled workers, but the industry also generated employment for less-skilled workers.

While the percentage of skilled and professional jobs in the semiconductor industry was typically much higher than that in, for example, the consumer electronics industry, still over 40 percent of the jobs were semiskilled or unskilled as of the mid-1980s. Even though manufacturing was highly automated, there was still a need for people to do things that could not be automated economically.[16]

## CELLULAR TELEPHONES

Large-scale sales of cellular telephones did not begin until the 1990s. Once they began, however, the volume of sales was astounding. In 2005, for example, more than 800 million cellular telephone handsets were sold.[17] In-Stat reported world revenues of $112 billion for the industry that year.[18] The three market leaders that year were Motorola (U.S.), Nokia (Finland), and Samsung (Korea).

... have been three generations of cellular phones so far. The first generation was pioneered by Motorola with the release of its DynaTAC 8000X model in 1983 after it received approval from the Federal Communications Commission (FCC). The first cell phone network with automatic roaming was built in Saudi Arabia in 1981. First-generation cell phones were much larger than they are now, but as time went on, their size was reduced to make them more portable.

The second generation of cell phones was pioneered in Western Europe. The key difference between first- and second-generation (2G) cell phones was that the first generation used analog signals and circuitry while the second was primarily digital. The Europeans negotiated a common standard, GSM (Global System for Mobile Communications), and opened the first GSM network in 1991. The U.S. government did not impose a single standard for 2G phones, and some argue this limited the ability of American firms such as Motorola and Qualcomm to compete globally. European firms, including Nokia, Siemens, and Alcatel, were successful in selling handsets during this phase. GSM was adopted widely outside Europe, and even U.S. manufacturers produced GSM handsets for those markets.

The third generation of cell phones, deployed in the first decade of the new millennium, increased the capabilities of networks to allow them to carry various kinds of data other than voice communications and to do so at higher speeds than was possible with 2G networks. Third-generation (3G) handsets had greater graphics capabilities and were capable of many computer-like functions. The two leading standards for 3G phones were the American CDMA (Code Division Multiple Access) and the European UMTS (Universal Mobile Telecommunication System).[19] At first, it appeared that the system from Japan's NTT DoCoMo was a clear winner in 3G services, but that impression turned out to be premature. Similarly, an experiment in mobile television using cell phones in Korea proved to be initially unsuccessful. It was still too early to tell who the most competitive manufacturers of 3G handsets would be.

Cell phone manufacturers are major customers of semiconductor firms such as Texas Instruments (TI). Chips for cell phones can be quite simple or very sophisticated, depending upon the complexity of the handset. So far, consumers seem to be favoring simpler handsets, but as they get used to 3G services, that may change.

Most assembly of cell phones occurs in East Asia and increasingly in China. Thirty percent of Motorola's cell phone handsets, for example, come from one plant in China. When the giant plant in China opened, workers in several Illinois plants were laid off.[20] VTech assembles more than 11 million cell phones annually for Nokia in its plant in Dongguan, China. Chinese workers there, mostly female, earn $120 per month and work twelve-hour days, seven days a week, when demand is strong.[21]

While assembly jobs have moved in large numbers to East Asia, R&D and management jobs remain primarily in the home countries of cell phone MNEs. Marketing jobs were located wherever there were major markets.

## PACKAGED SOFTWARE

There has been much talk about the impact of globalization on the software industry, but the evidence to date shows that, despite the hype, relatively few jobs have been outsourced to low-wage countries like India. Most of the outsourcing is domestic.[22] There is a trend toward outsourcing certain types of software maintenance and revision of so-called legacy systems[23] to India and elsewhere as the number of U.S. programmers who are trained to program in older languages such as FORTRAN and COBOL has declined.

A major push to sell Indian software services to U.S. firms occurred in the years leading up to the year 2000, as part of the global response to the "Y2K problem" (basically a problem created by the programming of chip-based calendars earlier in the twentieth century), but the problem was dealt with primarily in other ways. For example, many large firms simply scrapped their legacy systems and purchased modern database and enterprise packages offered by firms such as Oracle, SAP, and PeopleSoft.

Global packaged software revenues were more than $380 billion in 2005. Microsoft's software revenues alone in that year exceeded $44 billion. There were about 2.8 million employees worldwide in the industry. The Bureau of Labor Statistics of the U.S. Department of Commerce estimated that there were roughly 800,000 software engineers employed in the United States, about half of whom worked for packaged software companies. Total U.S. software employment was around a million workers and total U.S. software revenues were approximately $200 billion in 2001.

Software, and particularly packaged software, seems to be an industry that U.S. firms continue to dominate and where employment, particularly of very high-skilled workers, remains high. However, there has been some dropoff in overall employment in recent years (see table 7.1).[24] Competition from lower-skilled software engineers in India and elsewhere has reduced the wages of lower-skilled U.S. software workers, and even some highly skilled workers are noticing the effects of globalization.

**Table 7.1.**
**Software Workers and Revenues by Country, 2001**

| Country | Workers | Revenues |
|---|---|---|
| United States | 1,000,000 | $200 billion |
| Japan | 530,000 | $85 billion |
| Germany | 300,000 | $40 billion |
| India | 250,000 | $8.2 billion |
| China | 160,000 | $7.4 billion |
| Brazil | 190,000 | $7.7 billion |

*Source:* Ashish Arora and Alfonso Gambardella, "The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Developing Countries," NBER Working Paper No. 10,538, National Bureau of Economic Research, June 2004, p. 3, available at http://www.heinz.cmu.edu/wpapers/retrievePDF?id=2004-16.

## CONSUMER ELECTRONICS

Consumer electronics manufacturing comprises audio and video equipment, including receivers and recording devices, along with home personal computers (PCs) and a range of portable electronic devices such as personal digital assistants (PDAs) and calculators. It is not a new industry: its roots can be traced back to pre-electronic devices; the initial such product that sold in the millions worldwide was the record player or Victrola. The introduction of transistors in the 1960s and integrated circuits in the 1970s reinvigorated the industry and made it possible for new players to enter the market and survive. In 2005, U.S. sales of consumer electronics were around $125 billion. The global market was approximately four times larger.

In consumer electronics, there was very rapid change in international economic competitiveness over time. In the 1920s and 1930s, the United States was the global leader in the building of radios and the deployment of radio networks. The United Kingdom used a different model for developing radio broadcasting, centered on public rather than private broadcasting, which proved equally effective in promoting both consumer electronics and radio broadcasting. After World War II, the United States led in the development of television technology and broadcasting, again relying primarily on private competition. Britain was somewhat slower, but continued with its public broadcasting approach. The Japanese and other European governments mostly followed the British approach.

In the 1960s, a major shift occurred with the development of transistorized radios and televisions. Japanese firms moved more quickly than their U.S. counterparts to incorporate the new technologies into consumer electronic equipment, and their share of the global market increased rapidly as a result. There was also a bit of predatory pricing, but the most important factor was the rapid incorporation of new technologies. By the late 1980s, there was only one major consumer electronics firm operating in the United States: Zenith. At the beginning of the 1950s, there had been 140 firms in the industry; by 1956, 56 remained, by 1960 12, and by 1980 only 5.[25]

In Europe, an effort was made to protect domestic consumer electronics firms from American and Japanese competition by adopting incompatible regional standards and refusing to license the technologies associated with those standards to foreign firms. This worked for several decades—although at considerable expense to consumers—until European firms began to realize that they could build European-standard equipment in Asia for less than they could in Europe. Still, some effort was made in the 1980s to use the transition to high-definition television (HDTV) as a way of maintaining the standards barriers to Asian competitors.[26]

Competition for Japanese and Western European firms from Korean and Taiwanese companies began to intensify in the 1980s. By the end of the 1990s, almost all lower-priced color TVs and videocassette recorders were made in Korea and Taiwan. The Japanese and Europeans moved upmarket to wide-screen televisions and HDTV systems. The Koreans moved to higher value-added products, too, but at a somewhat slower pace. By the early 2000s, two Korean firms, Samsung and LG, had become major competitors to the Japanese consumer electronics giants Toshiba, Sharp, Mitsubishi, and Matsushita (Panasonic). New companies like Haier from China were also coming in at the lower end of the market, just as Korean and Taiwanese firms had done two decades earlier.[27]

Global consumer electronics sales were around $302 billion in 2006,[28] and U.S. sales were roughly $145 billion of that. Very little of U.S. consumption was domestically produced; most was manufactured in East Asia. There has been some increase in U.S. jobs in this industry due to the success of portable devices like MP3 players, PDAs, advanced cell phones, and satellite radios, but as in other industries, most new jobs are not in manufacturing but in design, R&D, and marketing.

## DIGITAL TELEVISION

The digital television market is a rapidly growing part of the larger consumer electronics market. The adoption of digital TV standards in the 1990s has resulted in new digital services that require digital TV receivers and peripherals. As one would expect, the general pattern of development and manufacturing of digital TV receivers is similar to the previous pattern of development and manufacturing of analog TVs. Most digital TVs are manufactured in Asia for distribution in the rest of the world. Some large-screen sets are assembled closer to final markets because of higher transportation costs.

There are a few exceptions to the East Asian dominance of consumer electronics in the case of digital TVs. A few new digital TV technologies were developed in the United States, and some of these have become important in the transition to digital TV. For example, the digital light processor (DLP) invented and developed commercially by Texas Instruments for projection TVs has generated revenues for TI and jobs for U.S. workers. TI's strategy has been to license DLP technology to consumer electronics manufacturers rather than to manufacture TVs themselves, so the benefit of this technological innovation has been felt mainly by TI stockholders.[29]

A handful of small U.S. firms have developed new digital TV technologies that they hope will be competitive with the more mainstream technologies (plasma display panels, liquid crystal displays, and projection TVs). An example is a small company called Brillian that developed a liquid-crystal-on-silicon (LCOS) technology and marketed its own brand of LCOS digital TVs. Another small firm that was an innovator in plasma technology, Plasmaco, was acquired by Matsushita and is now a division of that firm.

## PERSONAL COMPUTERS

The personal computer industry is younger than the consumer electronics industry, dating only from the mid-1970s. PCs were not economically

... until the invention of the integrated circuit in the early 1970s. By 2005, however, global PC sales were around $200 billion (about 200 million units). Revenues continued to rise despite declining prices, because lower prices tended to result in a higher volume of sales.

The leading firms in the personal computer industry were American from the start, with some limited competition from Japanese firms such as NEC, but only in Asian markets. At first, PC sales were limited to hobbyists. Apple was the first to sell millions of PCs by focusing on educational markets, but its sales were eclipsed by IBM and IBM-compatible PCs by the mid-1980s. European firms such as Olivetti and Siemens did well initially in Europe but fell by the wayside when they were unable to keep up with the more innovative U.S. firms. American corporations such as IBM, Compaq, Hewlett-Packard (which later merged with Compaq), and Dell remained industry leaders in desktop computers and in related markets like network servers, but in notebook (previously called laptop) computers, Taiwanese manufacturers became the undisputed leaders by the 1990s. Even though many firms have marketed notebook computers under their own brand names since then, most of these were made by Taiwanese original equipment manufacturing (OEM) companies.

How did the Taiwanese notebook firms come to be so competitive in this industry? Most accounts show that a combination of government industrial policies and the actions of private entrepreneurs are needed to explain the outcome. On the government side, subsidies for the petrochemical industry led to competitive strengths in chemical engineering that produced very strong skills in manufacturing processes and particularly in the plastics that are used to construct printed-circuit boards. This led to later governmental programs and private investment to promote the board-stuffing industry. The learning that came from board stuffing made it possible for firms to compete for OEM contracts with foreign computer manufacturers. Taiwanese electronics engineers who had been working for firms abroad were induced to come home to work in the domestic electronics industry. A few homegrown firms such as Acer and Prime Computer went on to assemble notebook computers under their own labels. The key point, however, is that neither private investment nor government subsidies alone would have done the job: it required a combination of both to make the Taiwanese firms internationally competitive.[30]

A key event in recent years was the sale in 2005 of IBM's PC operations to the Chinese firm Lenovo for $1.25 billion. This deal permitted 10,000 IBM employees to continue in their PC-related jobs in North Carolina alongside the more than 9,000 employees of the Chinese firm. Lenovo was to supply computers to IBM for the latter to sell under its own brand name for at least five years; IBM would provide technical assistance. The new firm became the third largest PC maker in the world after Dell and Hewlett-Packard. The deal in its essence was a way for IBM to gracefully exit a relatively unprofitable market and a recognition of the increasing tendency for electronics assembly to migrate to China, where the costs of electronics assembly were low and the domestic market was growing rapidly.

## WIDE-BODY JET AIRCRAFT

The design and final assembly of wide-body jet aircraft is done globally by two firms: Boeing and Airbus. Airbus replaced McDonnell Douglas in the 1990s as the second largest firm. There has been a long-standing dispute between the United States, the home of Boeing, and the European Union, the home of Airbus, over the question of government subsidies for the aircraft industry; each claims the other unfairly subsidizes its producer.

Even though assembly of aircraft takes place mainly in the home regions of the two firms, there has been a trend toward international outsourcing of components. Boeing, for example, contracted with Japanese firms for production of components for its 767, 777, and 787 models.

U.S. jobs in the aircraft industry declined sharply from 552,000 in 1994 to 432,000 in 2004 (see figure 7.1). Obviously some of this job loss is the result of increasing competition from Airbus, but David Pritchard and Alan MacPherson argue that it is also partly a result of Boeing's outsourcing policies, which are themselves a result of insufficient public and private investment in R&D in new composite materials.[31]

Boeing currently outsources about 60 percent of the value-added of its production to external suppliers. It does this not only to reduce costs but also to get access to needed capital and technology. The overall business strategy for the firm focuses on generating additional revenues and profits from after-sales services to customers. Thus, as in the case of large information technology firms like IBM, Boeing has shifted away from manufacturing and toward services in its attempt to maximize profits. In 2005, Boeing's revenues were just short of $55 billion.

## BIOTECHNOLOGY

Biotechnology is not new, but modern biotechnology depends on scientific knowledge of genetics, proteins, and cell dynamics of relatively recent origins.[32] Applications in modern biotechnology in agriculture are particularly important and widespread, but the largest revenues and profits so far are going to those firms that have harnessed biotechnology to the task of creating new pharmaceuticals and medical therapies.

U.S. firms such as Cetus, Cal Bio, Calgene, and Genentech were widely recognized as pioneers in the industry of the 1980s. Only a few of the start-up firms that began the biotech revolution went on to develop and commercialize biotech products and services, and only a few of these were able to do so successfully. Others were sold to larger pharmaceutical and chemical companies or went out of business. Still, the number of biotech start-ups continues to grow, especially in the United States, as the sciences of genomics, proteomics, and metabolomics develop.[33]

Global revenues for the biotech industry in 2005 were about $54 billion. U.S. revenues, at $42.7 billion, represented 78 percent of the global total. Global employment in the industry was approximately 183,000, of which 75 percent (137,000 jobs) was in the United States (see figure 7.1).[34] Total U.S. biosciences employment was much larger, approximately

1.2 million in 2005.[55] Many of these jobs were likely to be affected by advances in biotechnology, even though the direct employment of workers by biotech firms remained relatively small. The average annual income of U.S. biotechnology workers was more than $60,000, considerably higher than in other industries.

Some of the factors mentioned for the success of the U.S. industry in the literature on modern biotechnology are:

1. Generous federal funding of research in biological sciences, informatics, and health
2. Availability of venture capital for start-ups
3. Health policies favoring the creation, development, and marketing of new pharmaceuticals and therapies
4. The breadth and strength of U.S. university-based research in biotechnology-related fields

Although the number of countries with national programs to promote biotechnology has risen to more than fifty, including India and China, so far very few globally competitive biotech firms have emerged. This is clearly not a permanent situation, and there is some worry that the Bush administration's ban on federal funding for new stem-cell lines has forced some U.S. firms to look for foreign partners to continue their research in that area. Still, there is something about the U.S. business environment that is exceptionally favorable to the growth of this still rather young industry.

## CONCLUSIONS AND IMPLICATIONS: COMPARING HIGH-TECHNOLOGY INDUSTRIES

I have sought to summarize the discussion of individual industries above in figure 7.1 and table 7.2. Even though the pioneers in these industries were often U.S. firms, the recent industry leaders varied considerably in nationality. In younger industries, such as modern biotechnology, the leading firms were still American, but in even slightly older industries, cellular telephones, for example, there were industry leaders in other countries.

The shift to overseas development and manufacturing occurred mostly in the oldest of the eight industries: consumer electronics. Manufacturing but not development had shifted in a much younger industry, cell phones. In a relatively young segment of the consumer electronics market, digital TV, firms in countries like South Korea and Taiwan were ahead of or fully competitive with those in the United States and Japan. Western Europe and Japan had corporations that could compete with U.S. firms, but in the last decade or so in particular industries, businesses in industrializing countries such as Korea and Taiwan could be found in the lists of top firms globally. Chinese enterprises were beginning to flex their muscles in consumer electronics, and China was becoming the location of choice for high-labor-content manufacturing in cell phones, digital TVs, and PCs (the IBM/Lenovo deal being a prime example of this).

Table 7.2.
**Industry Comparisons**

| Industry | Dominant Firms | Diffusion Pattern | Division of Labor |
|---|---|---|---|
| Semiconductors | Intel, AMD, Hitachi, Fujitsu, Samsung, UMC | U.S. to Japan to Korea/Taiwan | Package assembly in low-wage countries; foundries vs. design houses |
| Cellular Telephones | Motorola, Nokia, Samsung, LG | U.S., Japan, and Europe to Korea | Handsets assembled in low-wage countries (China) |
| Packaged Software | Microsoft, IBM, SAP, Oracle, PeopleSoft | U.S. still dominant | Low-tech software to India, Israel, and Ireland |
| Consumer Electronics | Sony, Toshiba, Hitachi, Sharp, Samsung, LG, Philips | U.S. and Europe to Korea, Taiwan, and now China | Some assembly of large TVs close to markets |
| Digital Televisions | Same as consumer electronics | Japan to Korea and Taiwan | Some assembly of large TVs close to markets; assembly of LCD panels in low-wage countries (China) |
| Personal Computers | Dell, HP, IBM (Lenovo), Acer | U.S. to East Asia | PCs assembled close to markets; displays made in East Asia; assembly of components in low-wage countries |
| Wide-Body Jet Aircraft | Boeing, Airbus | U.S. to Europe | Increasing contracting out of components to industrializing countries |
| Biotechnology | Genentech, Eli Lilly, Monsanto, GSK, Novartis, Aventis | U.S. still dominant | Outsourcing in clinical trials; routine lab work |

To return to figure 7.1, the fastest and most important growth in U.S. employment in the high-technology industries discussed here was in software and computer services jobs. Biotechnology jobs increased, but were still fewer than 200,000 in 2005, whereas software and computer services numbered well over a million. Aerospace jobs hovered between 600,000 and 700,000 until the early 1990s and then began to decline somewhat. Semiconductor employment rose from the 1960s to the mid-1980s to around 600,000 and then flattened out.

In recent years, jobs in all of these industries, with the exception of biotechnology, grew more rapidly in East Asia than in the United States, albeit from a lower base. India experienced major growth in software and computer services jobs, while Korea, Taiwan, and China saw rapid expansion in employment in electronics manufacturing. One of the reasons for the relatively higher growth rate in high-tech jobs in East Asia is globalization, but globalization does not explain why the increase in jobs occurred in those countries as opposed to somewhere else.

Part of the explanation for the migration of high-tech jobs and wealth creation to Asia was the gradual but accelerating rate of diffusion of knowledge globally. But it is important to note that East Asian governments actively promoted investment in high technology, which had the result that new industrial technology and knowledge could be created outside the industrialized core. U.S.-based MNEs such as IBM, Motorola, and Boeing and European firms like Thomson, Philips, Nokia, and Airbus added to this trend by offshoring and outsourcing some activities to East Asia. Japanese firms that did not previously do much outsourcing were increasingly matching U.S. and European firms and sometimes jumping over them in their quest for a globally competitive edge.

One could argue that these trends are simply a consequence of the freer flow of goods, services, and information across national borders that came with globalization, and that there is no need to fight them. From this perspective, one might want to minimize the impediments to globalization as part of a general strategy of maintaining national economic competitiveness and maximizing the number of well-paying jobs. Nevertheless, the rapid shift in revenues and employment have caused significant difficulties in the U.S. economy, especially in older industries and in jobs held by individuals who were vulnerable to rapid change. What this chapter shows is that growth in jobs in some U.S. high-tech industries, especially electronics manufacturing, was lower in recent years than it had been in the past partly as a consequence of globalization.

It would be incorrect to jump to the conclusion that globalization is bad for the United States, however. While job growth rates in some industries have declined, in others they have increased. Overall, the employment picture remains good for U.S. workers. There has been downward pressure on wages in some industries, but not in others. While U.S. firms are going abroad in search of lower costs, they still maintain a major presence domestically not just for marketing but also for design, R&D, and other

More generally, while it may be possible to blame globalization for outsourcing and slow employment growth within high-tech U.S. industries, we cannot say for sure that the prospects of U.S. firms and their employees in these sectors would have been any better *absent* globalization—that is, without the better access to global markets and the efficiencies possible through global production.

Given that economic globalization is our current reality, U.S. policy makers should focus on enhancing U.S.-based firms' competitiveness in these high-tech industries. Several prescriptions emerge from this chapter's analysis:

1. Look for ways to spread the wealth and jobs created in rising high-technology industries (advanced software and biotechnology, for example) to the rest of the economy.
2. Do not put handcuffs on firms in either mature industries or high-tech industries that are increasingly competing with firms in Europe and Asia to prevent them from using globalization to remain internationally competitive.
3. Keep training scientists and engineers from around the world in U.S. colleges and universities, but try to induce as many as possible to stay in the United States to build U.S. competitiveness.
4. Keep training workers for expanding high-tech industries so these industries do not have to deal with shortages of skilled workers.

## NOTES

1. Jeffrey T. Macher and David C. Mowery, "Introduction: Running Faster to Keep Up," paper presented at the National Academies, Washington, DC, April 20, 2007.

2. See, for example, Ron Hira and Anil Hira, *Outsourcing America: What's Behind Our National Crisis and How We Can Reclaim American Jobs* (New York: AMACOM, 2005).

3. Aseem Prakash and Jeffrey Hart, "Coping with Globalization: An Introduction," in *Coping with Globalization*, edited by Aseem Prakash and Jeffrey A. Hart (New York: Routledge, 2000), 2.

4. Giorgio Barba Navaretti and Anthony J. Venables, *Multinational Firms in the World Economy* (Princeton, NJ: Princeton University Press, 2004), chaps. 3–4.

5. See Jerry Thursby and Marie Thursby, eds., *Here or There? A Survey on the Factors in Multinational R&D Location* (Washington, DC: National Research Council of the National Economies, 2006).

6. For an excellent discussion of this issue, see Leonard Lynn and Hal Salzmann, "The 'New' Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development," paper presented at the 21st European Group for Organizational Studies Colloquium on Unlocking Organizations, Berlin, June 2005, available at http://www.urban.org/uploadedpdf/411226_new_globalization.pdf.

7. See Dieter Ernst, "The New Mobility of Knowledge: Digital Information Systems and Global Flagship Networks," in *Digital Formations: IT and New Architectures in the Global Realm*

8. Two popular works that focus on the rise of China and India are Thomas Friedman, *The World Is Flat: A Brief History of the Twenty-First Century* (New York: Farrar, Straus, & Giroux, 2005), and Clyde Prestowitz, *Three Billion New Capitalists: The Great Shift of Wealth and Power to the East* (New York: Basic Books, 2005). See also C. Fred Bergsten, Bates Gill, Nicholas Lardy, and Derek Mitchell, *China—The Balance Sheet: What the World Needs to Know about the Emerging Superpower* (New York: PublicAffairs, 2006), and Edward Luce, *In Spite of the Gods: The Strange Rise of Modern India* (New York: Doubleday, 2007).

9. Charles W. Wade, "'A Rush to Judgment': Electronic Manufacturing Migration," paper presented at the National Academy of Sciences, Washington, DC, April 21, 2006. Mr. Wade works for Technology Forecasters, Inc.

10. Jason Dedrick and Kenneth L. Kraemer, "Global Innovation in the PC Industry: Implications for U.S. Competitiveness and Workforce Needs," paper presented at the National Academy of Sciences, Washington, DC, April 21, 2006.

11. See U.S. Government Accountability Office (GAO), *Offshoring: U.S. Semiconductor and Software Industries Increasingly Produce in China and India* (Washington, DC: GPO, 2006), and Clair Brown and Greg Linden, "Offshoring in the Semiconductor Industry: A Historical Perspective," paper prepared for the 2005 Brookings Trade Forum "Offshoring White-Collar Work," Washington, DC, May 12–13, 2005.

12. Jeffrey T. Macher, David C. Mowery, and Alberto di Minin, "'Globalization' of Innovation in the Semiconductor Industry," paper presented at the National Academies, Washington, DC, April 21, 2006.

13. An earlier division of labor had developed between companies that manufactured chips and their contractors in lower-wage countries who put the chips into chip housings or packages.

14. On the emergence of foundries, see Annalee Saxenian and Jinn-Yuh Hsu, "The Silicon Valley–Hsinchu Connection: Technical Communities and Industrial Upgrading," *Industrial and Corporate Change* 10 (2001): 893–920. Dieter Ernst argues that chip design is moving to Asia in his "Complexity and Internationalization of Innovation: Why Is Chip Design Moving to Asia?" *International Journal of Innovation Management* 9 (March 2005): 47–73.

15. GAO, *Offshoring*, 26.

16. See, for example, John Alic and Martha Caldwell Harris, "Employment Lessons from the Electronics Industry," *Monthly Labor Review* (February 1986): 27–36.

17. "Global Shipments of Cell Phones Could Hit the Billion Mark in the Not-So-Distant Future," *CNET News.com*, February 10, 2006, available at http://news.com.com/Mobile+phone+sales+pass+800+million/2100-1039_3-6037984.html.

18. "Another Record Year for Cell Handsets, But Growth Is Slowing Reports In-Stat," In-Stat press release, July 13, 2005, available at http://www.instat.com/press.asp?sku=in0502109wh&id=1396.

19. Johan Lembke, *Competition for Technological Leadership: EU Policy for High Technology* (Northampton, MA: Edward Elgar, 2003).

20. Kara Spak, "China's Cell Phone Frenzy," *Daily Herald*, April 23, 2006, available at http://www.dailyherald.com/special/crossingchina/part2.asp.

21. Alex Frew McMillan, "Dongguan Joins China's Assembly Line," CNN.com, November 28, 2002, available at http://edition.cnn.com/2002/BUSINESS/asia/11/28/china.dongguan/.

22. See GAO, *Offshoring*; Ashish Arora and Alfonso Gambardella, "The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Devel-

Research, June 2004, available at http://www.heinz.cmu.edu/wpapers/retrievePDF?id=2004-16; and William Aspray, Frank Mayadas, and Moshe Y. Vardi, eds., *Globalization and Offshoring of Software* (New York: Association for Computing Machinery, 2006), available at http://www.acm.org/globalizationreport.

23. *Legacy systems* are customized software systems that are written in older computer languages such as COBOL and FORTRAN that are no long employed in new systems. U.S. colleges and universities no longer train software engineers to program in these languages, so firms are faced with the choice of scrapping older systems or sending the work of upgrading their older systems to countries that have programmers who are willing to use the older languages.

24. It should be noted that the data on employment in software used in Figure 7.1 includes some computer services employment that is not directly related to software, so the employment levels are somewhat inflated.

25. Jeffrey A. Hart, "Consumer Electronics," in *Developing the Electronics Industry*, edited by Björn Wellenius, Arnold Miller, and Carl J. Dahlman (Washington, DC: World Bank, 1993), 60.

26. HDTV standards issues were not resolved until the 1990s and consumer demand remained low until the standards were set and the prices of high-resolution TVs and monitors descended to acceptable levels. For a thorough discussion, see Jeffrey A. Hart, *Technology, Television, and Competition: The Politics of Digital TV* (New York: Cambridge University Press, 2004).

27. Hart, "Consumer Electronics"; Hart, *Technology, Television, and Competition*, chap. 3; Alfred D. Chandler, *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries* (New York: Free Press, 2001); Alan Cawson, *Hostile Brothers: Competition and Closure in the European Electronics Industry* (Oxford, UK: Clarendon, 1999); Dieter Ernst, "Catching Up Crisis and Industrial Upgrading: Evolutionary Aspects of Technological Learning in Korea's Electronics Industry," *Asia Pacific Journal of Management* 15 (October 1998): 247–83.

28. "Consumer Electronics Sales to Rise 2.4% to $302.3 Billion in 2006," *Metrics 2.0*, October 26, 2006, available at http://www.metrics2.com/blog/2006/10/26/consumer_electronics_sales_to_rise_24_to_3023_bill.html.

29. Although U.S. firms are not required to reveal the nationality of owners of their outstanding stock and there are no clear restrictions on foreign ownership, one can be relatively confident in saying that only a small proportion of the tradable stock of a major U.S. firm like Texas Instruments is held by foreigners.

30. Jason Dedrick and Kenneth I. Kraemer, "The Globalization of Innovation: The Personal Computing Industry," paper prepared for the National Academy of Sciences STEP Project, April 21, 2006.

31. David Pritchard and Alan MacPherson, "Boeing's Diffusion of Commercial Aircraft Design and Manufacturing Technology to Japan: Surrendering the U.S. Aircraft Industry for Foreign Financial Support," State University of New York, Buffalo, March 2005, available at http://www.custac.buffalo.edu/docs/OccasionalPaper30.pdf.

32. *Biotechnology* is defined by the Organization for Economic Cooperation and Development (OECD) as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods, and services" (Brigitte van Beuzekom and Anthony Arundel, *OECD Biotechnology Statistics, 2006* [Paris: OECD, 2006], 7). Modern biotechnology is restricted to a narrower list of techniques, including, among others, DNA/RNA manipulati-

techniques; gene therapy; the application of bioinformatics techniques; and the application of nanotechnology to biological systems.

33. The best single source of statistical information on modern biotechnology is van Beuzekom and Arundel, *OECD Biotechnology Statistics, 2006*, but see also *Standard & Poor's Industry Surveys: Biotechnology*, May 15, 2003; Thomas Bernauer, *Genes, Trade, and Regulation: The Seeds of Conflict in Biotechnology* (Princeton, NJ: Princeton University Press, 2003); and the website of the Biotechnology Industry Organization, http://www.bio.org.

34. *Beyond Borders: Global Biotechnology Report, 2005* (Boston: Ernst & Young, 2005).

35. Biosciences employment includes employment in health care, pharmaceuticals, medical devices, agricultural chemicals, and other industries that require knowledge of biology.