Chapter 6
Industry, Technology, and the Global Marketplace

List of Sidebars

List of Tables

List of Figures

Highlights

Changing Global Marketplace

High-technology manufacturing industries are key contributors to economic growth in the United States and around the world.

- The global market for high-technology goods is growing faster than that for other manufactured goods.
- Over the past 24 years (1980–2003), world output by high-technology manufacturing industries grew at an inflation-adjusted average annual rate of 6.4%. Output by other manufacturing industries grew at just 2.4%.
- The European Union (EU) had the world's largest high-technology manufacturing sector between 1980 and 1995.
- Beginning in 1996 and for each year thereafter, U.S. high-technology manufacturers generated more domestic production (value added) than the EU or any other single country. Estimates for 2003 show U.S. high-technology industry accounting for more than 40% of global value added, the EU for about 18%, and Japan for about 12%.

Asia's status as both a consumer and a developer of high-technology products continues to advance, enhanced by the technological development of many Asian economies, particularly Taiwan, South Korea, and China. Several smaller European countries (e.g., Ireland, Finland, and the Netherlands) also have strengthened their capacities to develop new technologies and successfully supply high-technology products in global markets. However, the technological competencies in these latter countries are in a narrower set of technologies.

- Current data on domestic production by high-technology industries in Asia and in several smaller European countries reveal a capacity to compete successfully with high-technology industries operating in the United States and other advanced countries.
- High-technology domestic production within Asian nations has grown over the past two decades, led first by Japan in the 1980s and then by South Korea, Taiwan, and China in the 1990s. Recently, China's high-technology industries have surpassed those of South Korea and Taiwan and may soon rival those of Japan in size.
- In 2003, domestic production by China's high-technology industry accounted for an estimated 9.3% of global value added. In 1980, domestic production in China's high-technology industry accounted for less than 1% of global value added.
- Although some smaller European countries have become important sources for technology products, they tend to specialize more. For example, Ireland was the top supplier of biotechnology and life science products to the United States in 2004, as the source for 24% and 36% of U.S. imports in these categories.

From 1980 through 2003, market competitiveness of individual U.S. high-technology industries varied, although each sector maintained strong market positions.

- In 1998, U.S. manufacturers replaced Japanese manufacturers as the leading producers of communication equipment and have retained that position. In 2003, the United States accounted for nearly 51% of world production (value added), Japan for 16%, and the EU for 9%.
- In 1997, U.S. manufacturers also replaced Japanese manufacturers as the leading producers of office and computer machinery; by 2003, U.S. manufacturers accounted for an estimated 40% of global production while China's industry secured second place at 26%, with the EU in third place at 9%.
- The U.S. aerospace industry has long maintained a leading if not dominant position in the global marketplace. In recent years however, the aerospace industry's manufacturing share has fallen more than any other U.S. industry. U.S. industry share of global aerospace production is estimated to have fallen to about 35% in 2003. At its highest level in 1985, U.S. aerospace accounted for 57% of global production.
- The EU and the United States were the leading producers of drugs and medicines in the world market for the entire 24-year period examined, each accounting for about 32% of global production in both 2002 and 2003.
- The EU and the United States were also the leading producers of scientific instruments. Led by Germany and France, the EU accounted for an estimated 38% of global production in 2003, while the U.S. share was nearly 35%.

Shifting Export Trends

Historically, U.S. high-technology industries have been more successful exporting their products than other U.S. industries, positively contributing to the overall U.S. trade balance. Although U.S. high-technology industries continue to export a larger proportion of their total shipments than other U.S. manufacturing industries, their advantage has narrowed considerably.

- Throughout the 1990s and continuing through 2003, U.S. industry supplied 12%–14% of the world's general manufacturing exports. By comparison, during the 1990s, U.S. high-technology industries accounted for 19%–23% of world high-technology industry exports.
- The EU is the world's leading exporter, but if intra-EU shipments were excluded, the United States likely would rank above the EU. Estimates for 2003 show exports by U.S. high-technology industries account for about 16% of world high-technology industry exports. Japan accounts for about 9% and Germany for nearly 8%.

- The gradual drop in the U.S. share was partly due to competition from emerging high-technology industries in newly industrialized and industrializing economies, especially in Asia. China stands out, with its share of global high-technology industry exports reaching 7% in 2003, up considerably from slightly more than 1% in 1990.

The comparative advantage in U.S. trade in advanced technology products, historically a strong market segment for U.S. industry, has turned negative.

- In 2002, U.S. imports of advanced technology products exceeded exports, resulting in a first-time U.S. trade deficit in this market segment. The trade deficit has grown each year since. The U.S. trade deficit in advanced technology products was $15.5 billion in 2002; it increased to $25.4 billion in 2003 and to $37.0 billion in 2004.
- The imbalance of U.S. trade with Asian countries (imports exceeding exports), especially with China, Malaysia, and South Korea, overwhelms U.S. surpluses and relatively balanced trade with other parts of the world.

Knowledge-intensive service industries are key contributors to service-sector growth around the world.

- Global sales in knowledge-intensive service industries rose every year from 1980 through 2003 and exceeded $14 trillion in 2003.
- The United States was the leading provider of knowledge-intensive services, responsible for about one-third of world revenue totals during the 24-year period examined.
- Business services, which includes computer and data processing and research and engineering services, is the largest of the five service industries, accounting for 35% of global knowledge-intensive revenues in 2003.
- Business-service industries in the EU and United States are close in size and the most prominent in the world; together they account for more than 70% of services provided worldwide. Japan ranked a distant third at about 12%.

The United States continues to be a net exporter of manufacturing technological know-how sold as intellectual property.

- On average, royalties and fees received from foreign firms were three times greater than those paid out to foreigners by U.S. firms for access to their technology.
- In 2003, U.S. receipts from the licensing of technological know-how to foreigners totaled $4.9 billion, 24.4% higher than in 1999. The most recent data show a trade surplus of $2.6 billion in 2003, 28% higher than the prior year but still lower than the $3.0 billion surplus recorded in 2000.

New High-Technology Exporters

Based on a model of leading indicators, Israel and China received the highest composite scores of the 15 nations examined. Both nations appear to be positioning themselves for greater prominence as exporters of technology products in the global marketplace.

- Israel ranked first in national orientation based on strong governmental and cultural support promoting technology production, and first in socioeconomic infrastructure because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second and third on the two remaining indicators, technological infrastructure and productive capacity.
- Although China's composite score for 2005 fell just short of that calculated for Israel, the rise in its overall score over the past 2 years is noteworthy. China's large population helped to raise its score on several indicator components; this shows how scale effects, both in terms of large domestic demand for high-technology products and the ability to train large numbers of S&Es, may provide advantages to developing nations.

Global Trends in Patenting

Recent patenting trends, a leading indicator of future competition for U.S. industry, show growing capacities for technology development in Asia and in a transitioning Europe.

- Patents issued to foreign inventors have increased slightly since 1999. Inventors from Japan and Germany continue to receive more U.S. patents than inventors from any other foreign countries.
- Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, two Asian economies, Taiwan and South Korea, have increased their patenting activity in the United States.
- The latest data indicate that Taiwan (in 2001) and South Korea (in 2003) moved ahead of France and the United Kingdom to rank third and fourth as the residences of foreign inventors who obtained patents in the United States.
- In 2003, the top five economies receiving patents from the United States were Japan, Germany, Taiwan, South Korea, and France.
- Recent U.S. patents issued to foreign inventors emphasize several commercially important technologies. Japanese patents focus on photography, photocopying, office electronics technology, and communications technology. German inventors are developing new products and processes associated with heavy industry, such as motor vehicles, printing, metal forming, and manufacturing technologies. Taiwanese and South Korean inventors are earning more U.S. patents in communication and computer technology.
- In 2003, more than 169,000 patents for inventions were issued in the United States, 1% more than a year earlier.
- U.S. resident inventors received nearly 88,000 new patents in 2003, which accounted for about 52% of total patents granted.

U.S. patenting of biotechnologies accelerated during the 1990s, especially during the latter half of the decade.

The effort to map the human genome contributed to this trend as evidenced by a surge in applications to patent human DNA sequences. Since 2001, the number of biotechnology patents has remained high, but the trend has turned slightly negative.

- U.S. resident inventors accounted for more than 60% of all biotechnology patents issued by the U.S. patent office, a share about 10% higher than U.S. inventors hold when U.S. utility patents for all technologies are counted.
- Foreign sources accounted for about 36% of all U.S. biotechnology patents granted, and the patents are more evenly distributed among a somewhat broader number of countries than is the case when all technology areas are combined.
- Given the ongoing controversies surrounding this technology area, foreign inventors may be less inclined than U.S. inventors to file biotechnology patents in the United States.
- Also evident is the more prominent representation of European countries in U.S. patents of biotechnologies than Asian inventors.
- In the biotechnology area, universities, government agencies, and other nonprofit organizations are among the leading recipients of U.S. patents, although corporations are still awarded the most patents overall.

One limitation of patent counts as an indicator of national inventive activity is the inability of such counts to differentiate between minor inventions and highly important inventions. A database has recently been developed that counts *triadic patent families* (inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan). This database may more accurately indicate important inventions than simple patent counts.

- The United States has been the leading producer of triadic patent families since 1989, even when compared to inventors from the EU.
- Inventors residing in EU countries produced nearly as many triadic patented inventions as did inventors living in the United States since the late 1980s, and from 1985 through 1988 produced more than U.S. inventors.
- Estimates for 2000 show U.S. inventors' share of triadic patents at 34%, the EU's share at 31%, and Japan's share at 27%.
- Inventors residing in Japan produced only slightly fewer triadic patents than inventors in the United States or the EU. Given its much lower population, however, Japan's inventive productivity would easily exceed that of the United States or the EU if the number of inventions per capita were used as the basis for comparison. Among the big three (the United States, the EU, and Japan), Japan clearly is the most productive when size is factored into the measurement.
- Rankings change dramatically when national activity is normalized by population or by size of the economy as reflected in the gross domestic product. When data are normalized for size, smaller countries emerge, Switzerland and Finland in particular, and demonstrate high output of important inventions.
- Counts of triadic patent families also can be used to further examine patenting in biotechnology. During 1998 and 1999, the most recent 2 years that complete data are available, biotechnologies accounted for a larger share of the U.S. triadic patent portfolio compared with that in the European Union or Japan.

Venture Capital Investment Trends

The funds and management expertise provided by venture capitalists can aid the growth and development of small companies and new products and technologies, especially in the formation and expansion of small high-technology companies. Trends in venture capital investments also provide indicators of which technology areas venture capitalists view as the most economically promising.

- Internet-specific businesses involved primarily in online commerce were the leading recipients of venture capital in the United States during 1999 and 2000. They collected more than 40% of all venture capital funds invested in each year. Software and software services companies received 15%–17% of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third, receiving 14%–15% of dispersed funds.
- The U.S. stock market suffered a dramatic downturn after its peak in early 2000, with the sharpest drops in the technology sector. Nonetheless, venture capital investments continued to favor Internet-specific companies over other industries from 2000–2003.
- In 2003 and 2004, however, venture capital funds preferred other technology areas over Internet-specific companies for investments, in particular those identified as software and medical/health companies.
- Software companies attracted the most venture capital in 2003 and 2004, receiving about 21% of the total invested each year, followed by companies in the medical/health field that received 16% in 2003 and 18% in 2004. Internet-specific companies fell to only about 13% of all money disbursed by venture capital funds during this period.
- The decline in enthusiasm for Internet companies seems to have benefited other technology areas as well. Since 2000, biotechnology companies have gained steadily to receive 11% of total venture capital investments in 2003 and 2004—more than triple their share of 4% received in 1999 and 2000. Medical/health companies also have received higher shares: in 1999 and 2000, they received about 4% of total venture capital disbursements, rising to

an average of 11% in 2001 and 2002 and to 17% during this period.

- Contrary to popular perception, only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing has never accounted for more than 8% of all disbursements over the past 23 years and most often has represented 1%–5% of the annual totals. The latest data show that seed financing represented just 1.3% in 2003 and less than 1% in 2004.
- Over the past 25 years, the average amount invested in a seed-stage financing (per company) increased from a low of $700,000 in 1980 to a high of $4.3 million per disbursement in 2000. Since then, the average level of seed-stage investment has fallen steadily, to just $1.8 million in 2003 and $1.4 million in 2004.

Introduction

Chapter Overview

Science and engineering and the technological innovations that emerge from research and development activities enable high-wage nations like the United States to engage in today's highly competitive global marketplace. Many of the innovative new products exported around the world, many of the process innovations that have raised worker productivity, and many of the technological innovations that have created whole new industries can be traced back to earlier national investments in R&D. These innovations also make large contributions to national economic growth and industry competitiveness.

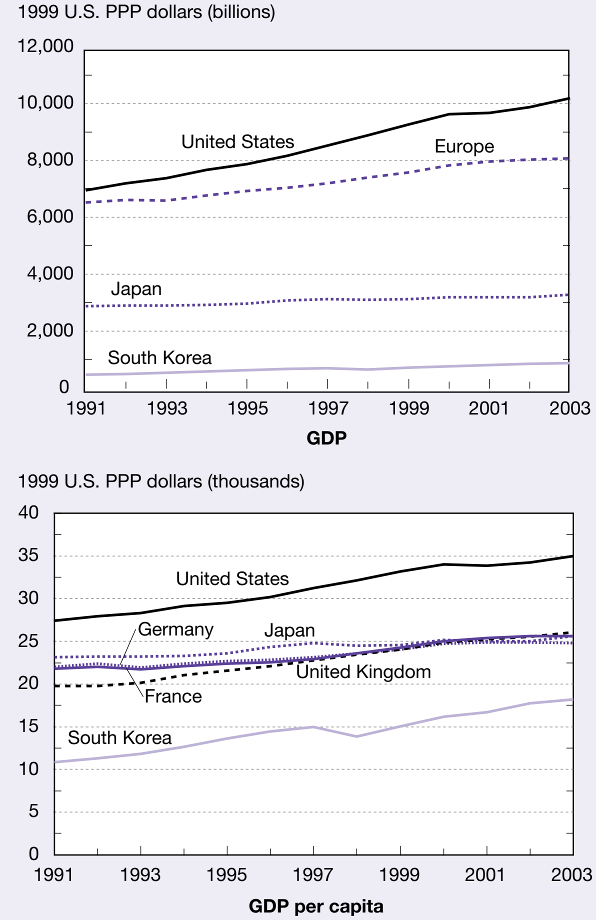
An international standard used to judge a nation's competitiveness rests on the ability of its industries to produce goods that find demand in the marketplace while simultaneously maintaining, if not improving, the standard of living for its citizens (OECD 1996). By this measure, the nation continues to be competitive; U.S. industry leads all others in the production of goods, and Americans continue to enjoy a high standard of living (figure 6-1; appendix table 6-1).

Faced with many of the same pressures from globalization as the United States, high-wage nations in Asia and Europe also have invested heavily in science and technology (S&T). Over the past decade, South Korea and Taiwan have advanced their technological capacity and increasingly challenge U.S. prominence in many technology areas and product markets. More recently, China, Finland, India, and Ireland have begun to distinguish themselves as producers of world-class S&T.

This chapter focuses on industry's vital role in the nation's S&T enterprise and how the national S&T enterprise develops, uses, and commercializes S&T investments by industry, academia, and government.[1] It presents various indicators that track U.S. industry's national activity and standing in the international marketplace for technology products and services and technology development. Using public and private data sources, U.S. industry's technology activities are compared with those of other major industrialized nations, particularly the European Union (EU) and Japan and, wherever possible, the newly or increasingly industrialized economies of Asia, Central Europe, and Latin America.[2]

Past assessments showed the United States to be a leader in many technology areas. *Science & Engineering Indicators 2004* showed that advancements in information technologies (computers and communication products and services) drove the rising trends in new technology development and dominated technical exchanges between the United States and its trading partners. In this 2006 edition, many of the same indicators are reexamined from new perspectives influenced by international data on manufacturing and selected service industries for the advanced nations and trends in biotechnology patenting. Also presented are updates to the Georgia Institute of Technology high-technology indicators model, which identifies developing nations with increased technology capacities as well as recent data on trends in venture capital investments in the United States.

Figure 6-1
International comparisons of GDP and GDP per capita, by country/region: 1991–2003



GDP = Gross domestic product; PPP = purchasing power parity

NOTES: GDP converted to U.S. dollars using PPP at 1999 prices. Top panel, Europe includes Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Sweden, and United Kingdom; bottom panel, Europe includes France, Germany, and the United Kingdom.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, special tabulations (December 2004). See appendix table 6-1.

Science and Engineering Indicators 2006

Chapter Organization

This chapter begins with a review of industries that rely heavily on R&D, referred to herein as *high-technology* or *knowledge-intensive industries*. Because no single authoritative methodology exists for identifying high-technology industries, most calculations rely on a comparison of R&D intensities. R&D intensities are determined by comparing industry R&D expenditures with the value of the industry's shipments. In this chapter, high-technology industries are identified using the R&D intensities calculated by the Organisation for Economic Co-operation and Development (OECD).

High-technology industries are noted for their R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also employ and train new scientists, engineers, and other technical personnel. Thus, the market competitiveness of a nation's technological advances, as embodied in new products, processes, and services associated with high-technology or knowledge-intensive industries, can serve as an indicator of the economic and technical effectiveness of that country's S&T enterprise.

The global competitiveness of the U.S. high-technology manufacturing industry is assessed by examining domestic and worldwide market share trends. (Unless otherwise noted, trends in high-technology industry production are derived from data on industry value added, i.e., the value of industry shipments minus the value of purchased inputs, to better measure manufacturing activity taking place in each country or region.) Only limited trend data tracking gross revenues are available for the knowledge-based service industries. Data on royalties and fees generated from U.S. imports and exports of manufacturing know-how that is sold or rented as intangible (intellectual) property are used to further gauge U.S. competitiveness. Also discussed are indicators that identify developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.[3]

The chapter also explores several leading indicators of technology development by presenting measures of inventiveness. This is done by comparing U.S. patenting patterns with those of other nations.

Finally, the disbursement in the United States of venture capital, which is money used to form and expand small companies, is examined by both the stage of development in which financing is awarded and the technology area receiving funds (see sidebar, "Comparison of Data Classification Systems Used").

U.S. Technology in the Global Marketplace

Policies in many countries reflect a belief that a symbiotic relationship exists between investment in S&T and success in the marketplace: S&T supports industry's competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, a nation's economic health is a performance measure for the national investment in R&D and S&T. This is true for the United States and for many countries around the world.

OECD currently identifies five industries as *high-technology,* i.e., science-based industries that manufacture products while performing above-average levels of R&D: aerospace, pharmaceuticals, computers and office machinery, communication equipment, and scientific (medical, precision, and optical) instruments.[4] Identified as the most R&D intensive by OECD, these industries also rank as the most R&D intensive for the United States (table 6-1).

This section examines the U.S. position in the global marketplace from three vantage points: U.S. high-technology industry share of global production and exports, the competitiveness of individual industries, and trends in U.S. exports and imports of manufacturing know-how. Before assessing the U.S. role in the global high-technology marketplace, however, it may be useful to consider how high-technology industries are driving global economic growth.

Importance of High-Technology Industries to Global Economic Growth

High-technology industries are driving economic growth around the world. According to the Global Insight World Industry Service database, which provides production data for the 70 countries that account for more than 97% of global economic activity, the global market for high-technology goods is growing at a faster rate than for other manufactured goods. During the 24-year period examined (1980–2003), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.4%, compared with 2.4% for other manufactured goods. Global economic activity in high-technology industries was especially strong during the late 1990s (1995–2000), when high-technology industry manufacturing, led by manufacturing in those industries producing communication and computer equipment, grew at more than four times the rate of growth for all other manufacturing industries (figure 6-2; appendix table 6-2).

Even during the recent, slow-growth, "postbubble" period (2000–03), high-technology industry continued to lead global growth at about four times the rate of all other manufacturing industries. Output by the five high-technology industries represented 8.1% of global production of all manufactured goods in 1980; by 2003, it had doubled to 17.7%.

High-technology industries are R&D intensive; R&D leads to innovation, and firms that innovate tend to gain market share, create new product markets, and use resources more productively (NRC, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; Tassey 2000).[5] These industries tend to develop high value-added products, tend to export more, and, on average, pay higher salaries than other manufacturing industries. Moreover, industrial R&D performed by high-technology industries benefits other commercial sectors by developing new products, machinery, and processes that increase productivity and expand business activity.

High-Technology Industries and Domestic Production

Increasingly, manufacturers in countries with high standards of living and labor costs have moved manufacturing operations to locations with lower labor costs. High-technology industries and their factories are coveted by local, state, and national governments because these industries consistently

Comparison of Data Classification Systems Used

This chapter incorporates several thematically related but very different classification systems. These measure activity in high-technology manufacturing and knowledge-intensive service industries, measure U.S. trade in advanced technology products, and track both the patenting of new inventions and trends in venture capital investments. Each classification system is described in the introduction to the section that presents those data. This sidebar shows the classification systems used in the chapter in tabular format for easy comparison.

System	Type of data	Basis	Coverage	Methodology	Data provider
High-technology manufacturing industries	Industry value added and exports in constant (1997) dollars	Industry by International Standard Industrial Classification	Aerospace, pharmaceuticals, office and computing equipment, communication equipment, scientific instruments	Organisation for Economic Co-operation and Development (OECD), research and development intensity (i.e., R&D/value added)	Global Insight, Inc., proprietary special tabulations
Knowledge-intensive service industries	Industry production (revenues from services) in constant (1997) dollars	Industry by International Standard Industrial Classification	Business, financial, communication, health, education services	OECD, R&D intensity (R&D/value added)	Global Insight, Inc., proprietary special tabulations
Trade in advanced technology products	U.S. product exports and imports, in current dollars	Product by technology area, harmonized code	Biotechnology, life sciences, optoelectronics, information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons, nuclear technology, software	U.S. Census Bureau, Foreign Trade Division	U.S. Census Bureau, Foreign Trade Division, special tabulations
Patents	Number of patents for inventions, triadic patents (invention with patent granted or applied for in U.S., European Patent Office, and Japan Patent Office)	Technology class, country of origin	More than 400 U.S. patent classes, inventions classified according to technology disclosed in application	U.S. Patent and Trademark Office, OECD	U.S. Patent and Trademark Office, OECD
Venture Capital	Funds invested by U.S. venture capital funds	Technology area defined by data provider	Biotechnology, communications, computer hardware, consumer related, industrial/energy, medical/health, semiconductors, computer software, Internet specific	Thomson Financial/ National Venture Capital Association	Thomson Financial Services, special tabulations

show greater levels of domestic production (value added) in the final product than that typically performed by other manufacturing industries. (Gross value added equals gross output minus the cost of purchased intermediate inputs and supplies.) In the United States, high-technology industries reported about 30% more value added than other manufacturing industries (figure 6-3; appendix tables 6-2 and 6-3). High-technology industries also generally pay higher wages than other manufacturing industries.[6] Recognition of these contributions has led to intense competition among nations and localities to attract, nurture, and retain high-technology industries.[7]

Data on manufacturing value added that follows are presented for the United States and other advanced countries in order to better examine domestic production by manufacturing industries. Value-added data also can be important indicators of economic and technological progress in developing countries. When foreign investments and foreign corporations control major portions of a developing country's manufacturing base, data on domestic value added and its contribution to final output can indicate the extent to which those foreign corporations are transferring technological and manufacturing know-how to the host country.

During the 1980s, manufacturing output in the United States and other high-wage countries shifted resources to produce higher value-added, technology-intensive goods, often referred to as *high-technology manufactures*. In 1980,

Table 6-1
Classification of manufacturing industries based on average R&D intensity: 1991–97
(Percent)

Industry	ISIC rev. 3	R&D intensity	
		Total[a]	United States
Total manufacturing	15–37	2.5	3.1
High-technology industries			
Aircraft and spacecraft	353	14.2	14.6
Pharmaceuticals	2423	10.8	12.4
Office, accounting, and computing machinery	30	9.3	14.7
Radio, television, and communication equipment	32	8.0	8.6
Medical, precision, and optical instruments	33	7.3	7.9
Medium-high-technology industries			
Electrical machinery and apparatus NEC	31	3.9	4.1
Motor vehicles, trailers, and semi trailers	34	3.5	4.5
Chemicals excluding pharmaceuticals	24 excl. 2423	3.1	3.1
Railroad equipment and transport equipment NEC	352 + 359	2.4	na
Machinery and equipment NEC	29	1.9	1.8
Medium-low-technology industries			
Coke, refined petroleum products, and nuclear fuel	23	1.0	1.3
Rubber and plastic products	25	0.9	1.0
Other nonmetallic mineral products	26	0.9	0.8
Building and repairing of ships and boats	351	0.9	na[b]
Basic metals	27	0.8	0.4
Fabricated metal products, except machinery and equipment	28	0.6	0.7
Low-technology industries			
Manufacturing NEC and recycling	36–37	0.4	0.6
Wood, pulp, paper, paper products, printing, and publishing	20–22	0.3	0.5
Food products, beverages, and tobacco	15–16	0.3	0.3
Textiles, textile products, leather, and footwear	17–19	0.3	0.2

na = not applicable
ISIC = International Standard Industrial Classification; NEC = not elsewhere classified

[a]Aggregate R&D intensities calculated after converting R&D expenditures and production with 1995 gross domestic product purchasing power parities.
[b]R&D expenditures in shipbuilding (351) included in other transport (352 and 359).

NOTE: R&D intensity is direct R&D expenditures as percentage of production (gross output).

SOURCES: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm; and STAN database, http://www.oecd.org/document/15/0.2340,en_2649_201185_1895503_1_1_1_1,000.html (May 2001).

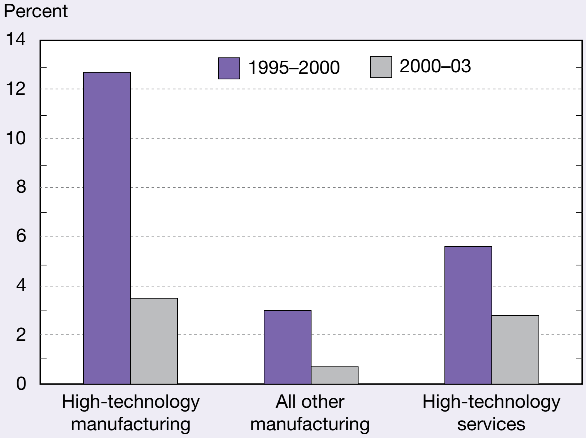
Science and Engineering Indicators 2006

high-technology manufactures accounted for about 11% of total U.S. domestic production. By 1990, this figure had increased to 13.5% and, led by demand for communication and computer equipment, exceeded 27% by 2000. By contrast, high-technology manufactures represented about 17% of total Japanese domestic production in 2000, double that in 1980 but only up about 1 percentage point from 1990. European nations[8] also saw high-technology manufactures account for a growing share of their total domestic production, although to a lesser degree. High-technology manufactures accounted for 9.5% of total EU manufacturing domestic output in 1980 and rose to 11% in 1990 and 13.2% by 2000 (figure 6-4; appendix table 6-3). The latest data, through 2003, show domestic output in high-technology industries continuing to grow faster than output in other manufacturing industries in the United States, flattening in the EU, and declining in Japan. In 2003, high-technology manufactures were estimated to be 34.2% of manufacturing domestic output in the United States, 13.4% in the EU, and 15.7% in Japan.

South Korea and Taiwan typify how R&D-intensive industries have grown in the newly industrialized economies. In 1980, high-technology manufactures accounted for 9.6% of South Korea's total domestic manufacturing output; this proportion jumped to 14.8% in 1990 and reached an estimated 21.5% in 2003. The transformation of Taiwan's manufacturing base is even more striking. High-technology manufacturing in Taiwan accounted for 9.7% of total domestic output in 1980, 15.9% in 1990, and jumped to an estimated 28.5% in 2003.

Other fast-moving economies also are converting to a focus on high technology. Directed national policies that combine government measures and corporate investments, including R&D facilities, have spurred growth in high-technology industries in Ireland, as well as in China and other Asian countries. Perhaps the clearest example, Ireland's high-technology manufacturing industries accounted for 12.4% of total domestic output in 1980, 26.4% in 1990, and for more than half its total domestic production since 1999.

Figure 6-2
Global industry sales, average annual growth rate, by sector: 1995–2003

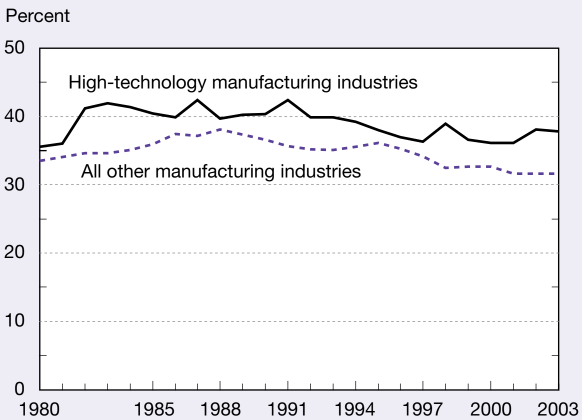


NOTE: Growth rates calculated from inflation adjusted 1997 dollars.

SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-5.

Science and Engineering Indicators 2006

Figure 6-3
Value added by U.S. industries as percentage of gross output: 1980–2003



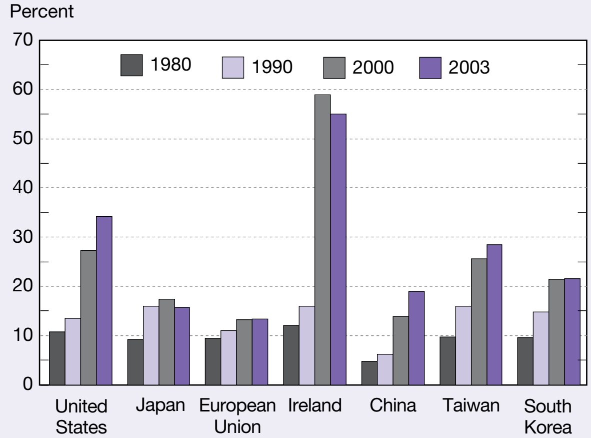
NOTE: Value added is value of final production minus value of purchased inputs used in production process.

SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-3.

Science and Engineering Indicators 2006

China's economy is also changing and, given its size, its transformation will have a large impact on the global marketplace. China's high-technology manufacturing accounted for just 4.8% of total domestic output in 1980, 6.2% in 1990, and an estimated 19.0% in 2003. However, the value of China's domestic high-technology production in 2003 is estimated to be twice that of Germany, nearly identical to production in Japan, and nearly five times that of Ireland.

Figure 6-4
High-technology value added as a share of total manufacturing value added in selected countries/regions: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

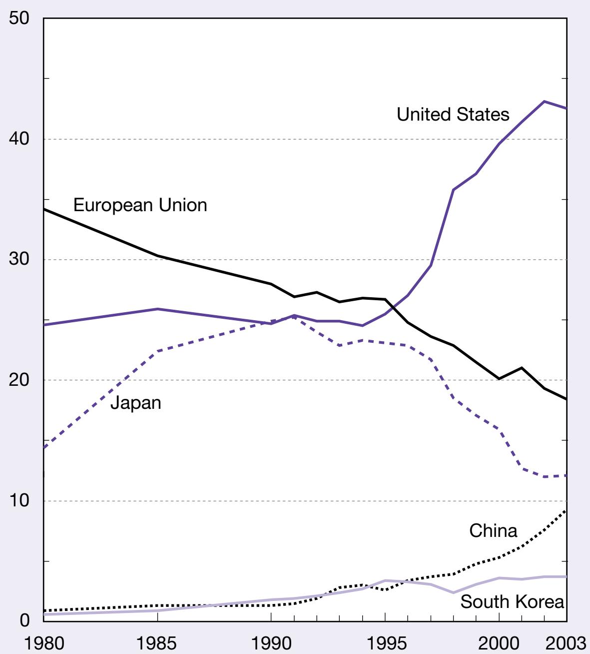
Global Market Shares

Over the 24-year period examined (1980–2003), the United States has consistently been one of the world's leading manufacturers of high-technology products. The same can be said of Japan. Although no single European country has a high-technology industry the size of the United States or Japan, the EU consistently ranks among the world's leading manufacturers of high-technology products. In fact, the EU contained the world's largest high-technology manufacturing sector from 1980 through 1995, but beginning in 1996 and for each year thereafter, U.S. high-technology manufacturers have accounted for more domestic output than the EU, Japan, or any other country.

U.S. high-technology industry value added (domestic production) accounted for about one-quarter of global production from 1980 to 1995 (figure 6-5). Its share began moving up sharply in the late 1990s, peaking in 2002 at 43.1%. Estimates for 2003 show the U.S. share dropping slightly (42.5%). Value added by Japan's high-technology industries and its share of global production peaked in the early 1990s and has trended downward each year thereafter. At its highest point in 1991, Japan's high-technology manufacturers accounted for 25.2% of global production; at its lowest point, in 2002, this fell to 12.0%. Estimates for 2003 show little change in Japan's share. Value added by the EU's high-technology manufacturing sector accounted for its largest global share at 34.2% in 1980. The EU share has fallen since then, to 28.0% in 1990, 20.1% in 2000, and an estimated 18.4% in 2003.

In Asia, high-technology manufacturing has grown dramatically over the past two decades, led first by Japan in the 1980s, then by South Korea, Taiwan, and China in the 1990s. The most recent data show that China's high-technology

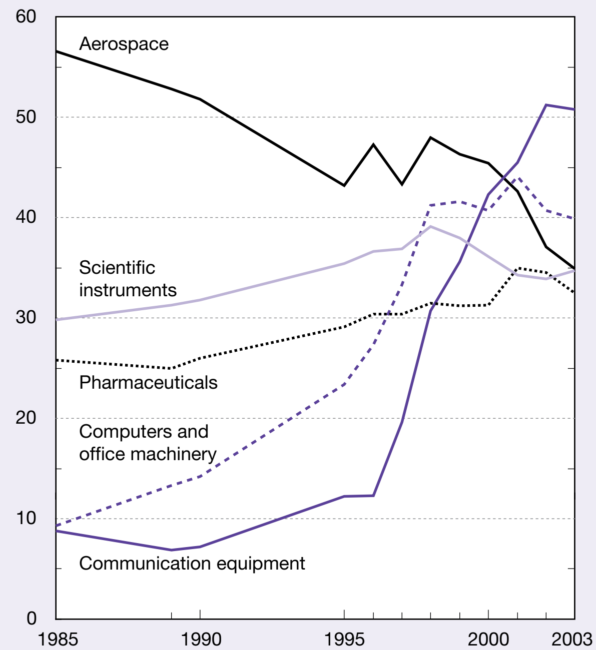
Figure 6-5
Share of global high-technology value added, by country/region: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

Figure 6-6
U.S. share of global value added, by high-technology industry: 1985–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

industries have surpassed those in South Korea and Taiwan. If these trends continue, China may soon rival Japan in size if not sophistication. Compared with Japan, however, China does not have the long record of large investments in R&D, has not produced the number of scientific articles across a broad range of technology areas, and has not been as successful patenting new inventions around the world. That may change in the near future, because China's investments in R&D are growing rapidly. (See chapter 4 for data on trends in U.S. and foreign R&D performance, chapter 5 for data on scientific article publishing trends, and the subsequent section on patenting in this chapter.) In 2003, domestic production (value added) by China's high-technology industry accounted for an estimated 9.3% of global production, whereas just 23 years earlier (in 1980), domestic production in China's high-technology industry accounted for less than 1% of world output.

Global Competitiveness of Individual Industries

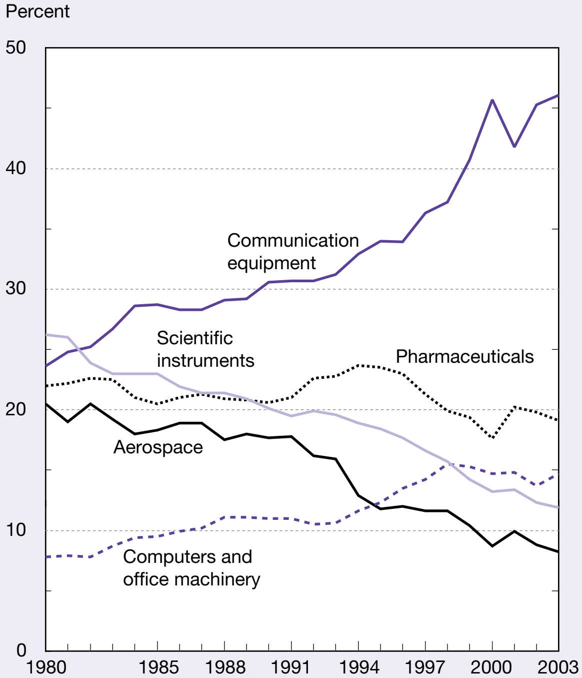
In each of the five industries that make up the high-technology group, the United States maintained strong, if not leading, positions in the global marketplace (figure 6-6). The U.S. market is large and mostly open, which benefits U.S. high-technology producers in the global market in two important ways. First, supplying a domestic market with many consumers offers scale effects for U.S. producers, resulting from potentially large rewards for new ideas and innovations. Second, the openness of the U.S. market to competing foreign-made technologies pressures U.S. producers to be more innovative to maintain domestic market share. Additionally, the U.S. government influences the size and growth of the nation's high-technology industries through investments in industrial R&D purchases of new products and through laws regulating sales to foreign entities of certain products produced by each of the five high-technology industries.[9]

Communication Equipment and Computers and Office Machinery

The global market for communication equipment is the largest of the high-technology markets, accounting for nearly half of global sales by all five high-technology industries (figure 6-7).[10] The market for computers and office machinery is a distant second, accounting for about 19% of global sales by the five high-technology industries. In these two industries, U.S. manufacturers reversed downward trends evident during the 1980s to grow and gain market share in the mid- to late 1990s, due in part to increased capital investment by U.S. businesses (see sidebar, "U.S. IT Investment").

From 1980 through 1997, Japan was the world's leading supplier of communication equipment, exceeding output in the United States and the EU. In 1998, however, U.S. manufacturers once again became the leading producers of

Figure 6-7
Global high-technology value added, by industry share: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-3.

Science and Engineering Indicators 2006

communication equipment in the world and have since retained that position. In 2003, the latest year for which data are available, the United States accounted for approximately 50.8% of world production of communication equipment, compared with Japan at 16.0% and the EU at 9.4%.

Since 1997, the United States has been the leading manufacturer of office and computer machinery, overtaking longtime leader Japan. EU countries, led by Germany and the United Kingdom, were also major producers.

In 2001, China replaced Japan as Asia's largest producer of office and computer machinery. This gap has been widening. In 2003, domestic production by U.S. high-technology manufacturers accounted for an estimated 39.9% of global production; China's industry is estimated to account for 26.4% of global production, and the EU's industry is estimated to account for 9.0%.

Aerospace

The U.S. aerospace industry has long maintained a leading if not dominant position in the global marketplace. The U.S. government is a major customer for the U.S. aerospace industry, contracting for military aircraft and missiles and for spacecraft. Since 1989, production for the U.S. government has accounted for approximately 40%–60% of total annual sales (AIA 2005). The U.S. aerospace industry position in the global marketplace is enhanced by this longstanding, customer-supplier relationship.

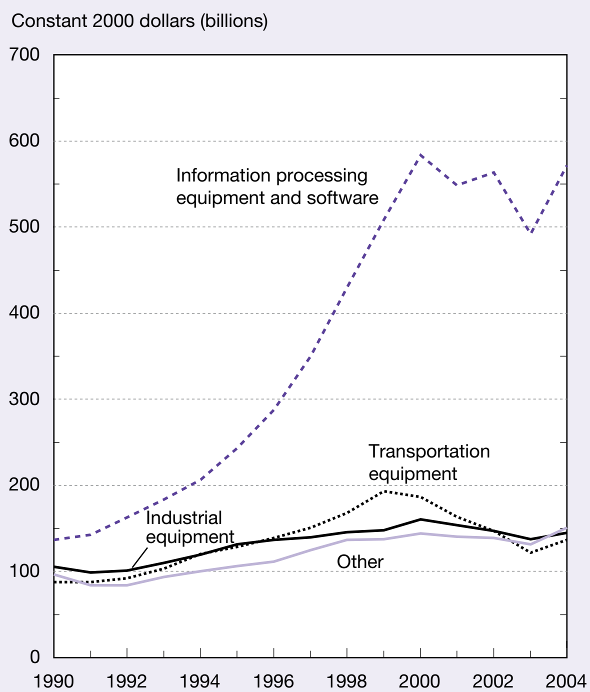
U.S. IT Investment

Information technology (IT) was a major contributor to innovation and productivity gains during the 1990s. In addition to technical changes within the IT field, companies used IT to transform how their products performed and how their services were delivered. IT applications also improved the flow of information within and among organizations, which led to productivity gains and production efficiencies.

From 1990 through 2004, U.S. industry purchases of IT equipment and software exceeded industry spending on all other types of capital equipment (figure 6-8). At its peak in 2000, U.S. industry spending on IT was more than three times the amount that all industries spent on industrial equipment and exceeded combined industry spending on industrial, transportation, and all other equipment.

Despite the bursting of the dot.com bubble beginning in the spring of 2000 and the economic downturn that began in March 2001, U.S. companies continued to place a high value on investments in IT. Industry spending on IT equipment and software accounted for 38% of all nonresidential investment (including structures and equipment) by industries in 2000, about 41% in 2002, and about 47% in 2004.

Figure 6-8
Industry spending on capital equipment: 1990–2004



SOURCE: U.S. Bureau of Economic Analysis, http://www.bea.doc.gov/bea/dn/nipaweb/

Science and Engineering Indicators 2006

In recent years however, the aerospace industry's manufacturing share has fallen more than any other U.S. industry. Since peaking at 57% of global production in 1985, U.S. aerospace domestic production fell to 43% of global production by 1995. The U.S. share increased slightly during the late 1990s, then proceeded to fall each year thereafter. In 2003, the U.S. share of global aerospace production is estimated to have fallen to about 35%. European aerospace manufacturers, particularly within France and Germany, made gains during this time. By 2003, the EU accounted for 29% of world aerospace production, up from 25% in 1985 and 26% in 1995.

China's aerospace industry began to grow very rapidly in the early 1990s, quickly overtaking Japan by the mid-1990s to become the largest producer of aerospace products in Asia. In 1980, China's aerospace industry output accounted for less than 1% of world output; by 1995, its market share had risen to 3%. A succession of year-to-year gains from 1995 through 2000 followed, eventually lifting China's market share to nearly 7%. Production in China's aerospace industry is estimated at about 10% of world production in 2003. In Latin America, Brazil exhibited a very different trend, falling from about 18% of world aerospace production in 1980 to about 15% in 1995 and an estimated 10% in 2003.

Pharmaceuticals

The EU and the United States were the leading producers of drugs and medicines in the world market for the entire 24-year period examined, together accounting for about two-thirds of global production in 2002 and 2003. As a result of differing national laws governing the distribution of foreign pharmaceuticals, domestic population dynamics play a more important role than global market forces and affect the overall demand for a country's pharmaceutical products. In Asia, Japan and China are the largest producers of drugs and medicines. Although Japan has the larger domestic industry, China's share has grown steadily while Japan's has generally declined. In 1990, domestic production by Japan's industry accounted for nearly 19% of global production, but this proportion gradually fell to 11% by 2003. In 2003, China's pharmaceutical industry is estimated to account for 6% of global production, up from about 1% in 1990.

Scientific Instruments

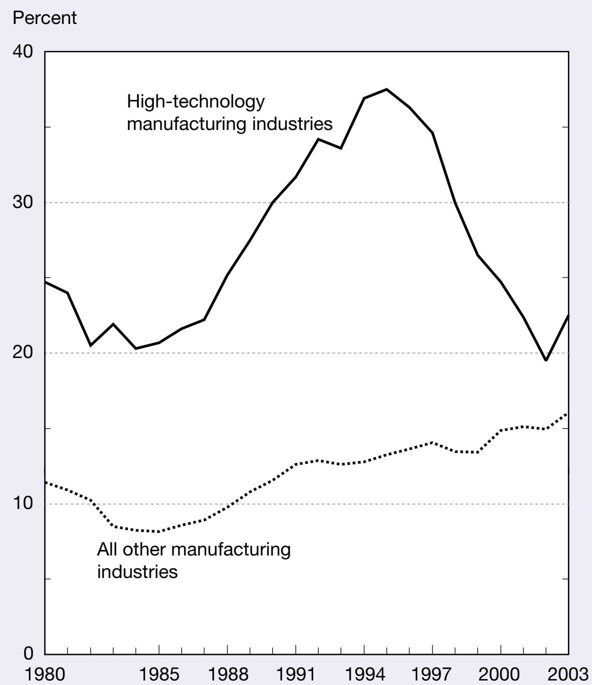
In 2001, the industry that produces scientific instruments (medical, precision, and optical instruments) was added to the group of high-technology industries, reflecting that industry's high level of R&D in advanced nations (table 6-1). From 1980 through 2003, the EU and the United States were the leading producers of scientific instruments. Since 2001, the EU, led by Germany and France, has been the world's largest manufacturer of scientific instruments, accounting for an estimated 37.5% of global production in 2003. This share has risen irregularly since the late 1990s. In 2003, the United States accounted for 35% of global production, down slightly from the 36%–39% share held during the late 1990s.

In Asia, Japan and China are the largest producers, and once again, Japan's share of global production is declining while China's is increasing. In 1990, Japan's industry producing scientific instruments accounted for about 15% of world production; however, this declined to about 10% in 2000 and is estimated to have fallen to about 8% in 2003. China's industry, which accounted for less than 1% of global production in 1990, rose to 2% in 2000 and is estimated to account for slightly more than 3% in 2003.

Exports by High-Technology Industries

Although U.S. producers benefit from having the world's largest home market as measured by gross domestic product (GDP), mounting U.S. trade deficits highlight the need to serve foreign markets as well. (See figure 6-1 for comparisons of country GDPs.) Traditionally, U.S. high-technology industries have been more successful exporting their products than other U.S. industries; therefore, these industries can play a key role in restoring the United States to a more balanced trade position.[11] Although U.S. high-technology industries continue to export a larger proportion of their total shipments than other U.S. manufacturing industries, that advantage has narrowed considerably (figure 6-9).[12]

Figure 6-9
U.S. exports as percentage of sector output: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix tables 6-2 and 6-4.

Science and Engineering Indicators 2006

Foreign Markets

In addition to serving its large domestic market, the United States was an important supplier of manufactured products to foreign markets from 1980 to 2003. Throughout the 1990s and continuing through 2003, U.S. industry supplied 12%–14% of the world's general manufacturing exports (appendix table 6-4).[13] In 2003, the United States ranked second only to the EU in its share of world exports, and if intra-EU shipments were excluded, would likely rank above the EU. Japan accounted for 8%–10% of world exports during this same period.

Exports by U.S. high-technology industries grew rapidly during the mid-1990s, contributing to the nation's strong export performance (figure 6-10). During the 1990s, U.S. high-technology industries accounted for 19%–23% of world high-technology exports, at times nearly twice the level achieved by all other U.S. manufacturing industries. However, by 2003, the latest year for which data are available, exports by U.S. high-technology industries had fallen to about 16% of world high-technology exports, whereas Japan accounted for about 9% and Germany nearly 8%.

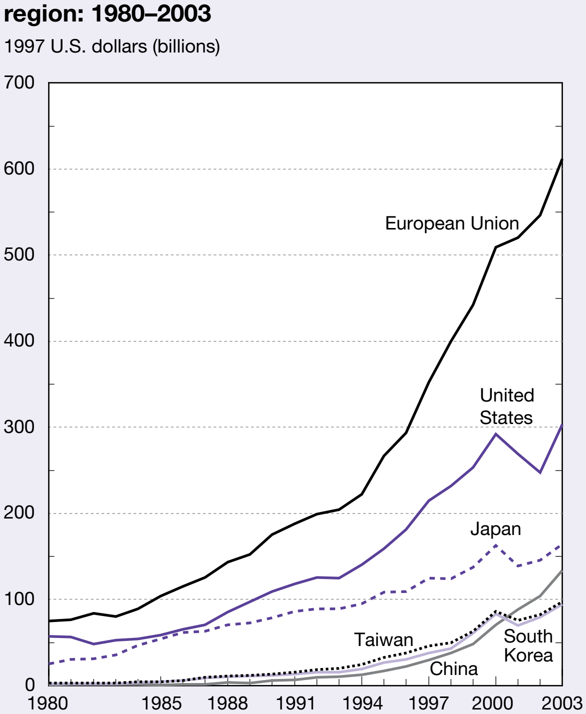
The gradual drop in the U.S. share during 1990–2003 was partly due to competition from emerging high-technology industries in newly industrialized and industrializing economies, especially in Asia. China stands out, with its share of global high-technology industry exports reaching 7% in 2003, up from just 1% in 1990. High-technology industries in South Korea and Taiwan each accounted for about 2.5% of world high-technology exports in 1990; 2003 data show that each economy's share nearly doubled. Singapore's share, which was 3.6% in 1990 and 5.7% in 2003, is also noteworthy, especially in light of its relatively small economy.

Industry Comparisons

Over the past two decades, U.S. high-technology industries were large and active exporters in each of the five industries that make up the high-technology group. The United States was the export leader in four of the five high-technology industries in 2003 (figure 6-11). However, U.S. aerospace, computers and office machinery, communication equipment, and scientific instruments industries recorded successively smaller shares of world exports in 2003 compared with earlier years (table 6-2).

Communication equipment and computers and office machinery. The export market for communication equipment is the largest of the high-technology industry group, accounting for more than 42% of total exports by all five high-technology industries in 2002 and 2003 (figure 6-12). The export market for computers and office machinery ranks second at about 32% of exports by the five high-technology industries. U.S. shares of exports in both industries have trended downward for most of the period examined (1980–2003),

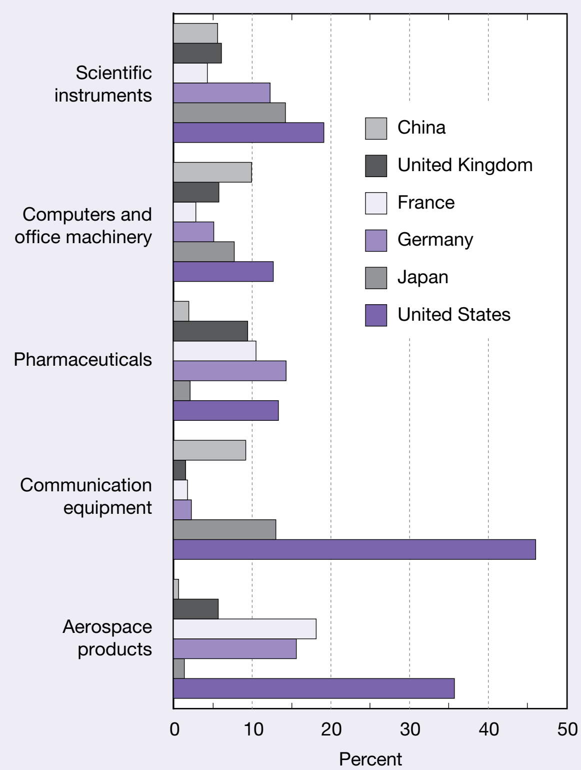
Figure 6-10
High-technology exports, by selected country/region: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

Figure 6-11
High-technology industry exports, by selected countries: 2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

Table 6-2
Share of global high-technology industry exports, by country/region: 1990, 2000, and 2003
(Percent)

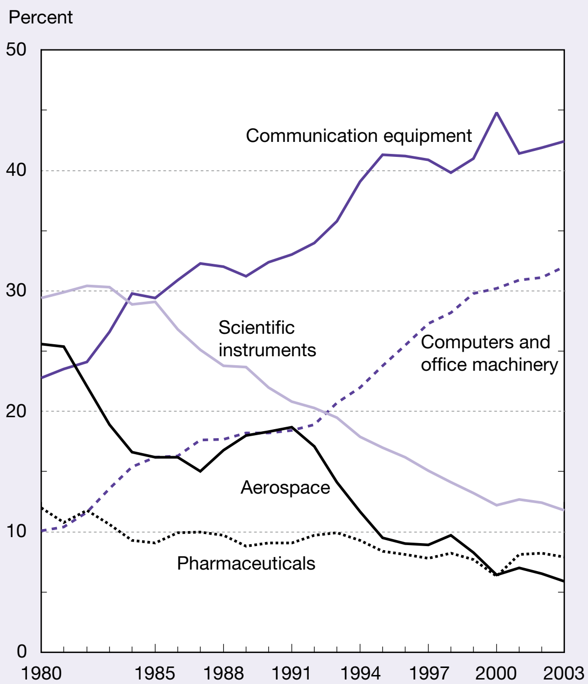
Industry	United States			EU			Japan			Germany			China		
	1990	2000	2003	1990	2000	2003	1990	2000	2003	1990	2000	2003	1990	2000	2003
Top five total	23.0	17.8	16.0	37.0	31.1	32.2	16.6	10.0	8.6	9.7	6.8	7.6	1.3	4.3	7.0
Aerospace	46.1	39.2	35.7	44.4	44.0	45.7	0.7	1.3	1.4	10.3	14.1	15.6	0.0	0.6	0.6
Communication equipment	16.5	16.2	15.2	24.9	25.2	25.4	25.9	11.5	10.0	6.6	5.2	5.9	1.9	4.3	7.1
Pharmaceuticals	10.8	13.6	13.3	64.6	64.8	66.0	2.8	2.4	2.1	15.8	12.6	14.3	2.4	1.8	1.9
Computers/office machinery	21.8	15.1	12.7	33.5	28.4	28.5	19.2	8.8	7.7	6.5	4.7	5.1	0.3	5.6	9.9
Scientific instruments	19.5	21.5	19.1	40.1	35.3	37.3	19.6	15.7	14.2	13.7	11.2	12.3	1.7	4.5	5.6

EU = European Union-15 excluding Luxembourg

SOURCE: Global Insight, Inc. See appendix table 6-4.

Science and Engineering Indicators 2006

Figure 6-12
Global high-technology exports, by industry share: 1980–2003



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-4.

Science and Engineering Indicators 2006

although an upturn is estimated for the latest year, 2003. U.S. exports of computers and office machinery represented 29% of world exports in 1980, 22% in 1990, 11% in 2002, and 13% in 2003. The market share for U.S. manufacturers of communication equipment fluctuated within the much narrower range of 14%–18%, reaching highs during the early 1980s and again during the mid-1990s before falling to a low of 14% in 2002. Estimates for 2003 show the U.S. share rising to about 15%.

On the other hand, EU industries are the leading exporters, accounting for about 25% of world communication equipment exports and 28%–34% of world computers and office machinery exports from 1990 through 2003 (table 6-2). In 2003, Germany, the United Kingdom, and France were the leading European exporters of communication equipment, and the Netherlands, the United Kingdom, and Germany led Europe in exports of computers and office machinery.

In Asia, exports from industries located in Japan, China, South Korea, Singapore, Taiwan, and Malaysia together account for a larger share of exports than the EU. China (including Hong Kong) is the leading Asian exporter in these two industries.

Aerospace. U.S. exports of aerospace technologies accounted for 54% of world aerospace exports in 1980, 46% in 1990, and 36% in 2003 (table 6-2). U.S. aerospace products lost out primarily to the EU's aerospace industry, whose shares of world exports increased from 36% in 1980 to 44% in 1990 and to 46% in 2003.

By comparison, aerospace industries within Asia apparently are building mostly for their domestic markets and have supplanted U.S. aerospace exports to the region.[14] In 2003, aerospace industry exports from Japan accounted for 1.4% of global exports, and exports from industries in China, South Korea, and Singapore accounted for about 0.5%. Aerospace industries in Canada and Brazil supplied larger shares of global exports than those in Asia during the 24-year period examined.

Pharmaceuticals. As noted previously, national laws governing the distribution of pharmaceuticals produced in other countries differ widely among countries, consequently affecting comparisons among countries and comparisons with other high-technology industries. Generally, each country's share of industry exports fluctuated within a fairly narrow range during the past 24 years.

The U.S. pharmaceutical industry's share of world industry exports fluctuated 10%–14% during the 1990s and held steady at about 13% from 2000 to 2003 (table 6-2). Among the EU countries, Germany is the leading exporter with an export share of 14%–16% during the 1990s, settling in at about 14% between 2001 and 2003. France and the United Kingdom are also key exporters, together accounting for 9%–11% of world industry exports from 1990 to 2003. In Asia, Japan and China are the largest producers of drugs and medicines, each accounting for about 2%–3% of world industry exports during the period 1990–2003. Industries in India and Singapore account for about 1% of world exports.

Scientific instruments. In 2001, the industry that produces scientific instruments (medical, precision, and optical instruments) was added to the group of high-technology industries, reflecting the industry's high level of R&D in advanced nations (table 6-1). From 1990 through 2003, the U.S. industry share of world exports changed only slightly: from 20% in 1990 to 21.5% in 2000 and 19% in 2003. Germany is the largest exporter among the EU countries; its share of world industry exports fluctuated 11%–14% during 1990–2003. The United Kingdom, France, and the Netherlands were the other large European exporters of scientific instruments.

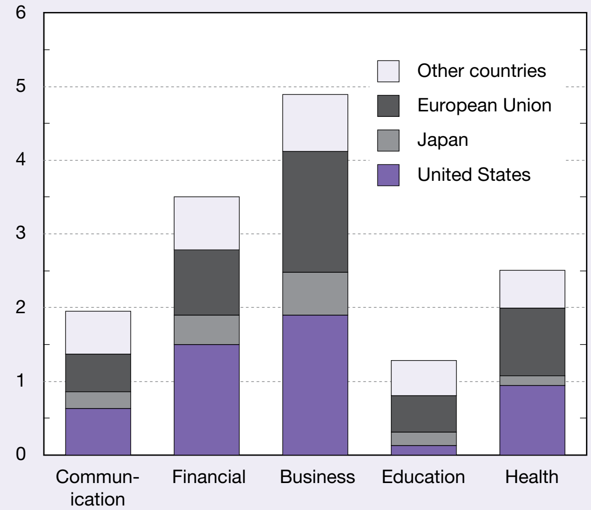
In Asia, Japan and China are the largest producers, and once again, Japan's share of world industry exports is declining while China's is increasing. In 1990, Japan's industry producing scientific instruments accounted for about 20% of world industry exports, but its share fell to less than 16% in 2000 and is estimated to be about 14% in 2003. China's industry accounted for less than 8% of world industry exports in 1990 but rose to 10% in 2000 and is estimated to account for slightly more than 11% in 2003.

Global Business in Knowledge-Intensive Service Industries

For several decades, revenues generated by U.S. service-sector industries grew faster than those generated by the nation's manufacturing industries. Data collected by the U.S. Department of Commerce show that the service sector's share of U.S. GDP grew from 49% in 1959 to 64% in 1997 (National Science Board 2002). This growth has been fueled largely by *knowledge-intensive* industries, i.e., those that incorporate science, engineering, and technology in either their services or the delivery of their services.[15] Five knowledge-intensive industries, as classified by the OECD, are communication services, financial services, business services (including computer software development), education services, and health services. This section presents data tracking the overall revenues earned by these industries in 70 countries[16] (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

Combined global sales in knowledge-intensive service industries exceeded $14.1 trillion in 2003 and have risen every year during the 24-year period examined. The United States is the leading provider of high-technology services, responsible for slightly more than one-third of total world service revenues during the period 1980–2003 (figure 6-13; appendix table 6-5).

Figure 6-13
Global revenues generated by five knowledge-intensive service industries: 2003
1997 U.S. dollars (trillions)



SOURCE: Global Insight, Inc., World Industry Service database (2005). See appendix table 6-5.

Science and Engineering Indicators 2006

Business Services

Business services, which include computer and data processing and research and engineering services, is the largest of the five service-sector industries and accounted for 34% of global high-technology service revenues in 2003. Business-service industries in the United States and the EU are the most prominent in the global marketplace and are close in size. Business services in these two economies account for more than 70% of business services provided worldwide; the U.S. share was 38% in 2003 and the EU share was 34%. Japan ranks a distant third at about 12%. Data on country activity in individual business services are not available.

Financial Services and Communication Services

Financial services and communication services each accounted for about 25% of global revenues generated by high-technology service industries in 2003. Forty-three percent of world revenues for financial services in 2003 went to the U.S. financial services industry, the world's largest. The EU was second, earning approximately 25%, followed by Japan at nearly 11%. Communication services, which include telecommunication and broadcast services, could be considered the most technology-driven of the service industries. In this industry, U.S. firms again hold a lead position. In 2003, U.S. firms generated revenues equal to 32% of world revenues. The EU accounted for 26%, and Japan accounted for nearly 12%.

Health Services and Education Services

Many nations' governments serve as the primary provider of the remaining two knowledge-intensive service industries, health services and education services. The size and distribution of each country's population profoundly affect delivery of these services. For these reasons, global comparisons based on market-generated revenues are less meaningful for health services and education services than for other service industries.

The United States, with arguably the least government involvement, has the largest health-service industry in the world, although the EU's health-service industry comes quite close. In 2003, the U.S. health-service industry accounted for 38% of world revenues, while the EU share was 37%. Again, Japan's industry is a distant third.

Education services, the smallest of the five knowledge-intensive service industries in terms of revenue generated, includes governmental and private educational institutions of all types that offer primary, secondary, and university education, as well as technical, vocational, and commercial schools. In 2003, fees (tuition) and income from education service-related operations accounted for about 9% of revenues generated by all five knowledge-intensive service industries and about one-fourth of the revenues generated by the business-service industry worldwide. Europe's education service industry generated the most revenues by far (39% of worldwide industry revenues), with Japan second (14%), and the United States third (10%).

U.S. Trade Balance in Technology Products

The methodology used to identify high-technology industries relies on a comparison of R&D intensities. R&D intensity is typically determined by comparing industry R&D expenditures or the number of technical people employed (e.g., scientists, engineers, and technicians) with industry value added or the total value of shipments (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter). Classification systems based on industry R&D intensity tend to overstate the level of high-technology exports by including all products shipped overseas by those high-technology industries, regardless of the level of technology embodied in each product, and by the somewhat subjective process of assigning products to specific industries.

In contrast, the U.S. Census Bureau has developed a classification system for exports and imports that embody new or leading-edge technologies. The system allows a more highly disaggregated, better-focused examination of embodied technologies and categorizes trade into 10 major technology areas:

- **Biotechnology—**the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Life science technologies—**the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing techniques, have led to new products that help control or eradicate disease.
- **Optoelectronics—**the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Information and communications—**the development of products that process increasing amounts of information in shorter periods of time, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Electronics—**the development of electronic components (other than optoelectronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that improve performance and capacity and, in many cases, reduce product size.
- **Flexible manufacturing—**the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Advanced materials—**the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace—**the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (communication satellites excepted), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Weapons—**the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.
- **Nuclear technology—**the development of nuclear production apparatus (other than nuclear medical equipment), including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life sciences rather than this category).

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value. In this report, computer software is examined separately, creating an 11th technology area. In official statistics, computer software is included in the information and communications technology area (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

Importance of Advanced Technology Products to U.S. Trade

During much of the 1990s, U.S. trade in advanced technology products grew in importance as it accounted for larger and larger shares of overall U.S. trade (exports plus imports) in merchandise and produced consistent trade surpluses for the United States. Beginning in 2000 and coinciding with the dot.com meltdown, the trade balance for U.S. technology products began to erode.[17] In 2002, U.S. imports of advanced technology products exceeded exports, resulting in the first U.S. trade deficit in this market segment in history. The trade deficit has grown each year since then (figure 6-14; appendix table 6-6). In 2002, the U.S. trade deficit in advanced technology products was $15.5 billion; it increased to $25.4 billion in 2003 and $37.0 billion in 2004. The imbalance of U.S. trade with Asia (imports exceeding exports), especially with China, Malaysia, and South Korea, overwhelms U.S. surpluses and relatively balanced trade with other parts of the world.

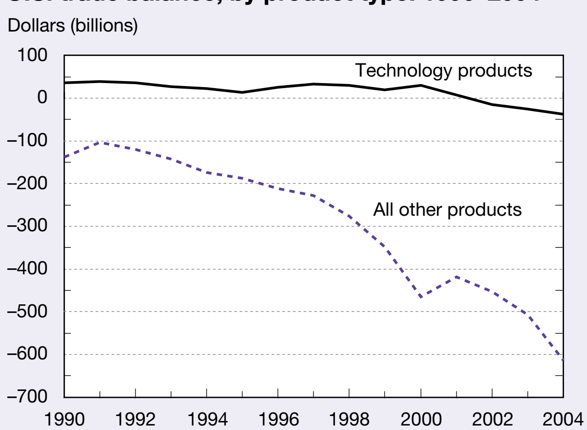
Technologies Generating a Trade Surplus

Throughout most of the 1990s, U.S. exports of advanced technology products generally exceeded imports in 9 of the 11 technology areas.[18] Trade in aerospace products consistently produced the largest surpluses for the United States during this time.

Since 2000, the number of technology areas in which U.S. exports of advanced technology products generally exceeded imports has slipped from nine showing a trade surplus during the 1990s to five or six areas in 2003 (table 6-3). Aerospace products continue to produce the largest surpluses. Surpluses in aerospace trade began to narrow in the mid-1990s as competition from Europe's Airbus Industrie challenged U.S. companies' preeminence at home and in foreign markets. U.S. aerospace exports and imports both declined in 2002 and 2003 and both increased in 2004. In 2004, U.S. trade in aerospace products generated a net inflow of $30.5 billion, creating a surplus 14.6% higher than the 2003 surplus.

U.S. trade classified as electronics products (e.g., electronic components including integrated circuits, circuit boards, capacitors, and resistors) is the only other technology area that has generated large surpluses in recent years. However, unlike the U.S. trade surplus in aerospace products where exports increased between 2000 and 2004, the larger surplus in this technology area resulted mainly from a greater drop in U.S. imports than exports. In 2001, U.S. trade in electronics products generated a net inflow of $14.5 billion and increased to $16.1 billion in 2002, before rising to more than $21 billion in both 2003 and 2004. Trade activity in biotechnologies, flexible manufacturing products (e.g., industrial automation products, robotics), and weapon technologies generated small surpluses over the past few years.

Figure 6-14
U.S. trade balance, by product type: 1990–2004



NOTES: Technology products from special tabulations. All other product trade calculated from data on total product trade.

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (2004); and data on total product trade, http://www.fedstats.gov. Accessed February 2005.

Science and Engineering Indicators 2006

Technologies Generating a Trade Deficit

Throughout most of the 1990s, trade deficits were recorded in just 2 of the 11 technology areas: information and communications and optoelectronics. Rapidly rising imports of life science technologies during the late 1990s produced the first U.S. trade deficit in that third technology area in 1999. Since 2000, U.S. imports have exceeded exports in 5 of the 11 technology areas, although the largest trade deficits continue to be in the information and communications technology area (table 6-3). In 2004, U.S. trade in information and communications resulted in a net outflow of $73.3 billion; in life science technologies, the net outflow was $18.3 billion; and in optoelectronics, it was $4.3 billion. Small deficits of about $0.65 billion resulted from trade in both nuclear technologies and advanced materials.

Top Customers by Technology Area

Asia, Europe, and North America together purchase nearly 90% of all U.S. exports of advanced technology products. Asia is the destination for about 40%, Europe about 30%, and Canada and Mexico together about 18% (appendix table 6-6).

Canada, Japan, and Mexico are the largest country customers across a broad range of U.S. technology products, with Canada accounting for about 10% of all U.S. exports of advanced technology products in 2003 and 2004, Japan for about 9%, and Mexico about 8%. In 2004, Canada ranked among the top three customers in 5 of 11 technology areas, Japan in 9, and Mexico in 4 (figure 6-15).

Asia is a major export market for the United States. In addition to the broad array of technology products sold to Japan, the latest data show Taiwan among the top three customers in optoelectronics, flexible manufacturing, and nuclear technologies, while China is among the top three customers in electronics and advanced materials, and South

Table 6-3
U.S. trade in advanced-technology products: 2000–04
(Millions of U.S. dollars)

Category	2000	2001	2002	2003	2004
Exports					
All technologies	225,415.3	202,107.8	180,629.3	181,789.5	201,454.0
Biotechnologies	1,728.8	1,615.0	2,130.5	2,862.8	3,743.2
Life sciences	11,950.6	12,839.6	11,858.6	13,002.0	14,515.9
Optoelectronics	4,113.0	3,402.7	2,430.6	2,467.0	3,506.4
Information and communications	76,250.4	65,260.4	53,309.3	53,127.8	59,210.1
Electronics	56,884.0	45,358.4	42,762.8	46,597.2	48,564.4
Flexible manufacturing	14,295.1	9,451.4	8,562.5	8,319.6	13,044.3
Advanced materials	2,651.2	2,309.6	1,088.9	1,036.5	
Aerospace	52,747.5	56,916.7	53,255.2	49,432.9	54,377.3
Weapons	1,528.8	1,522.7	1,557.7	1,451.8	1,852.1
Nuclear technology	1,266.0	1,430.3	1,671.2	1,488.9	1,503.1
Computer software	118.4	80.0	1,310.9	1,628.1	1,807.6
Imports					
All technologies	195,660.30	195,265.20	196,100.10	207,196.20	238,478.30
Biotechnologies	1,136.00	1,294.40	1,871.90	2,183.90	1,967.40
Life sciences	16,210.50	20,113.00	25,950.30	30,936.90	32,799.00
Optoelectronics	5,822.90	5,607.50	5,436.60	5,254.90	7,795.00
Information and communications	91,864.70	95,158.60	100,765.90	110,088.50	132,539.00
Electronics	41,651.50	30,882.60	26,649.50	25,135.20	27,454.00
Flexible manufacturing	8,684.90	7,473.40	6,562.20	6,262.80	7,587.20
Advanced materials	2,707.40	2,435.90	1,484.90	1,510.50	1,794.40
Aerospace	25,733.10	30,511.00	25,212.90	22,773.10	23,832.80
Weapons	413.2	383.1	407	461.4	539.7
Nuclear technology	1,436.10	1,405.70	1,758.90	2,589.00	2,169.90
Computer software	826	723.6	780.8	955.2	1,053.90
Balance					
All technologies	29,755.00	6,842.50	–15,470.8	–25,406.7	–37,024.3
Biotechnologies	592.8	320.6	258.6	678.9	1,775.80
Life sciences	–4,259.9	–7,273.4	–14,091.7	–17,934.8	–18,283.1
Optoelectronics	–1,710.0	–2,204.8	–3,006.1	–2,787.9	–4,288.6
Information and communications	–15,614.3	–29,898.2	–47,456.6	–56,960.7	–73,328.9
Electronics	15,232.50	14,475.80	16,113.40	21,462.00	21,110.40
Flexible manufacturing	5,610.20	1,978.00	2,000.30	2,056.90	5,457.10
Advanced materials	–56.2	–126.3	–396.0	–474.0	–657.2
Aerospace	27,014.40	26,405.70	28,042.30	26,659.80	30,544.50
Weapons	1,115.60	1,139.60	1,150.70	990.3	1,312.50
Nuclear technology	–170.1	24.6	–87.7	–1,100.1	–666.7
Computer software	–707.6	–643.6	530.1	672.9	753.7

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (2005).

Science and Engineering Indicators 2006

Korea is among the top three in nuclear technologies and flexible manufacturing.

European countries are also important consumers of U.S. technology products, particularly Germany, the United Kingdom, France, and the Netherlands. The European market is particularly important in two technology areas: biotechnology and aerospace. The Netherlands and Belgium are the top customers for U.S. biotechnology products, together consuming more than half of all U.S. exports within this technology area. France is the leading consumer of U.S. aerospace technology products (11% of U.S. exports in this technology area) and the United Kingdom is third (nearly 9%).

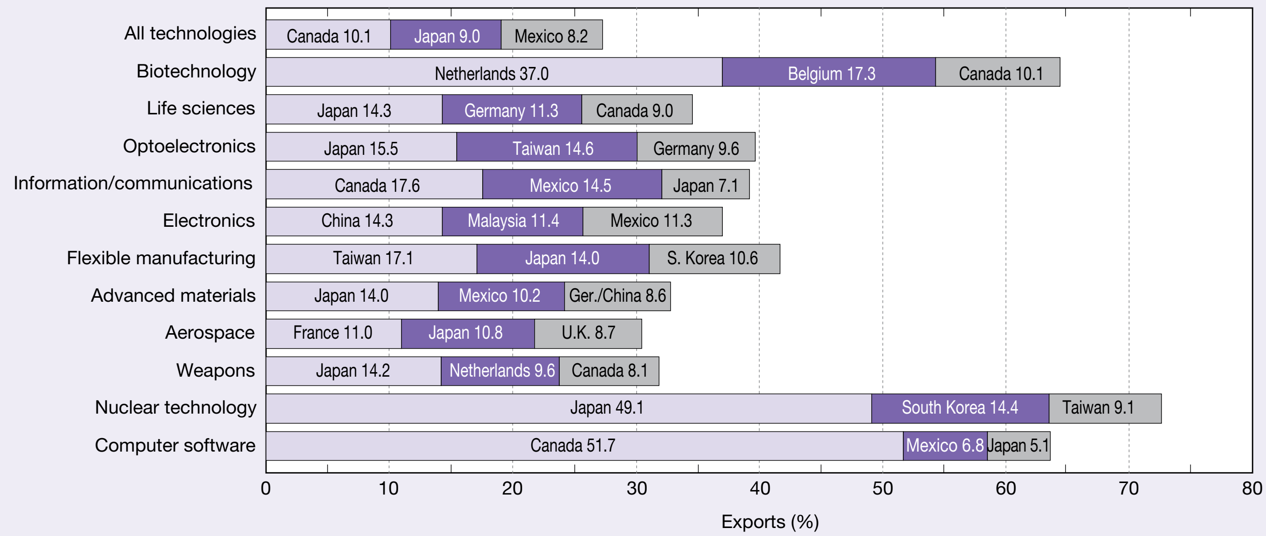
Top Suppliers by Technology Area

The United States is not only an important exporter of technologies to the world but also is a major consumer of imported technologies. The leading economies in Asia, Europe, and North America are important suppliers to the U.S. market in each of the 11 technology areas examined. Together, they supply about 95% of all U.S. imports of advanced technology products. In 2004, Asia supplied almost 60%, Europe about 20%, and North America about 15%.

China is by far the largest supplier of technology products to the United States, as the source for almost 20% of U.S. imports in 2004 (appendix table 6-6). Japan is a distant second, as the source for 10% of U.S. technology imports in 2004. Malaysia, South Korea, and Taiwan are other major Asian suppliers. In the electronics technology area, the top three suppliers are all in Asia (figure 6-16).

Among the European countries, Germany, the United Kingdom, and France are major suppliers of technology products to the United States. Many smaller European countries have also become important sources for technology products, although they tend to specialize more. Ireland was the top supplier of biotechnology and life science products to the United States in 2004, as the source for 24% and 36% of U.S. imports in these categories. Hungary supplied 14% of U.S. biotechnology imports, and the Netherlands supplied nearly 8% of U.S. flexible manufacturing technology imports in 2004.

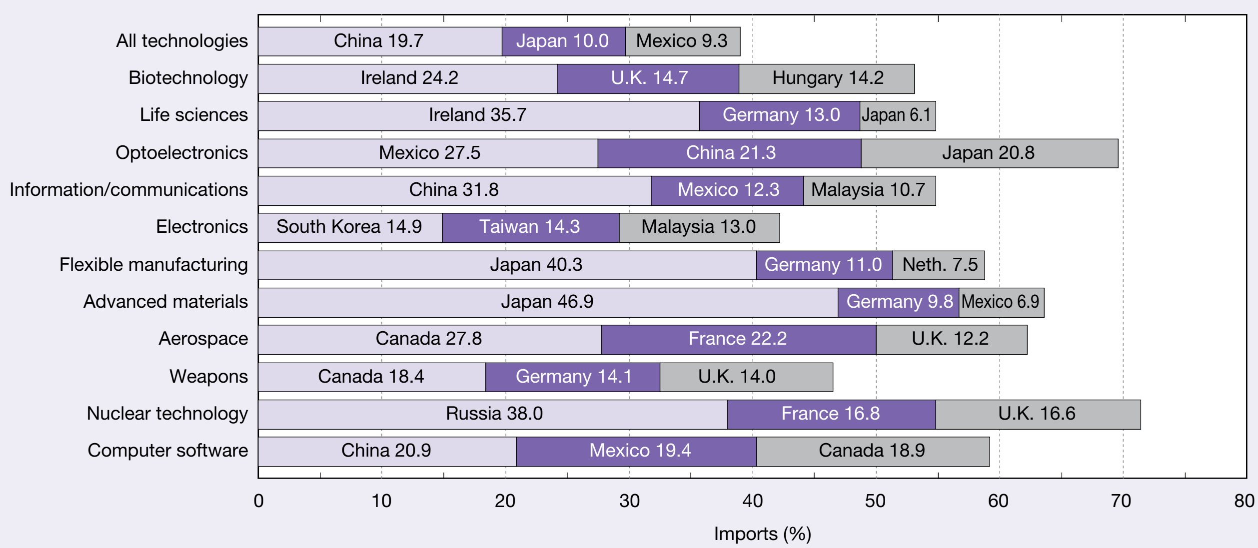
Figure 6-15
Three largest export markets for U.S. technology products: 2004



SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations.

Science and Engineering Indicators 2006

Figure 6-16
Top three foreign suppliers of technology products to United States: 2004



SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations.

Science and Engineering Indicators 2006

U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large surplus when trading intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. Trade in intellectual property can involve patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary rights; broadcast rights and other intangible rights; and the rights to distribute, use, and reproduce general-use computer software. These transactions generate revenues in the form of royalties and licensing fees.[19]

U.S. Royalties and Fees From All Transactions

In 2001, U.S. receipts from trade in intellectual property declined for the first time, interrupting a steady succession of year-to-year increases dating back to 1982.[20] New data for 2002 and 2003, however, show a resumption of the prior growth pattern. U.S. receipts grew by 8.7% in 2002 and by nearly 9.2% in 2003. In 2003, U.S. receipts totaled $48.3 billion (figure 6-17; appendix table 6-7).

In contrast to the country's merchandise trade, U.S. receipts for transactions involving intellectual property generally were four to five times greater than U.S. payments to foreign firms. During the late 1990s, however, this gap began to narrow as U.S. payments increased faster than receipts. The ratio of receipts to payments shrunk to about 3:1 by 1999 and nearly 2:1 by 2002.

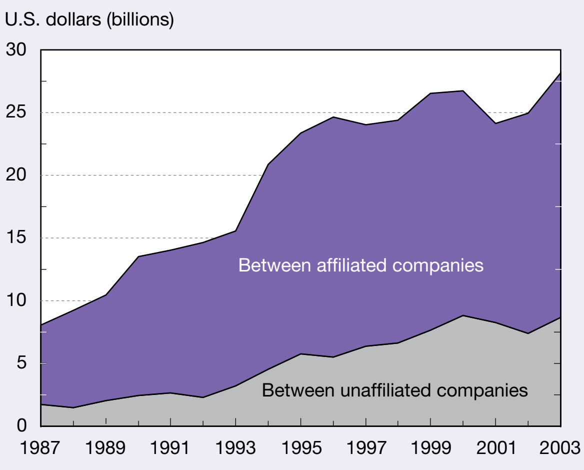
In 2003, U.S. trade in intellectual property produced a surplus of $28.2 billion, up about 5% from the $25.0 billion surplus recorded a year earlier. About 75% of transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[21] Exchanges of intellectual property among affiliates grew at about the same pace as those among unaffiliated firms. These trends suggest both a growing internationalization of U.S. business and a growing reliance on intellectual property developed overseas.[22]

U.S. Royalties and Fees From Trade in Manufacturing Know-How

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in manufacturing know-how. Trade in manufacturing know-how described here tracks U.S. trade in industrial processes used in the production of goods. Tracking data on transactions between unaffiliated firms in which prices are set through market-based negotiation may better reflect the value of manufacturing know-how at a given time than tracking data on exchanges among affiliated firms. When receipts (sales of manufacturing know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. Tracking the record of receipts and payments also provides an indicator of trends in the production and diffusion of manufacturing knowledge.

The United States is a net exporter of manufacturing know-how sold as intellectual property (figure 6-18; appendix table 6-8). The gap between imports and exports narrowed during the late 1990s and has remained somewhat erratic. The most recent data show a trade surplus of $2.6 billion in 2003, which is 28% higher than 2002 and the second highest surplus on record, after the peak $3.0 billion surplus recorded in 2000. U.S. receipts totaled to $4.8 billion in 2003, an increase of 19% over the previous year and the first increase in 2 years. A large part of this increase is due

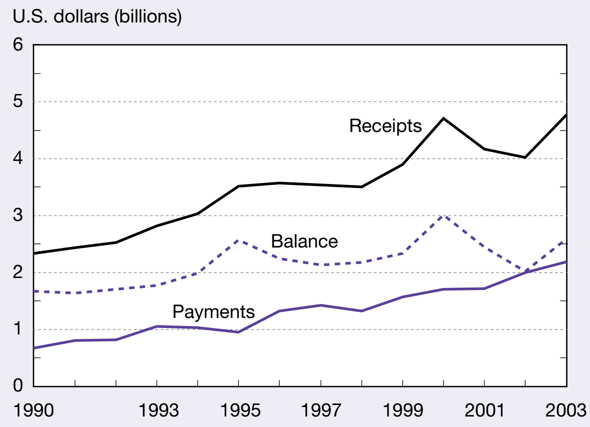
Figure 6-17
U.S. trade balance of royalties and fees paid for intellectual property: 1987–2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business* 84(10):25–76 (2004). See appendix table 6-7.

Science and Engineering Indicators 2006

Figure 6-18
U.S. trade in intellectual property involving manufacturing know-how, between unaffiliated companies: 1987–2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business* 84(10):25–76 (2004). See appendix table 6-8.

Science and Engineering Indicators 2006

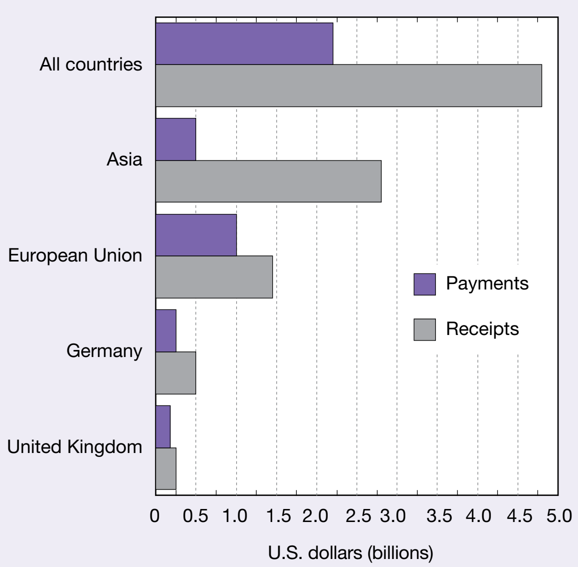
to a rise in receipts reported by several large pharmaceutical and telecommunications companies. This rise in receipts lifted total U.S. 2003 receipts from trade in manufacturing know-how above those earned from licensing use of computer software (Borga and Mann 2004).

Trading Partners

The U.S. surplus from trade in manufacturing know-how is driven largely by trade with Asia (appendix table 6-8). In 1995, U.S. receipts (exports) from manufacturing know-how licensing transactions were nearly seven times the amount of U.S. payments (imports) to Asia. That ratio closed to less than 4:1 by 1999, but has since widened. The most recent data show U.S. receipts from manufacturing know-how licensing transactions at about five times the amount of U.S. payments to Asia (figure 6-19). Japan and South Korea were the biggest customers for U.S. manufacturing know-how sold as intellectual property, accounting for 45% of total receipts in 2003.

Receipts. Japan has consistently been the single largest consumer of U.S. manufacturing know-how, although its purchases have fluctuated downward since the mid-1990s. Japan's share of U.S. receipts peaked in 1993 at approximately 51%; more recently, Japan's share was 30% in 2002 and 28% in 2003. South Korea was the second largest consumer, accounting for 17% of U.S. receipts in 2003. A major consumer of U.S. manufacturing know-how since the early 1990s, South Korea's share of U.S. receipts was 11% in 1990 and reached its highest level, 19%, in 2000.

Figure 6-19
U.S. royalties and fees generated from trade in intellectual property in the form of manufacturing know-how, between unaffiliated companies: 2003



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business*, 84(10):25–76 (2004). See appendix table 6-8.

Science and Engineering Indicators 2006

Unlike trade with Asia, U.S. trade with Europe in manufacturing know-how in the form of intellectual property is fairly balanced. U.S. firms trade manufacturing know-how primarily with Switzerland and the EU countries of France, Germany, Sweden, and the United Kingdom. Receipts from European countries nearly reached $1.7 billion in 2003, or about 36% of all U.S. receipts for technology sold as intellectual property. EU countries accounted for 30%. Germany is the third-largest consumer of U.S. manufacturing know-how, spending twice as much as the other large European customers, the United Kingdom, France, or Switzerland.

Payments. Foreign sources for U.S. firms' purchases of manufacturing know-how have varied over the years (appendix table 6-8). The EU has been the biggest supplier for U.S. firms, accounting for 37%–54% of foreign-supplied U.S. purchases of manufacturing know-how sold as intellectual property over the 15-year period examined (1987–2003). Germany, the United Kingdom, and Switzerland are the principal European suppliers.[23] In 2003, U.S. payments to Switzerland exceeded those paid to any other European country, second only to those paid to Japan.

Asia also has been an important supplier of manufacturing know-how, although its share of U.S. purchases has dropped considerably since 1999. In 2001, Asian countries accounted for 26% of U.S. purchases, down from 39% in 1999. Japan is the source for nearly all of these purchases, with small amounts coming from South Korea, Taiwan, and China. Since 1992, Japan has been the single largest foreign supplier of manufacturing know-how to U.S. firms; about one-fourth of all U.S. payments in 2003 were made to Japanese firms.

New High-Technology Exporters

Several nations made tremendous technological advances over the past decade and are positioned to become more prominent in technology development because of their large, ongoing investments in S&T education and R&D.[24] However, their success also may depend on other factors such as political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:[25]

- **National orientation**—evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure**—the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.

- **Technological infrastructure—**the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights, the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity—**the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force including the presence of skilled labor, and the existence of innovative management practices.

National Orientation

The national orientation indicator identifies nations in which businesses, government, and culture encourage high-technology development. It was constructed using information from a survey of international experts and previously published data. The survey asked the experts to rate national strategies that promote high-technology development, social influences that favor technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment during the next 5 years.

Five of the 15 countries examined received high overall scores on this indicator: Israel, Malaysia, the Czech Republic, China, and Ireland. The high scores for this indicator for Israel, China, and Malaysia reflect high ratings for each of the expert-opinion components, while the Czech Republic's score was elevated by its rating as one of the safest countries for foreign investment. Like the Czech Republic, Ireland was considered a safe haven for foreign investment, but its score was strengthened more by the experts' high opinions of Ireland's national strategies promoting high-technology development and social influences favoring technological change. The Czech Republic and China stand apart from the other three countries by showing marked improvement over results published just 2 years ago,[26] when, for example, China's score was more than 13 points lower than the 2005 score (figure 6-20, appendix table 6-9).

Venezuela received the lowest composite score of the economies examined. It was rated low for all variables, but mostly suffered because it was considered the riskiest or least attractive site for foreign investment. Indonesia and Argentina also received consistently low scores on each variable, but mostly were affected by the very low expert ratings of their national strategies for high-technology development.

Socioeconomic Infrastructure

The socioeconomic infrastructure indicator assesses the underlying physical, financial, and human resources needed to support modern, technology-based nations. It was built from published data on percentages of the population in secondary school and in higher education and from survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country[27] (figure 6-20).

Israel and Ireland received the highest scores among the emerging and transitioning economies examined. In addition to their strong records in general and higher education, Ireland and Israel's scores reflect high ratings for the mobility of capital and the encouragement of foreign investment. Their scores were similar to two other economies that currently export large quantities of high-technology products in the global marketplace—Taiwan and Singapore.

Among the remaining nations, Malaysia and two other Central European countries, Hungary and Poland, all received similar high scores. As with Ireland and Israel, the socioeconomic infrastructure score for Malaysia was bolstered by the experts' high opinion of the mobility of capital in the country and its encouragement of foreign investment, whereas the two Central European countries received high scores for their strong showing in the published education data and expert opinion on the mobility of capital.

As it did 2 years ago, Indonesia received the lowest composite score of the 15 nations examined, largely because of low marks on two of the three variables: educational attainment (particularly university enrollments) and the variable rating of the extent to which foreign businesses are encouraged to invest and do business in Indonesia.

Technological Infrastructure

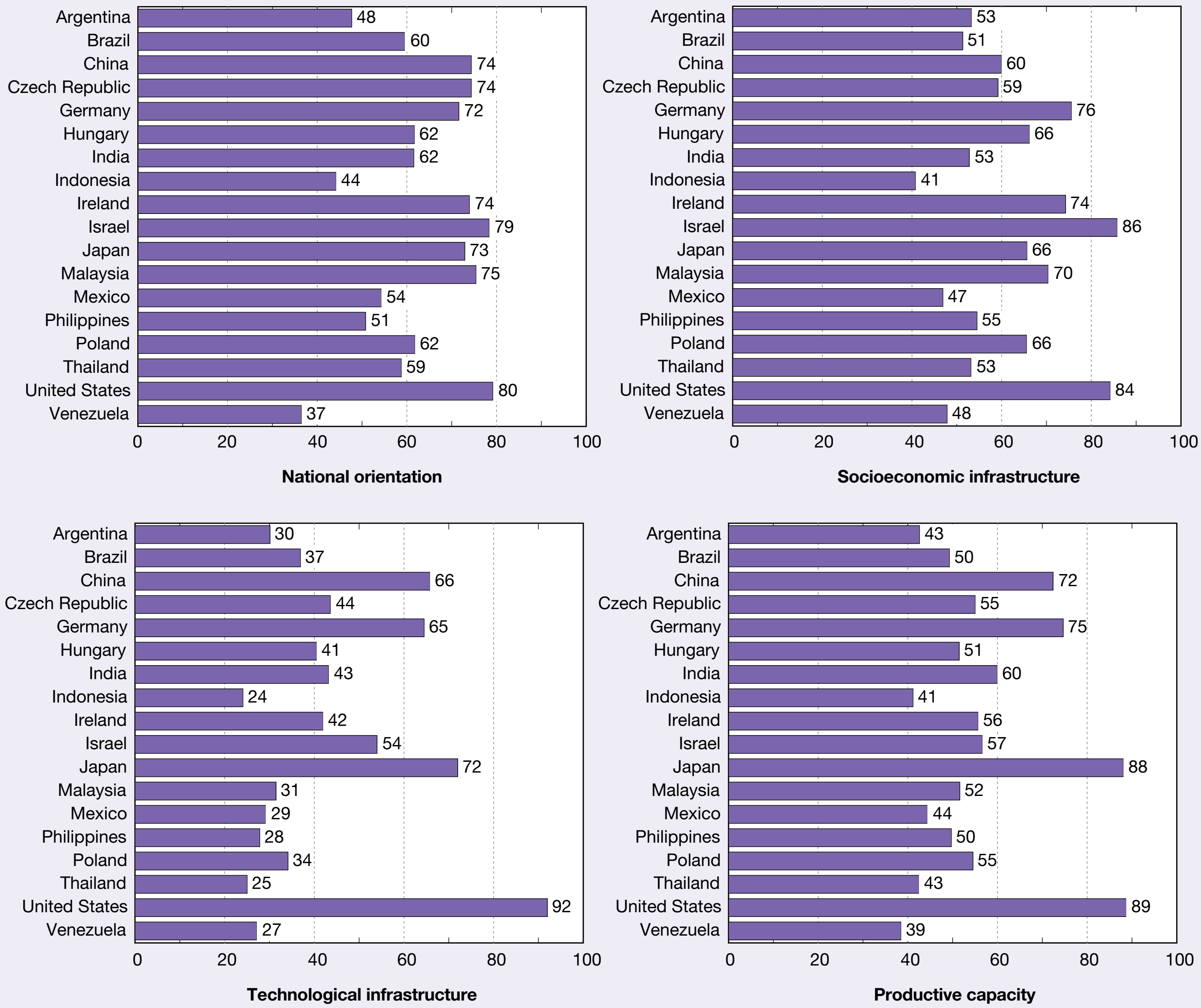
Five variables were used to develop the technological infrastructure indicator, which evaluates the institutions and resources that help nations develop, produce, and market new technology. This indicator was constructed using published data on the number of scientists in R&D, published data on national purchases of electronic data processing (EDP) equipment, and survey data that asked experts to rate each nation's ability to (1) locally train its citizens in academic S&E, (2) make effective use of technical knowledge, and (3) link R&D to industry.

Although the United States and Japan scored highest for technological infrastructure, with Germany close behind, China and Israel received the highest scores in this area among the newly industrialized or transitioning economies examined (figure 6-20). This was also the case 2 years ago, but at that time, the two nations' scores were very close. By 2005, China had surged ahead of Israel by 12 points.

China's high score for this indicator was influenced greatly by the two components that reflect the size of its population: its large purchases of EDP equipment and its large number of scientists and engineers engaged in R&D. Another factor behind China's high score is the experts' higher rating this year for China's ability to locally train its citizens in S&E.

Israel's high score on this indicator was based primarily on high expert ratings for its ability to locally train its

Figure 6-20
Leading indicators of technological competitiveness in selected countries: 2005



NOTE: Raw data were converted into 0–100 scale for each indicator component.

SOURCE: Georgia Institute of Technology, *High Tech Indicators: Preliminary Report* (2005). See appendix table 6-9.

Science and Engineering Indicators 2006

citizens in academic S&E, make effective use of technical knowledge, and link R&D to industry, as well as Israel's contribution to scientific knowledge.

Indonesia and Thailand received the lowest scores among the 15 countries examined.

Productive Capacity

The productive capacity indicator evaluates the strength of a nation's manufacturing infrastructure and uses that evaluation as a baseline for assessing the country's capacity for future growth in high-technology activities. The indicator considers expert opinion on the availability of skilled labor, the number of indigenous high-technology companies, and the level of management ability, combined with published data on current electronics production in each country.

By a wide margin, China had the highest score in productive capacity among the 15 developing and transitioning nations examined. China's score was boosted by its prominence in producing electronics, but it also received strong scores on each expert-derived indicator component. Trailing China on this indicator was a group of five nations that received similar overall scores: India, Israel, Ireland, the Czech Republic, and Poland (figure 6-20). Although all five of these countries posted higher scores than China on each of the expert-derived indicator components, they fell considerably short of China in the current production of electronics. Production of electronics products within Malaysia and Mexico was greater than all other 15 developing countries examined except for China. Malaysia's overall score was hurt by experts' low ratings of its indigenous electronics components suppliers and of the capabilities of its industrial managers. Mexico's overall score suffered from the experts' low rating of the quality of Mexican skilled manufacturing labor.

Findings From the Four Indicators

Based on this set of four leading indicators, Israel and China received the highest composite scores of the 15 nations examined. Both appear to be positioning themselves for future prominence as exporters of technology products in the global marketplace. Israel ranked first in national orientation based on strong governmental and cultural support promoting technology production, and first in socioeconomic infrastructure because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second and third on the two remaining indicators (figure 6-21, appendix tables 6-9, 6-10, and 6-11).

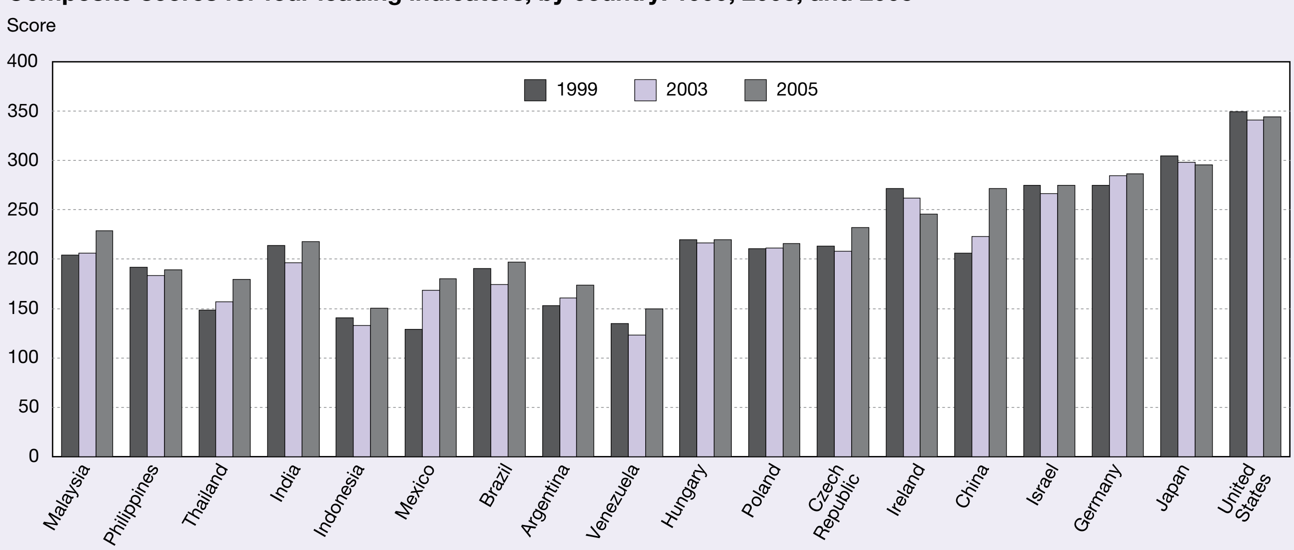
China's composite score for 2005 fell just short of Israel's, but the rise in its overall score over the past 2 years is noteworthy. China showed improvement in all four indicators and significant improvement in three: national orientation, technological infrastructure, and productive capacity. Its large population helped raise its score on several indicator components; this shows how scale effects, both in terms of large domestic demand for high-technology products and the ability to train large numbers of scientists and engineers, provide advantages to developing nations.[28]

Ireland, the co-leader with Israel two years ago, fell below China in this latest round of data, although it still made a strong showing across all four indicators. The Czech Republic and Malaysia posted high composite scores bolstered by high scores in the national orientation and productive capacity indicators.

Although not yet compiling high composite scores, several other countries appear to be laying the foundation for manufacturing and exporting high-tech products in the near future. Overall scores for Thailand, Mexico, and Argentina have trended upward in each of the last two periods, 2003 and 2005. Thailand's 2003 score was elevated because of a jump in a statistical rating for a rise in the number of Thai students enrolled in tertiary education, while its score in 2005 was elevated by a jump in electronics production. Mexico's overall score rose in 2003 based on higher expert-derived ratings in national orientation and technological infrastructure and improved statistical scores on student enrollments in secondary and tertiary education. In 2005 Mexico's scores held steady on these three indicators while its rating in the productive capacity indicator increased. Argentina showed gradual steady increases in most indicators during 2003 and 2005.

These indicators provide a systematic way to compare future technological capability for a wider set of nations than would be available using other indicators. The results highlight how the group of nations that compete in high-technology markets may broaden in the future. Results also reflect the large differences among several emerging and transitioning economies.

Figure 6-21
Composite scores for four leading indicators, by country: 1999, 2003, and 2005



SOURCE: Georgia Institute of Technology, *High Tech Indicators: Preliminary Report* (2005). See appendix tables 6-9, 6-10, and 6-11.

Science and Engineering Indicators 2006

Patented Inventions

Inventions are of great economic importance to a nation because they often result in new or improved products, more efficient manufacturing processes, or entirely new industries. To foster inventiveness, nations assign property rights to inventors in the form of patents. These rights allow the inventor to exclude others from making, using, or selling the invention for a limited period of time. Inventors obtain patents from government-authorized agencies for inventions judged to be new, useful, and not obvious.[29]

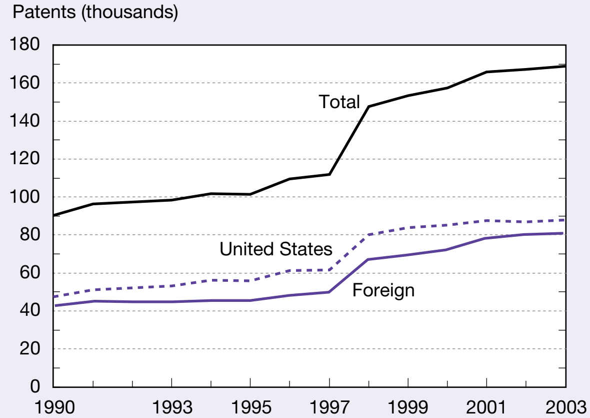
Although the U.S. Patent and Trademark Office (PTO) grants several types of patents, this discussion is limited to utility patents, commonly known as patents for inventions. They include any new, useful, or improved-on method, process, machine, device, manufactured item, or chemical compound.

Patenting indicators have several well-known drawbacks, including:

- **Incompleteness—**many inventions are not patented at all, in part because laws in some countries already protect industrial trade secrets.
- **Inconsistency across industries and fields—**the propensity to patent differs by industry and technology area.
- **Inconsistency in importance—**the importance of patented inventions can vary considerably.

Despite these limitations, patent data provide useful indicators of technical change and serve as a way to measure inventive output over time. In addition, information about foreign inventors seeking U.S. patents enables the measurement of inventiveness in foreign countries and can serve as a leading indicator of new technological competition (see sidebar, "Comparison of Data Classification Systems Used" in the introduction to this chapter).

Figure 6-22
U.S. patents granted, by country of origin: 1990–2003



NOTE: Country of origin determined by residence of first-named inventor.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-12.

Science and Engineering Indicators 2006

U.S. Patenting

Although a record number of patents (more than 169,000) were issued in the United States in 2003, the rate of growth in U.S. patenting has slowed since 2000[30] (figure 6-22; appendix table 6-12). Nonetheless, U.S. patents have enjoyed a period of nearly uninterrupted growth since the late 1980s.

Patents Granted to U.S. Inventors

The share of U.S. patents granted to U.S.-resident inventors has been fairly stable over the years, fluctuating within a narrow range (52%–56%). Since peaking at 56% in 1996, the share of U.S. patents granted to and held by U.S. resident inventors has declined slightly. In 2003, U.S. inventors were awarded nearly 88,000 new patents, or about 52% of the total patents granted in the United States. The increase in the share of U.S. patents granted to foreigners (from 44% in 1996 to 48% in 2003) reflects the growing global capacity for technological innovation in a broader array of countries as well as the openness of the U.S. market to new products.

Patents granted to U.S. inventors can be further analyzed by patent ownership at the time of the grant. Inventors who work for private companies or the federal government commonly assign ownership of their patents to their employers; self-employed or independent inventors typically retain ownership of their patents. The owner's sector of employment is thus a good indication of the sector in which the inventive work was done. In 2003, corporations owned 84% of patents granted to U.S. entities.[31] This percentage has risen rapidly since the late 1990s. From 1987 to 1997, corporate-owned patents accounted for 73%–78% of all U.S.-owned patents. Since 1997, corporations have increased this share to 80% in 1999, 82% in 2001, and 84% in 2003.

Individuals (independent inventors) are the second-largest group of U.S. patent owners. Before 1990, individuals owned, on average, 24% of all patents granted to U.S. entities.[32] This figure has trended downward to a low of 12% in 2003. Government's share (whether U.S. federal or state or foreign government) of issued patents averaged 3% from 1963 to 1990 and has stayed around 1% since the mid-1990s.[33]

Patents Granted to Foreign Inventors

Patents issued to foreign inventors represented 48% of all patents granted by the United States in 2003. This share reflects a slight increase since 1999, but has changed little since 1990. In 2003, the top five countries receiving patents from the United States were Japan, Germany, Taiwan, South Korea, and France. (See sidebar "Top Patenting Corporations" for discussion of the top 10 corporations receiving U.S. patents.)[34] During the period examined (1990–2003), inventors from Japan and Germany consistently were awarded more U.S. patents than inventors from any other country. The share of U.S. patents granted to inventors from Japan fluctuated 20%–23% during the 14-year span examined, and the share granted to inventors from Germany fluctuated 6%–8%. In 2003, Japan's share was 21%, Germany's share was 7%, and France's share was 3%.

Top Patenting Corporations

A review of corporations that received the largest number of patents in the United States during the past 25 years illustrates Japan's technological transformation over a relatively short period. During the 1970s, no Japanese companies ranked among the top 10 corporations seeking patents in the United States. During the 1980s, several Japanese companies became a part of the top 10 and by the early 1990s, Japanese companies outnumbered U.S. companies.

The number of U.S. patents granted to inventors residing in South Korea and Taiwan has risen quite sharply in recent years. One company headquartered in South Korea cracked the top 10 in 1999 and has remained there every year since, except for 2002 (its final rank was 11 that year). The most recent data (2003) show 1 South Korean company, 1 Dutch company, 3 U.S. companies, and 5 Japanese companies among the top 10 (table 6-4). In 2003, IBM was again awarded more patents than any other U.S. or foreign organization, the 11th consecutive year that the company earned this distinction. Micron Technology, Inc., joined the top 10 in 2000 and Intel Corporation in 2003. IBM, Micron, and Intel were the only U.S. companies to make the top 10 in 2003.

Table 6-4
Top patenting corporations in United States: 1999, 2001, and 2003

Company	Patents
1999	
International Business Machines	2,756
NEC	1,842
Canon	1,795
Samsung Electronics	1,545
Sony	1,417
Toshiba	1,200
Fujitsu	1,193
Motorola, Inc.	1,192
Lucent Technologies	1,163
Mitsubishi Denki	1,054
2001	
International Business Machines	3,411
NEC	1,953
Canon	1,877
Micron Technology, Inc.	1,643
Samsung Electronics	1,450
Matsushita Electric Industrial	1,440
Sony	1,363
Hitachi	1,271
Mitsubishi Denki	1,184
Fujitsu	1,166
2003	
International Business Machines	3,415
Canon	1,992
Hitachi	1,893
Matsushita Electric Industrial	1,774
Micron Technology	1,707
Intel Corporation	1,592
Koninklijke Philips Electronics	1,353
Samsung Electronics	1,313
Sony	1,311
Fujitsu	1,302

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (November 2004).

Science and Engineering Indicators 2006

Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, two Asian economies, Taiwan and South Korea, have stepped up their patenting activity in the United States and are proving to be strong inventors of new technologies (figure 6-23; appendix table 6-12).[35] The latest data show Taiwan (in 2000) and South Korea (in 2003) ahead of France and the United Kingdom, ranking third and fourth as residences for foreign inventors that obtain U.S. patents. Only inventors from Japan and Germany receive more U.S. patents.

Between 1963 (the year data first became available) and 1990, Taiwan received just 2,341 U.S. patents. During the subsequent 13 years, inventors from Taiwan were awarded more than 38,000 U.S. patents. U.S. patenting activity by inventors from South Korea shows a similar growth pattern. Before 1990, South Korean inventors received just 599 U.S. patents; since then, they have been awarded nearly 29,000 new patents.

Trends in Applications for U.S. Patents

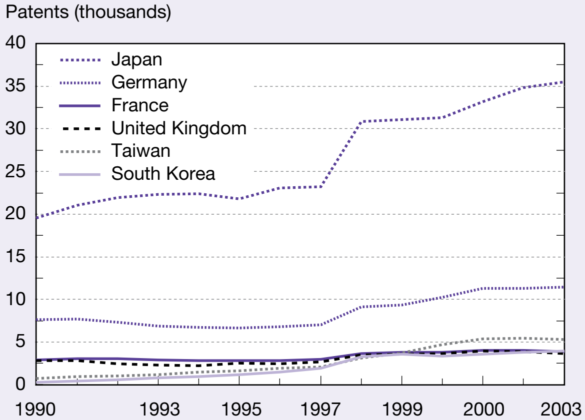
The review process leading up to the official grant of a new patent takes an average of 2 years, therefore, examining year-to-year trends in the number of patents granted does not always show the most recent changes in patenting activity.[36] Consequently, the number of patent applications filed with the PTO is examined to obtain an earlier, albeit less certain, indication of changes to patterns of inventiveness.

Patent Applications From U.S. and Foreign Inventors

Applications for U.S. patents reached 342,400 in 2003, an increase of only 2.4% from 2002, similar to the increase in 2001. Still, these latest data add to what has been nearly a decade of annual increases (figure 6-24; appendix table 6-13).

Shares of patent applications from U.S. residents have fluctuated between 54%–56% of all applications since the

Figure 6-23
U.S. patents granted to foreign inventors, by country/economy of origin: 1990–2003

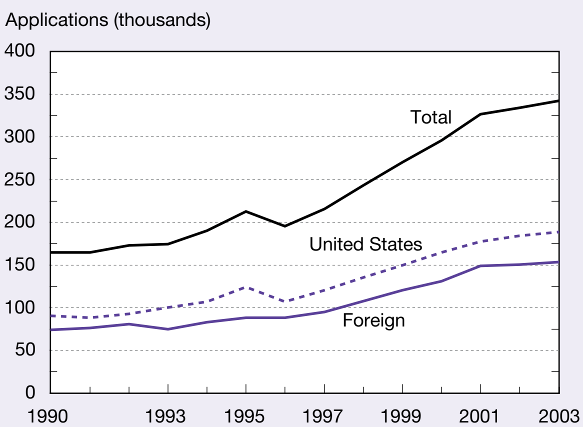


NOTES: Selected countries/economies are top six recipients of U.S. patents during 2003. Country of origin is determined by residence of first-named inventor.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-12.

Science and Engineering Indicators 2006

Figure 6-24
U.S. patent applications, by country of residence of first-named inventor: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations (2005). See appendix table 6-13.

Science and Engineering Indicators 2006

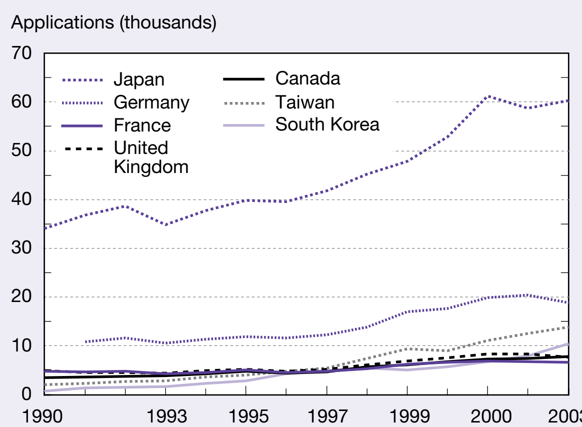
mid-1990s; in 2002 and 2003, U.S. residents accounted for 55%. Because patents granted to foreign inventors generally accounted for about 44%–48% of total U.S. patents granted, the success rate for foreign applications appears to be about the same or slightly higher than that for U.S. inventor applications.[37]

Over time, residents of Japan have applied for more U.S. patents than residents of any other foreign country. Since 1990, they accounted for 39%–48% of yearly U.S. patent applications made by foreign residents, generally at least three times that of Germany, which had the next most active group of applicants (figure 6-25). Japan's share slipped in the late 1990s, falling to a decade low of 40% in 1999. Its share has hovered around 40% since then. The German share has generally exhibited a downward trend, falling from a high of 16% in 1989 to about 12% in 2003.

Although patent filings by inventors from the leading industrialized countries have leveled off or begun to decline, other countries, particularly Asian economies, have stepped up their patenting activity in the United States. This is especially true for Taiwan and South Korea, and data on recent patent applications suggest that the rising trend in U.S. patents granted to residents of these two Asian economies is likely to continue. Since 1997, Taiwan and South Korea replaced France and Canada in the top five foreign sources of inventors seeking U.S. patents. In 2003, Taiwan accounted for 9% of foreign sources of U.S. patent applications and South Korea for close to 7%. Canada and the United Kingdom accounted for 5% and France for 4%. If recent patents granted to residents of Taiwan and South Korea are indicative of the technologies awaiting review, many of these applications will prove to be for new computer and electronic inventions.

Also impressive is the growth in patent applications by inventors from Israel, Finland, India, and China. In 2003, inventors from Israel filed more than 2,500 U.S. patent applications, up from about 600 in 1990; inventors from Finland filed more than 1,900 U.S. patent applications, up from about 600 in 1990; inventors from India filed for nearly 1,200 U.S. patent applications, up from 58 in 1990; and inventors from China filed for 1,034 U.S. patent applications, up from 111 in 1990. These dramatic increases over the past several years provide yet another indication of the ever-widening community of nations active in global technology development and diffusion.

Figure 6-25
U.S. patent applications filed by selected foreign inventors, by country/economy of residence: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-13.

Science and Engineering Indicators 2006

Technical Fields Favored by Foreign Inventors

A country's inventors and the distribution of its patents by technical area is a reliable indicator of the country's technological strengths as well as its focus on product development. This analysis can also indicate which U.S. product markets are likely to see increased foreign competition. The following section discusses the key technical fields favored by U.S. resident inventors and inventors from the top five foreign countries obtaining patents in the United States.[38]

Fields Favored by U.S. and Leading Foreign Resident Inventors

Corporate patenting patterns reflect activity in several technology areas that have already greatly contributed to the nation's economic growth. In 2003, for example, corporate patent activity indicated U.S. technological strengths in business methods, computer hardware and software, medical and surgical devices, and biotechnology (table 6-5).

The 2003 data also show Japan's continued emphasis on photography, photocopying, and office electronics technology, as well as its broad range of U.S. patents in communication technology. From improved information storage technology for computers to wave transmission systems, Japanese inventors have earned many U.S. patents in areas that aid in the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in areas associated with heavy manufacturing, a field in which they traditionally have maintained a strong presence. The 2003 U.S. patent activity index shows that Germany emphasizes inventions for printing, motor vehicles, metal forming, and material-handling equipment.

In addition to inventions for traditional manufacturing applications, British patent activity is high in oil-drilling technologies, biotechnology, communications, and chemistry (appendix table 6-14). Like German and British inventors, French inventors are quite active in patent classes associated with manufacturing applications; however, they also show added activity in aeronautics and automotive technologies (appendix table 6-15). They share U.S. and British inventors' emphasis on biotechnology.

As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. But by the 1990s, Taiwan was active in communication technology, semiconductor manufacturing processes, and internal combustion engines. Data from 2003 show that Taiwan's inventors also added semiconductors, semiconductor manufacturing devices, and electrical systems to their technology portfolio.

U.S. patenting by South Korean inventors also reflects that country's rapid technological development. The 2003 data show that South Korean inventors are currently patenting heavily in a broad array of computer technologies that include liquid crystal cells, devices for dynamic and static information storage, and television technologies (table 6-6).

Patents for Biotechnologies

When inventions result in new or improved products or processes, patent owners can reap economic benefits that, in turn, typically spill over to users and consumers. But inventions that lead to the creation of entire new industries have more profound impact on national economies and on international relations. Patented biotechnologies are an example of industry-creating inventions.

Shadowing the widely anticipated economic and medical benefits associated with this technology area is a great deal of controversy. Proponents argue that biotechnology patents are necessary to allow for commercial development of many new diagnostic and therapeutic products. Others voice concerns

Table 6-5
Top 15 most-emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 2003

Rank	United States	Japan	Germany
1	Business practice, data processing	Electrophotography	Printing
2	Surgery: light, thermal, and electrical applications	Television signal processing	Clutches and power-stop control
3	Computers and digital processing systems	Computer storage and retrieval	Land vehicles, bodies, and tops
4	Data processing, file management	Photography	Machine element or mechanism
5	Surgery instruments	Photocopying	Brake systems
6	Data-processing software	Liquid crystal cells	Power delivery controls, engines
7	Wells	Ceramic compositions	Internal combustion engines
8	Prosthesis	Facsimile	Metal forming
9	Processing achitectures	Power delivery controls, engines	Valves
10	Input/output digital processing systems	Optical image projector	Joints and connections
11	Data processing, artificial intelligence	Incremental printing of symbolic information	Sheet-feeding machines
12	Analytical and immunological testing	Bearings	Land vehicles
13	Surgical, medicators, and receptors	Electric lamp and discharge devices	X-ray or gamma-ray systems
14	Multicellular living organisms	Electrical generators	Rotary motors or pumps
15	Computer memory	Radiation imagery chemistry	Chairs, seats

NOTES: Rank based on patenting activity index for nongovernmental U.S. or foreign organizations, which are primarily corporations. Patenting by individuals and governments excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (December 2004).

Science and Engineering Indicators 2006

Table 6-6
Top 15 most-emphasized U.S. patent classes for corporations from South Korea and Taiwan: 2003

Rank	South Korea	Taiwan
1	Liquid crystal cells, elements, and systems	Semiconductor device manufacturing process
2	Electric lamp and discharge devices	Electrical connectors
3	Semiconductor device manufacturing process	Electrical systems and devices
4	Dynamic magnetic information storage or retrieval	Circuit makers and breakers
5	Electric lamp and discharge systems	Electric power conversion systems
6	Static information storage and retrieval	Active solid-state devices
7	Brushing, scrubbing, and general cleaning	Typewriting machines
8	Television	Substrate etching process
9	Refrigeration	Sheet-feeding machines
10	Active solid-state devices	Illumination
11	Pumps	Heat exchange
12	Power delivery controls, engines	Cleaning
13	Electrical audio signal systems	Optical image projector
14	Television recording systems	Communication radio wave antennas
15	Electrical nonlinear devices	Facsimile

NOTES: Rank based on patenting activity index for nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division (2004).

Science and Engineering Indicators 2006

about the patenting of naturally occurring elements and more general concerns that giving companies monopoly rights in certain biotechnologies may hinder scientific progress (see sidebar "A Patent System for the 21st Century"). Ethical issues surrounding cloning for reproductive and therapeutic purposes are also part of the debate.

Despite these ongoing controversies, patent offices worldwide have issued thousands of patents for biotechnologies. This section examines recent trends in biotechnology patenting in the United States and Europe and identifies countries that are the source for most of the biotechnology patenting in these two major markets.

U.S. Patenting of Biotechnologies

U.S. patenting of biotechnologies accelerated during the 1990s, especially during the latter half of the decade (figure 6-26; appendix table 6-16). The effort to map the human genome certainly contributed to this trend, as evidenced by the surge in applications to patent human DNA sequences. Although the number of biotechnology patents has remained high since 2001, the trend has turned slightly negative.[39]

U.S. resident inventors accounted for more than 60% of all biotechnology patents issued by PTO. This share is about 10% higher than U.S. inventors hold when U.S. patents for all technologies are counted.[40] Given the ongoing controversies surrounding this technology area, foreign inventors may be less inclined than U.S. inventors to file biotechnology patents in the United States.

Foreign sources account for about 36% of all U.S. biotechnology patents. These patents are more evenly distributed among a somewhat broader number of countries than that for all technology areas combined. Another evident pattern is the more prominent representation of European countries in U.S. patents of biotechnologies and the smaller representation by Asian inventors (figure 6-27). Not only are Japan and Germany the leading foreign sources for U.S. patents overall, they are the leading foreign sources for U.S. patents granted for biotechnologies. Recently, however, Germany's share of U.S. biotechnology patents granted has been rising while Japan's share has been falling. In 2003, Germany was still the leading foreign source, accounting for 6.5% of U.S. biotechnology patents granted, up from around 4% in the late 1990s, while Japan's share was 6.4%, about half the share held by Japanese inventors in the early 1990s.

Like Germany, inventors from the United Kingdom, France, Canada, and the Netherlands also accounted for a larger share of U.S. patents granted in the biotechnology area compared with their shares of U.S. patents granted in all other technology areas. Conversely, inventors from Taiwan and South Korea are far less active in this technology area than for all technology areas combined.

Top Biotechnology Patenting Organizations

In the biotechnology area, universities, government agencies, and other nonprofit organizations are among the leading recipients of U.S. patents, although corporations are still awarded the most patents overall (table 6-7; appendix tables 6-16 and 6-17). The University of California system has been awarded the most patents; its total represents 1.6% of total patents granted in this technology area since 1977.[41] The U.S. Department of Health and Human Services was the second leading recipient with more than 1,000 U.S. biotechnology patents, accounting for about 1.1% of the total. Corporations, U.S.- and foreign-based, are well represented among the top 25 and include most of the large pharmaceutical companies and several companies closely identified with this field.

A Patent System for the 21st Century

For some time there has been a growing concern that patents and other forms of exclusive ownership of intellectual property may discourage research into, communication about, and diffusion of new technologies. This concern led to the question whether, in some cases, the extension of intellectual property rights (IPR) has stifled rather than stimulated innovation. To provide answers and guide IPR policy over the next decade and beyond, the Science, Technology, and Economic Policy Board of the National Research Council reviewed the purposes and functioning of the IPR legal framework in the United States and assessed how well those purposes are being served.

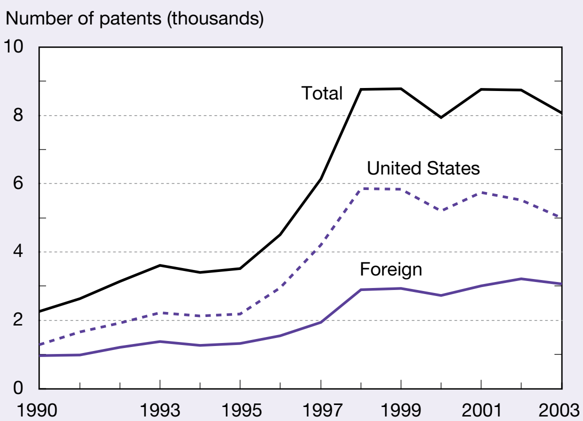
The board held several conferences and workshops and commissioned new data collection and analysis efforts to investigate issues of patent quality, licensing, and litigation, especially as these issues relate to patents for information technology and biotechnology. They identified the following concerns for the research enterprise:

- ♦ Standards of patentability, in particular the nonobviousness standard, are eroding.
- ♦ A proliferation of upstream patents on scientific discoveries, especially in biomedical science, could impede research.
- ♦ Rising patent costs, longer patent pendancy, and differences in national patent systems are contributing to unnecessary costs and delays.
- ♦ The U.S. intellectual property system is struggling with the accelerating pace of technological developments in the knowledge economy.

The committee composed of economists, legal experts, technologists, and university and corporate officials made the following recommendations to address these concerns:

- ♦ *Institute an "open review" procedure.* The committee recommended that Congress pass legislation creating a streamlined, relatively low-cost procedure for third parties to challenge issued patents in a proceeding before administrative patent judges of the U.S. Patent and Trademark Office (PTO).
- ♦ *Reinvigorate the nonobviousness standard.* The requirement that to qualify for a patent an invention cannot be obvious to a person of ordinary skill in the art should be assiduously observed.
- ♦ *Shield some research uses of patented inventions from liability for infringement.* In light of the ruling that even noncommercial scientific research enjoys no protection from patent infringement liability, the committee recommended that Congress consider appropriately narrow legislation to protect certain cases of academic researcher use of patented inventions.
- ♦ *Strengthen PTO capabilities.* The PTO should be provided additional budget resources to hire and train additional examiners and improve its electronic processing capabilities.
- ♦ *Harmonize U.S., European, and Japanese patent examination systems.* This would help reduce redundancy in search and examination and could eventually lead to mutual recognition of results.

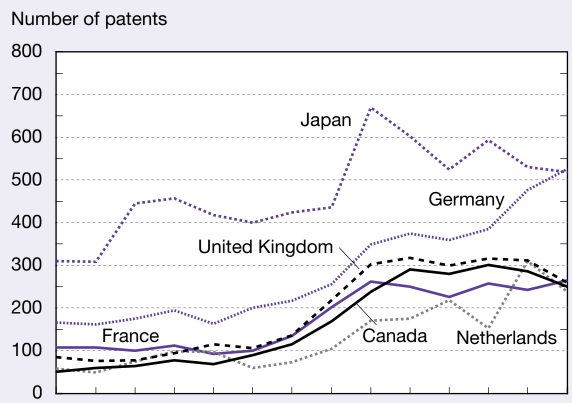
Figure 6-26
U.S. biotechnology patents granted, by residence of first-named inventor: 1990–2003



SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-16.

Science and Engineering Indicators 2006

Figure 6-27
U.S. biotechnology patents granted to foreign inventors, by residence of inventor: 1990–2003



NOTE: Selected countries are top six recipients of U.S. patents during 2003.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (2004). See appendix table 6-16.

Science and Engineering Indicators 2006

Table 6-7
Top 25 biotechnology patenting organizations: 1977–2003

Company	Patents	Share of group	Share of total
All organizations	89,448	na	100.00
University of California	1,585	10.54	1.77
U.S. Department of Health and Human Services	1,021	6.79	1.14
Merck and Co., Inc.	943	6.27	1.05
Genentech, Inc.	792	5.27	0.89
Yoder Brothers, Inc.	729	4.85	0.82
Pioneer Hi-Bred International, Inc.	693	4.61	0.77
Eli Lilly and Company	674	4.48	0.75
Abbott Laboratories	654	4.35	0.73
Smithkline Beecham Corporation	636	4.23	0.71
University of Texas	576	3.83	0.64
Incyte Pharmaceuticals, Inc.	572	3.80	0.64
Boehringer Mannheim G.M.B.H.	549	3.65	0.61
Isis Pharmaceuticals, Inc.	512	3.40	0.57
Novo Nordisk A/S	490	3.26	0.55
Chiron Corporation	484	3.22	0.54
E. I. Du Pont De Nemours and Company	461	3.07	0.52
Becton, Dickinson and Company	427	2.84	0.48
Hoffmann-La Roche Inc.	426	2.83	0.48
U.S. Department of Agriculture	418	2.78	0.47
General Hospital Corporation	414	2.75	0.46
Johns Hopkins University	412	2.74	0.46
Hoechst Aktiengesellschaft	402	2.67	0.45
Institut Pasteur	395	2.63	0.44
Miles Inc.	387	2.57	0.43
Takeda Chemical Industries Ltd.	387	2.57	0.43
Subtotal	15,039	100.00	16.81

na = not applicable

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (January 2005).

Science and Engineering Indicators 2006

Patenting of Valuable Inventions: Triadic Patent Families

One limitation of using patent counts as an indicator of national inventive activity is that such counts cannot differentiate between minor inventions and highly important inventions. A database developed through an international partnership of patent offices in the United States, Europe, and Japan provides a new tool for patent researchers that helps to address this problem.[42] This data set counts only those inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan.[43] Each invention that satisfies this condition forms a *triadic patent family.*[44]

The high cost of filing for patents from three separate patent offices makes triadic patent families a more accurate measure of important inventions than simple patent counts, because generally only highly valuable inventions justify the costs (see sidebar "Identifying Valuable Inventions: A Comparison of Results When Using PTO, EPO, and PCT Patent Citations"). For example, application fees alone can exceed several thousand dollars, not counting related legal costs. The costs for an inventor to file for patent protection in his or her country of residence are significant. The costs to file in other countries are even greater.

Counts of triadic patent families, sorted by the inventor's residence for selected countries, are listed by priority year, i.e., the year of the first patent filing. The United States has been the leading producer of triadic patent families since 1989, even when compared with European inventors. Inventors residing in EU countries produced nearly as many triadic patented inventions as did inventors living in the United States since the late 1980s, and they produced more than the U.S. inventors from 1985 through 1988 (figure 6-28). Within the EU, Germany had more triadic patent inventors than the next three leading European countries: France, the United Kingdom, and the Netherlands. Inventors residing in Japan produced only slightly fewer triadic patents than inventors in the United States or the EU. Estimates for 2000 show U.S. inventors' share at 34%, EU's share at 31%, and Japan's share at 27%. However, given its much lower population, Japan's inventive productivity would easily exceed that of the United States or the EU if the number of inventions per capita were used as the basis for comparison.

When the data are examined by the patent applicant's or owner's country of residence rather than by the inventor's residence, the overall rankings for the United States, the EU, and Japan do not change, although the U.S. share increases, the EU share decreases, and Japan's share stays about the

Identifying Valuable Inventions: A Comparison of Results When Using PTO, EPO, and PCT Patent Citations

When applying for a patent, the applicant usually includes references to previous patents or nonpatent literature to distinguish the subject invention from previous inventions. These references to "prior art" are used by the granting agency to investigate and establish the validity of the applicant's claims. During the examination of the application, the patent examiner considers the applicant's citations to prior art and may add other citations that the examiner feels are relevant. Patent citations typically reference other patents and nonpatent literature, such as scientific or technical journal articles, books, reference works, and other forms of public disclosure.

Technology analysts can use patent citations to develop indicators that measure the value or importance of a group of patents. Data on patent citations from the U.S. patent system often are used for this purpose. In recent years, as patent data at the European Patent Office (EPO) and other granting authorities have become increasingly accessible, researchers have raised the question whether a citation analysis using EPO or other patent data than U.S. patent citations would provide different or better results.

U.S. Patent System Citations

Some observers have noted that features of the U.S. patent system (such as the duty of candor and the Information Disclosure Statement) can result in large numbers of references, many of which may be only marginally relevant to the validity of the claims made on the patent application. Moreover, there is no categorization of citations on U.S. patents identifying those that are directly relevant to patentability and distinguishing them from citations that are merely background information. Therefore, it is possible that large numbers of marginally relevant citations on U.S. patents either undermine the effectiveness of citation analysis or distort the results.

Another criticism of U.S. patent citations is that they are biased toward other U.S. patents and English-language patents in general.

Comparison of U.S. and Other Patent Systems

Those who examine patents in the EPO and for the Patent Cooperation Treaty (PCT) are instructed to include only the most important documents in the references. In addition, EPO and PCT references are categorized by their relevance to the submitted application. Thus, citations on EPO and PCT patent documents (especially citations that directly anticipate some or all of the subject matter of the citing patent application) may be more directly related to value and therefore provide better data for citation analysis.

Under contract with the National Science Foundation, Mogee Research & Analysis conducted a statistical comparison of citations from U.S., EPO, and PCT patent documents to determine whether better information could be extracted from EPO and/or PCT patent citations or from using U.S. patent citations alone.* The analysis was conducted on patent families (i.e., groups of equivalent patent documents in different patent systems) that included at least one patent document each from the United States, EPO, and PCT. These are called *triadic patent families*. Citations to and from the U.S., EPO, and PCT documents within a given triadic patent family were compared, thus keeping the subject invention constant. Issued patents and published applications from the U.S. Patent and Trademark Office (PTO) were covered, as were issued patents and published applications from the EPO and published applications from the PCT system. References on the front page of the U.S. patent were compared with references in the search report for the EPO and PCT patent documents. The patenting and referencing processes in the three systems also were studied.

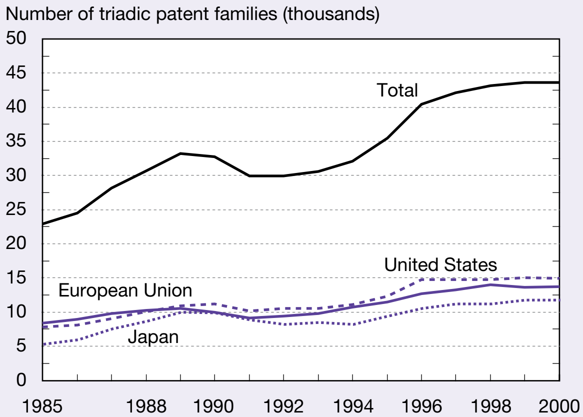
Two cases were studied: Solid Waste Disposal, with 332 triadic families, and Advanced Batteries for Automobiles, with 324 triadic families.

Preliminary Findings

- In these two cases, ranking the inventions (triadic families) by the number of citations received by EPO or PCT patent documents did not give drastically different results from their ranking by the number of citations received by U.S. patents.
- U.S. patent documents referenced patents from a broader range of priority countries than EPO and PCT patent documents referenced.
- U.S. patent documents tended to cite U.S. patents more than EPO patent documents cited EPO patents.
- U.S. patent citations by themselves are a satisfactory source to develop citation indicators, as measured by their ability to predict the value distribution of a group of patents. However, a citation analysis that also includes citations from the EPO and PCT may lead to a more robust analysis in the sense of a better accounting for patent value.
- EPO and PCT citations provided more information than could be obtained from the U.S. citations alone and improved the predictions of patent value, as measured by both patent renewals and the number of family members.

*Full report forthcoming in 2006.

Figure 6-28
Triadic patent families, by residence of inventor: 1985–2000



SOURCE: Organisation for Economic Co-operation and Development/ World Intellectual Property Organization, Triadic Patent Families, unpublished tabulations (2004).

Science and Engineering Indicators 2006

same (table 6-8). The shift in shares between the United States and the EU is nearly identical; it appears that the percentage increase in the U.S. share comes almost completely from the EU. The difference in country shares when triadic patent families are sorted by the owner's residence as opposed to the inventor's residence suggests that U.S. companies (corporations own most triadic patent families) employ or otherwise purchase ownership of more European innovations than European firms employ or otherwise purchase ownership of U.S. innovations. Another explanation might be that U.S. companies' European operations are more R&D- or discovery-oriented than European operations in the United States. The near-constant shares for Japan tend to reinforce the image of Japanese firms as more insular, relying mostly on the discoveries of inventors residing in Japan.

Rankings change dramatically when national activity is normalized by population or by size of the economy as reflected in the GDP (figure 6-29). When data are normalized for size, smaller countries emerge, Switzerland and Finland in particular, and demonstrate high output of important inventions. Among the big three (the United States, the EU, and Japan), Japan clearly is the most productive when size is factored into the measurement.

Counts of triadic patent families also can be used to further examine patenting in biotechnology. During 1998 and 1999, which are the most recent 2 years for which complete data are available, the United States, the EU, and Japan together accounted for more than 90% of all biotechnology triadic patents, a percentage slightly lower than their share of all triadic patents formed during this period. Biotechnologies account for a larger share of the U.S. patent portfolio compared with the EU or Japan. Combining these 2 years, biotechnology patents accounted for 6.8% of total U.S. triadic patent families, 3.5% for the EU, and 1.5% for Japan (figure 6-30).

Venture Capital and High-Technology Enterprise

Venture capitalists typically invest in small, young companies that may not have access to public or credit-oriented institutional funding. Such investments can be long term and high risk and, in the United States, almost always include hands-on involvement in the firm by the venture capitalist. The funds and management expertise venture capitalists provide can aid the growth and development of small companies and new products and technologies. In fact, venture capital is often an important source of funds used in the formation and expansion of small high-technology companies. These new high-technology companies play a vital role in the U.S. economy and have become important employers of recent S&E graduates (National Venture Capital Association 2002). Tracking venture capital investments also provides indicators of technology areas that venture capitalists consider the most economically promising.

Table 6-8
Triadic patent families, by inventor and applicant (owner) place of residence and priority year: 1988–99
(Percent)

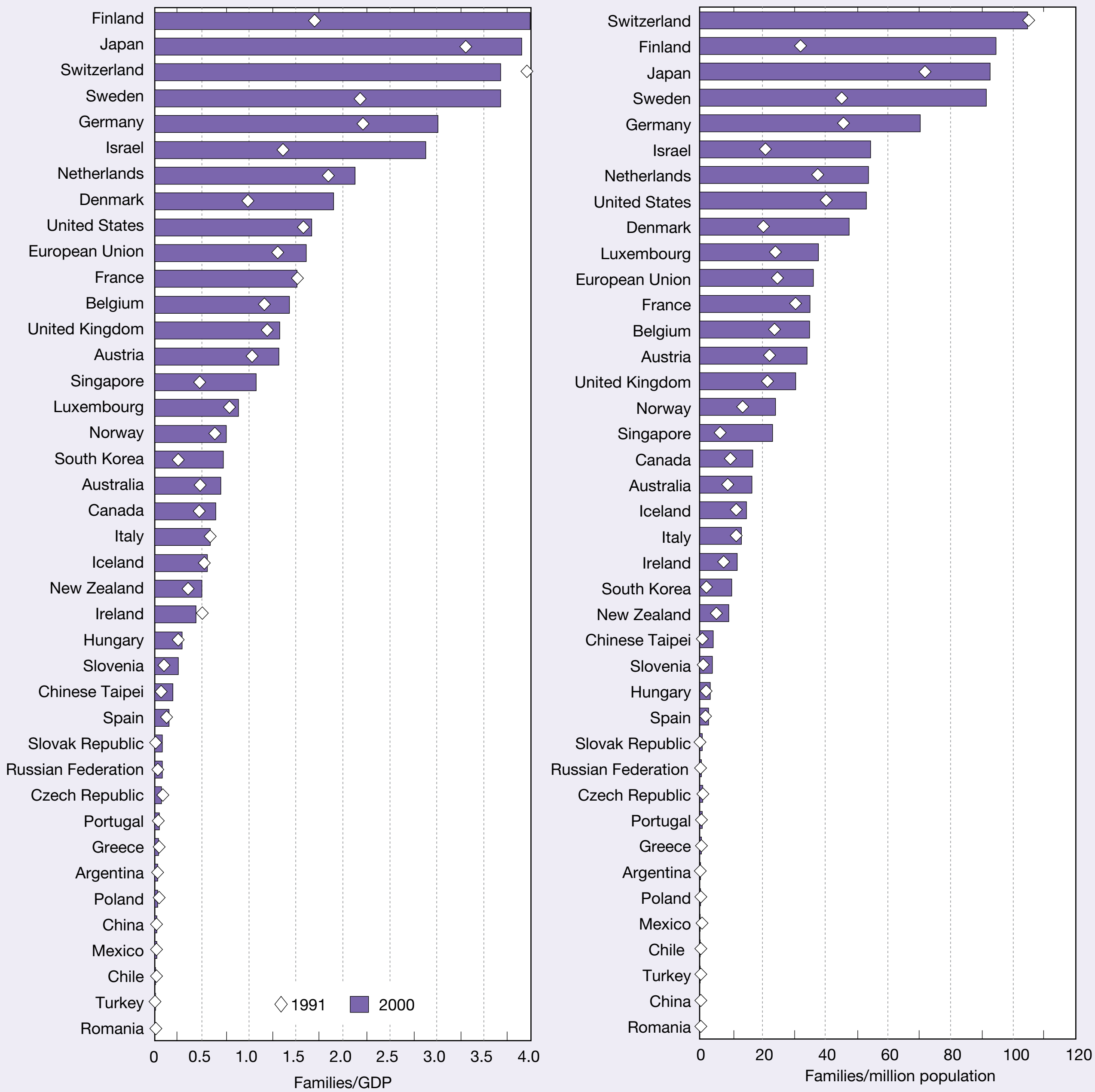
Place of residence	Total	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Inventor													
United States	34.9	33.0	33.0	34.4	34.9	36.2	35.4	34.8	34.3	33.9	35.6	36.2	36.1
European Union	31.6	33.5	31.7	30.2	30.5	31.3	31.8	33.6	32.7	32.8	31.0	35.4	28.7
Japan	27.5	28.3	30.2	30.3	29.1	26.7	26.8	25.3	26.5	26.9	26.6	29.8	28.6
Applicant													
United States	39.4	37.9	37.5	38.8	39.4	40.8	40.3	40.0	38.8	38.4	39.3	39.7	37.9
European Union	27.7	29.4	28.0	26.7	26.7	27.3	27.7	29.4	28.6	28.5	27.5	32.1	27.0
Japan	27.3	28.0	30.0	29.9	28.9	26.5	26.6	24.9	26.3	26.8	26.7	29.9	28.6

NOTE: A triadic patent family is formed when patent applications for same invention are filed in Europe, Japan, and United States.

SOURCE: Organisation for Economic Co-operation and Development/World Intellectual Property Organization, Triadic Patent Families, unpublished tabulations (2004).

Science and Engineering Indicators 2006

Figure 6-29
Triadic patent families, by residence of inventor: Priority years 1991 and 2000



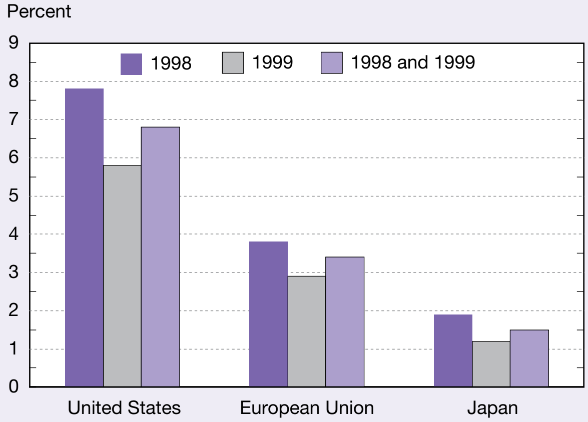
GDP = gross domestic product

NOTES: Applications for patents filed with European Patent Office, U.S. Patent and Trademark Office, and Japanese Patent Office. 2000 values are estimates. GDP calculated is 1995 U.S. dollars using purchasing power parity.

SOURCE: Organisation for Economic Co-operation and Development, patent database (September 2004).

Science and Engineering Indicators 2006

Figure 6-30
Share of biotechnology triadic patents, by country/region: 1998 and 1999



SOURCE: Organisation for Economic Co-operation and Development, patent database (September 2004)

Science and Engineering Indicators 2006

This section examines venture capital investment patterns in the United States since 1980, with special emphasis on a comparison of trends in 1999 and 2000 (hereafter called the *bubble years*) with trends in 2001 and 2002 (the *postbubble years*) and most recently in 2003 and 2004. It discusses changes in the overall level of investment, those technology areas U.S. venture capitalists find attractive, and the types of investments made.[45]

U.S. Venture Capital Resources

Several years of high returns on venture capital investments during the early 1990s led to a sharp increase in investor interest. The latest data show new commitments rising vigorously each year from 1996 through 2000, with the largest increase in 1999 (table 6-9). Investor commitments to venture capital funds jumped to $62.8 billion that year, a 111% gain from 1998. By 2000, new commitments reached $105.8 billion, more than 10 times the level of commitments recorded in 1995. Evidence of a slowdown emerged in 2001, when new commitments declined for the first time in 10 years.[46] Commitments fell by more than 64% that year, to $37.9 billion. Still, this sharply reduced total was quite large compared with capital investments before the bubble years. Another sharp drop in 2002 reduced the amount of new money coming into venture capital funds to only $7.7 billion, a level not seen since 1994.

The pool of money managed by venture capital firms grew dramatically over the past 20 years as pension funds became active investors, following the U.S. Department of Labor's clarification of the "prudent man" rule in 1979.[47] In fact, pension funds became the single largest supplier of new funds. During the entire 1990–2002 period, pension funds supplied about 44% of all new capital. Endowments and foundations were the second-largest source, supplying 17% of committed capital, followed closely by financial and insurance companies at 16% (table 6-10). California, New York, and Massachusetts together account for about 65% of venture capital resources, because venture capital firms tend to cluster around locales considered to be "hotbeds" of technological activity, as well as in states where large amounts of R&D are performed (Thomson Financial Venture Economics 2002).

Table 6-9
New capital committed to U.S. venture capital funds: 1980–2002
(Billions of U.S. dollars)

Year	New capital
1980	2.1
1981	1.6
1982	1.7
1983	4.1
1984	3.1
1985	4.0
1986	3.9
1987	4.4
1988	4.9
1989	5.6
1990	3.5
1991	2.1
1992	5.4
1993	3.9
1994	7.8
1995	10.0
1996	12.2
1997	19.0
1998	29.7
1999	62.8
2000	105.8
2001	37.9
2002	7.7

SOURCE: Thomson Financial Services, special tabulations (June 2003).

Science and Engineering Indicators 2006

U.S. Venture Capital Disbursements

High returns on venture capital investments during the 1990s made the funds attractive for risk-tolerant investors. Starting in 1994, the amount of new capital raised exceeded that disbursed by the industry, creating a large pool of money available for investments in new or expanding firms and leading to a period of large year-to-year jumps in venture capital disbursements. In 1994, money disbursed by venture capital funds totaled to $4.1 billion and increased to $11.6 billion in 1996 and $21.4 billion in 1998, before peaking at $106.3 billion in 2000 (figure 6-31).

As early as 1990, firms producing computer software or providing computer-related services began receiving large amounts of venture capital (appendix table 6-18). Software companies received 17% of all new venture capital disbursements in 1990, more than any other technology area. This figure fluctuated between 12% and 21% thereafter. Communication companies also attracted large amounts of venture capital during the 1990s, receiving 12%–21% of total

Table 6-10
Capital commitments, by limited partner type: 1990–2002
(Billions of U.S. dollars)

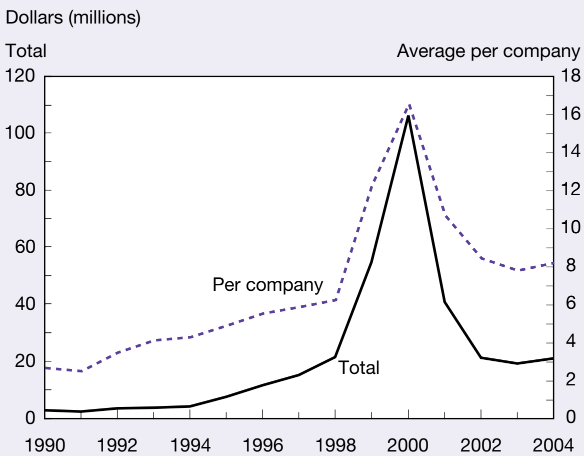
Limited partner type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All types	2.55	1.48	3.39	4.12	7.35	8.42	10.47	15.18	25.29	60.14	93.44	2.81	2.54
Pension funds	1.34	0.63	1.41	2.43	3.36	3.12	5.74	5.77	15.03	26.16	37.47	0.83	1.12
Banks and insurance	0.24	0.08	0.49	0.43	0.70	1.62	0.30	0.91	2.59	9.32	21.77	0.37	0.24
Endowments and foundations	0.32	0.36	0.63	0.44	1.57	1.65	1.18	2.43	1.58	10.34	19.72	0.29	0.25
Individuals and families	0.29	0.18	0.37	0.30	0.87	1.36	0.68	1.82	2.83	5.77	11.03	0.75	0.35
Corporations	0.17	0.06	0.11	0.34	0.67	0.35	1.98	3.64	2.97	8.54	3.46	0.41	0.21
Foreign investors	0.19	0.17	0.38	0.18	0.18	0.32	0.59	0.61	0.29	0.00	0.00	0.15	0.00
Other NEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Intermediaries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18

NEC = not elsewhere classified

SOURCE: Thomson Financial Services, special tabulations (June 2003).

Science and Engineering Indicators 2006

Figure 6-31
Venture capital disbursements, total and by company: 1990–2004



SOURCES: Thomson Financial Services, special tablulations (May 2005). See appendix tables 6-18 and 6-19.

Science and Engineering Indicators 2006

disbursements. Medical and health care-related companies received a high of almost 21% of venture capital in 1992 before dropping almost each year thereafter to just 5% in 1999 and to 4% in 2000.

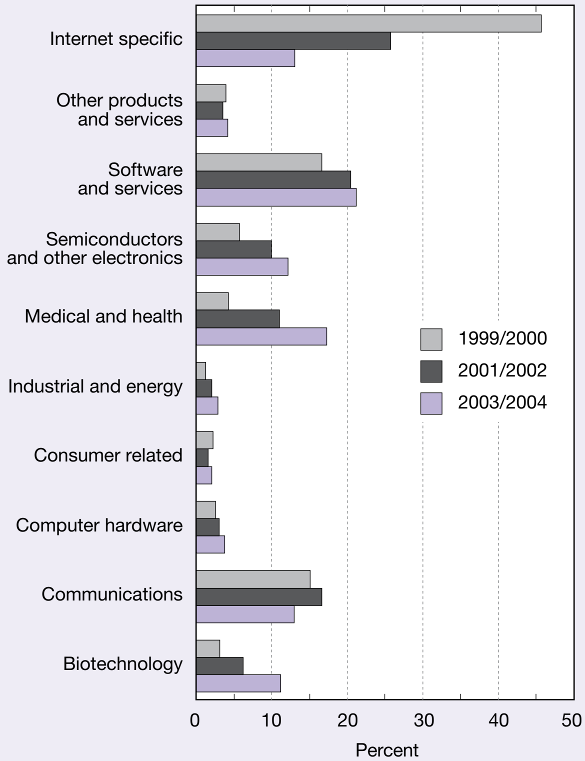
In the late 1990s, the Internet emerged as a business tool, and companies developing Internet-related technologies drew venture capital investments in record amounts. Beginning in 1999, investment dollars disbursed to Internet companies were classified separately, whereas before 1999, some of these funds were classified as going to companies involved in computer hardware, computer software, or communication technologies. Internet-specific businesses involved primarily in online commerce were the leading recipients of venture capital in the United States during the bubble years, collecting more than 40% of all venture capital funds invested each year. Software and software services companies received 15%–17% of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third with 14%–15%.

The U.S. stock market suffered a dramatic downturn after its peak in early 2000, with the sharpest drops in the technology sector. Led by a dot.com meltdown, technology stock valuations generally plummeted, and many Internet stocks were sold at just a fraction of their initial price. Venture capital investments, however, continued to favor Internet-specific companies over other industries in the postbubble period. During this period (2001–02), Internet companies received 28% and 21%, respectively, of the total venture capital dollars disbursed. Although a sharp drop from the previous 2 years, this still exceeded the amount received by any other industry area.

In 2003 and 2004, however, venture capital funds preferred other technology areas for investment, in particular software and medical/health companies, over Internet-specific companies. Software companies attracted the most venture capital in 2003 and 2004, receiving about 21% of the total invested each year. Companies in the medical/health field received 16% in 2003 and 18% in 2004. Internet-specific companies received about 13% of all money disbursed by venture capital funds in the latest 2 years (figure 6-32).

The decline in enthusiasm for Internet companies seems to have benefited other technology areas as well. Biotechnology companies were only attracting about 3% of total venture capital when Internet-specific companies were hot. Since 2000, however, biotechnology companies have gained steadily to receive 11% of total venture capital investments in 2003 and 2004, more than triple their share of 4% received in 1999 and 2000. Medical/health companies also have received higher shares, rising from a level of about 4% in 1999 and 2000 to an average of 11% in 2001 and 2002, and to 17% during 2003–04. Other industries attracting larger shares of the smaller pool of investment funds in the postbubble period are semiconductor and other electronics companies, and, to a lesser extent, industrial and energy companies.

Figure 6-32
U.S. venture capital disbursements, by industry: 1999–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-18.

Science and Engineering Indicators 2006

Venture Capital Investments by Stage of Financing

Investments made by venture capital firms can be categorized by the stage at which the financing is provided (Venture Economics Information Services 1999):

- **Seed financing** usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. It may support product development but is rarely used for marketing.
- **Start-up financing** provides funds to companies for product development and initial marketing. This type of financing usually is provided to companies that have just organized or that have been in business just a short time and have not yet sold their products in the marketplace. Generally, such firms already have assembled key management, prepared a business plan, and completed market studies.
- **First-stage financing** provides funds to companies that have exhausted their initial capital and need funds to initiate commercial manufacturing and sales.
- **Expansion financing** includes working capital for the initial expansion of a company, funds for major growth expansion (involving plant expansion, marketing, or development of an improved product), and financing for a company expecting to go public within 6–12 months.
- **Acquisition financing** provides funds to finance the purchase of another company.
- **Management and leveraged buyout** provides funds to enable operating management to acquire a product line or business from either a public or private company. Often these companies are closely held or family owned.

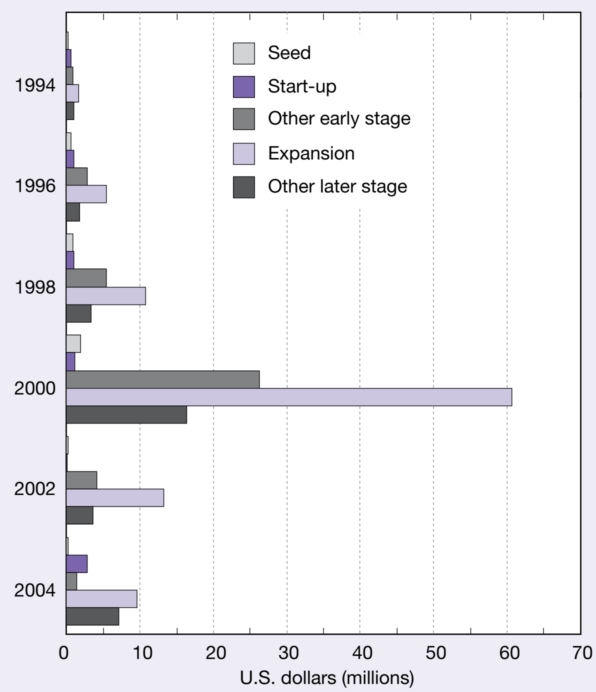
For this report, the first three types of funds are referred to as *early-stage* financing and the remaining three as *later-stage* financing.

Two patterns stand out when venture capital disbursements are examined by financing stage: (1) most funds' investment dollars are directed to later-stage investments, and (2) during the postbubble period, venture capital funds directed more money to later-stage investments than ever before.

Later-stage investments ranged from 50% to 80% of total venture capital disbursements, with the highest point reached in 2003 and the lowest point back in 1980. In 1999 and 2000, later-stage investments made up 72% of total disbursements, rising to 79%–80% in the postbubble period. Although early-stage, venture-backed investments as a share of total disbursements have gradually declined over time, during 2003–04 they fell to their lowest level ever (figure 6-33; appendix table 6-19).

The postbubble trend toward later-stage investing is also evident when analyzing the three early-stage categories. In

Figure 6-33
U.S. venture capital disbursements, by stage of financing: 1994–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-19.

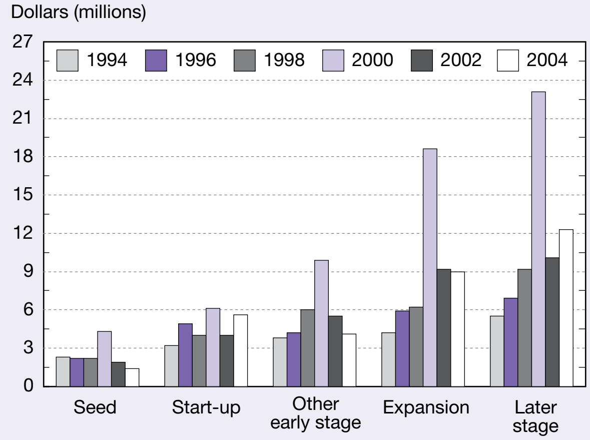
Science and Engineering Indicators 2006

2001 and 2002, seed and start-up financing were the hardest hit among the three early stages. During a period when venture capital became increasingly scarce, the highest-risk, early-stage projects suffered the most.

Expansion financing has typically been favored by venture capital funds. This stage alone accounts for more than half of all venture capital disbursements from 1997 through 2003. In 2000, the amount of venture capital invested to finance company expansions reached 57% of total disbursements. This upward trend continued into the postbubble period, with the share rising to 62% in 2002.

The latest data show two seemingly contrary trends. In 2003 and 2004, among the three early stages, venture capital is shifting to riskier start-up investments. Start-up financings jumped to 13% of total venture capital investments in both years. Conversely, later-stage financing investments are moving away from company expansions and toward even later-stage investments that involve acquisitions of existing companies (appendix table 6-19). These contrary trends may simply reflect companies' efforts to mitigate risk by rebalancing the stage diversification in their investment portfolio.

Figure 6-34
Value of average investment by venture capital funds, by stage of financing: 1994–2004



SOURCE: Thomson Financial Services, special tabulations (May 2005). See appendix table 6-19.

Science and Engineering Indicators 2006

Venture Capital as Seed Money

Contrary to popular perception, only a relatively small amount of dollars invested by venture capital funds ends up as seed money to support research or early product development. Seed-stage financing has never accounted for more than 8% of all venture capital disbursements over the past 23 years and most often has represented 1%–5% of the annual totals. The latest data show that seed financing represented just 1.3% in 2003 and less than 1% in 2004.

Over the past 25 years, the average amount invested in a seed-stage financing (per company) increased from a low of $700,000 in 1980 to a high of $4.3 million per disbursement in 2000. Since then, the average level of seed-stage investment has fallen steadily, providing just $1.8 million in 2003 and only $1.4 million in 2004 (figure 6-34).

Internet, communication, and computer software companies were the largest recipients of venture capital seed financing during the 1999 and 2000 bubble years. Internet companies were the preferred investment, receiving 58% of all disbursements in 1999 and 43% in 2000 (appendix table 6-20). In 2001 and 2002, seed investments going to Internet companies fell off considerably but still represented 21% of all such investments in 2001 and 7% in 2002. Most recently, Internet companies received 8% in 2003 and 13% in 2004.

As dot.com panic replaced dot.com mania, other technology areas attracted more attention. Medical and health care-related companies received 10% of seed money in 2001 and 20% in 2002, up from 4% and 5% during the bubble years. In 2003 and 2004, medical and health-related companies received more seed money than any other technology area. The share going to biotechnology companies rose to 5% in 2001 and 15% in 2002 and 2003. Semiconductor companies received 8% in 2001 and 15% in 2002, up from 4% in 1999. In 2004, semiconductor companies and software companies each received about 22% of venture capital seed money.

In sum, over the past 25 years, venture capital investment has consistently supported technology-oriented businesses, particularly companies and industries that develop and rely on information technologies. Although information technologies continue to attract the largest shares of total U.S. venture capital and seed money, life sciences (including medical, health, and biotechnology companies) have gained favor in the past few years.

Conclusion

The United States continues to rank high among the world leaders in major technology areas. Advances in U.S. biotechnology, computer, and telecommunication industries continue to influence new technology development and dominate technical exchanges between the United States and its trading partners. New data on patenting trends in the United States bear this out.

Although it also continues to be a leading provider of knowledge-intensive services, the United States may face greater competition in the near future as European countries devote more resources to service-sector R&D. For now, however, exports of U.S. technological know-how sold as intellectual property continue to exceed U.S. imports of technological know-how.

Asia's status as both a consumer and developer of high-technology products is advancing, enhanced by the technological development of many Asian economies, particularly Taiwan, South Korea, and China. Several small European countries, in particular Ireland, Finland, and the Netherlands, also exhibit strong national capacities to develop new technologies and to lead in global markets.

Current data on manufacturing output by high-technology industries in Asia and the several smaller European countries show that these industries already have a capacity to compete successfully with high-technology industries operating in the United States and other advanced countries. A leading indicator of future competition for U.S. industry, recent patenting trends show capacities for technology development growing and broadening within Asia and a transitioning Europe.

The U.S. trade balance in advanced technology products, historically a strong market segment for U.S. industry, has turned negative. Imports of technology products from Asia have grown to the point that they overwhelm trade surpluses with other world regions.

Despite the growing pressures of today's fast-moving global marketplace, the United States continues to be a leading developer and supplier of high-technology at home and abroad. Most likely this success has been influenced by a combination of factors: the nation's long commitment to S&T investments; the scale effects derived from serving a large, demanding domestic market; and the U.S. market's willingness to adopt new technologies. However, these same market dynamics already show signs of benefiting Asia and a more unified Europe and will likely continue to enhance the value of their investments in S&T in the future.

Notes

1. Educating for a workforce so that it can fully participate in an S&T-oriented economy is critical to its success. Three chapters of this report track trends in education: elementary and secondary education (chapter 1), higher education in S&E (chapter 2), and the S&E workforce (chapter 3).

2. This chapter presents data from various public and private sources. Consequently, the countries included vary by data source.

3. Other factors (e.g., business cycles, commodity shortages, international financial markets) also affect industry competitiveness but are not discussed in this chapter.

4. In designating these high-technology manufacturing industries, OECD took into account both the R&D done directly by firms and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct intensities were calculated as the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated by using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have equal or greater R&D intensities. See Godin (2004a) for additional perspectives on OECD's methodology.

5. One of the earliest quantitative analyses of R&D was done in 1955 by R.H. Ewell and the National Science Foundation. This study showed a definite correlation between research and productivity. Also see Godin (2004b).

6. This conclusion is derived from an examination of weighted U.S. data on average annual pay for 1997–2001 (BLS/OES).

7. Europe's success in growing its aerospace industry and China's efforts to develop a semiconductor industry are two examples.

8. Reported here are EU aggregate data from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

9. In 1999, the U.S. State Department's responsibilities under the International Traffic in Arms Regulation were expanded to include research activity formerly covered under the U.S. Commerce Department's export regulations. The transfer placed scientific satellites, related data, and certain computer components and software on the U.S. Munitions List. Related research activities and the country of origin of researchers working on related research activities also became subject to many of the same regulations controlling exports of sensitive products.

10. In February 1996, the Telecommunications Act became U.S. law. This Act was the first major telecommunications reform in more than 60 years. It facilitated competition between cable companies and telephone companies and may have contributed to increased U.S. manufacturing activity in both the communications and computer hardware industries.

11. The U.S. trade balance is affected by many other factors as well, including differing monetary policies and export subsidies between the United States and its trading partners.

12. To the extent that national markets are not open to foreign producers (i.e., if public procurement is reserved for domestic producers), these data will understate the export competitiveness of foreign producers.

13. Unlike the previous section that examined data on industry manufacturing value added (domestic content), the value of exports reported in this section reflects the final value of industry shipments exported, not just that resulting from domestic production. Exported shipments will, therefore, often include the value of purchased foreign inputs.

14. Like the United States, national governments usually have strong ties to the aerospace industry in their country, often supporting its development, funding R&D, and serving as a major customer for its products.

15. See OECD (2001) for discussion of classifying economic activities according to degree of "knowledge-intensity."

16. Compared to the extensive data available for the manufacturing industries, national data that track activity in many rapidly growing service sectors are limited in the level of industry disaggregation and types of data collected.

17. The U.S. dollar rose against other major currencies in the late 1990s and continued to rise until early 2002. The sharp rise in the U.S. dollar was a contributing factor in the broad-based decline in exports by U.S. manufacturers during 2000 to 2003. The U.S. export decline was also affected by slower rates of GDP growth experienced by some U.S. trading partners during that time, including the EU and Japan.

18. U.S. trade in software products is not a separate Advanced Technology Program (ATP) category in the official statistics but is included in the ATP category covering information and communications products. For this report, trade in software products is examined separately, creating an 11th category.

19. The U.S. government and U.S. corporations have long advocated the establishment and protection of intellectual property rights. The Office of the U.S. Trade Representative monitors countries with reported violations and reports on the status of intellectual property protection in its annual report, *Foreign Trade Barriers*.

20. Data presented in appendix table 6-7 only go back to 1987, but data held by the Bureau of Economic Analysis indicate that year-to-year increases date back to 1982. See Borga and Mann (2004).

21. An *affiliate* refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity in another country. The controlling interest for an incorporated business is 10% or more of its voting stock; for an unincorporated business, it is an interest equal to 10% of voting stock.

22. In addition, data on the destination of multinational corporate sales to foreign affiliates also suggest that market access is an important factor in the firms' decision to locate production abroad. See Borga and Mann (2004).

23. France also has been an important source of technological know-how over the years. In 1996, France was the leading European supplier to U.S. firms. Since then, data for France have been intermittently suppressed to avoid disclosing individual company operations. Data were last published for France in 2003 and showed an increase in U.S. purchases of French technological know-how compared with 2000 or 1996.

24. See chapter 2 for a discussion of international higher education trends and chapter 4 for a discussion of trends in U.S. R&D.

25. See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

26. See National Science Board 2002, vol. 1, figure 6-14: 6-17; and vol. 2, appendix table 6-5: A6-32.

27. The Harbison-Myers Skills Index, which measures the percentage of the population attaining secondary and higher education, was used for these education-based assessments. See appendix table 6-9 for complete source reference.

28. See Romer PM (1996). Why, indeed, in America? Theory, history, and the origins of modern economic growth. *American Economic Review* 86(2)(May):202–6; also see Freeman RB (2005). Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?, Working Paper 11457, National Bureau of Economic Research, June 2005, www.nber.org/papers/w11457; and Jacobson K (2005). China and India Are Poised to 'Leapfrog' U.S. in Innovation. *Manufacturing & Technology New* 12(14).

29. Rather than granting property rights to the *inventor* as is the practice in the United States and many other countries, some countries grant property rights to the *applicant*, which may be a corporation or other organization.

30. The number of U.S. patents granted jumped by 32% from 1997 to 1998. Although patent applications had been rising before that, the PTO attributes much of the increase in 1998 to greater administrative efficiency and the hiring of additional patent examiners.

31. U.S. universities and colleges owned about 1.9% of U.S. utility patents granted in 2001. The PTO counts these as being owned by corporations. For further discussion of academic patenting, see chapter 5.

32. Before 1990, data are provided as a total for the period 1963–1980. In U.S. PTO statistical reports, the ownership category breakout is independent of the breakout by country of origin.

33. The Bayh-Dole Act of 1980 (PL 96–517) permitted government grantees and contractors to retain title to inventions resulting from federally supported R&D and encouraged the licensing of such inventions to industry. The Stevenson-Wydler Technology Innovation Agreement of 1980 (PL 96–480) made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the mission of many government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 (PL 99-502) to provide additional incentives for the transfer and commercialization of federally developed technologies. In April 1987, Executive Order 12591 ordered executive departments and agencies to encourage and facilitate collaborations among federal laboratories, state and local governments, universities, and the private sector, particularly small business, to aid technology transfer to the marketplace. In 1996, Congress strengthened private-sector rights to intellectual property resulting from these partnerships. See chapter 4 for a further discussion of technology transfer and other R&D collaborative activities.

34. Although historically, U.S. patents awarded to all companies headquartered in Germany rank that country among the top five countries receiving U.S. patents, no single German company ranks among the top 10.

35. Some of the decline in U.S. patenting by inventors from the leading industrialized nations may be due to movement toward European unification, which has encouraged wider patenting within Europe.

36. As of September 30, 2004, the U.S. Patent and Trademark Office reports that average pendency is 27.6 months for utility, plant, and reissue patent applications. Applications for utility patents account for the overwhelming majority of these requests.

37. The additional expenses associated with applying for a patent in a foreign market may discourage weak foreign applications.

38. Information in this section is based on the U.S. PTO classification system, which divides patents into approximately 400 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared using an activity index. For any year, the activity index is the proportion of corporate patents in a particular class granted to inventors resident in a specific country divided by the proportion of all patents granted to inventors resident in that country. The activity indices are restricted to corporate patents to facilitate comparability between the United States and foreign countries because most U.S. patents granted to foreign inventors are filed by foreign corporations.

39. Trends reported in this section include all patents (i.e., utility, design, and plant patents), although most are utility patents otherwise known as patents for inventions. According to a recent report issued by the U.S. Patent and Trademark Office, biotechnology patents can span eight patent classes and describe subject matter related to bioinformatics, gene therapy, cellular immunology, and recombinant enzymes and proteins to name a few. See U.S. Patent and Trademark Office Technology Profile Report. 2004. Patent examining technology center, groups 1630–1660, biotechnology. Office of Electronic Information Products.

40. One seminal court decision opening the floodgate for biotechnology-related patents is the 1980 Supreme Court decision, *Diamond* v. *Chakrabarty,* which ruled that genetically engineered living organisms could be patented.

41. Patent data cover years 1977–2003.

42. The project is a collaboration among OECD, the National Science Foundation, the EU, the World Intellectual Property Organization, patent offices in the United States and Japan, and the European Patent Office. The database was developed by and is currently housed at OECD.

43. Up until March 2001, only patents granted in the United States were published. Technically, the data set counts those inventions for which patent protection is sought in Europe and Japan and obtained in the United States.

44. Although patents granted in one country do not offer any protection under another country's intellectual property laws.

45. Data presented here are compiled by Thomson Financial Services for the National Venture Capital Association. These data are obtained from a quarterly survey of venture capital practitioners that include independent venture capital firms, institutional venture capital groups, and recognized corporate venture capital groups. Information is at times augmented by data from other public and private sources.

46. Recent reports from the National Venture Capital Association show that new money coming into venture capital funds slowed down during the last quarter of 2000, following several quarters of lackluster returns to investors in venture capital funds. See National Venture Capital Association, "Venture capital fundraising slows in fourth quarter, but hits new record for the year," press release, February 23, 2001.

47. Under the Department of Labor "Prudent Person" standard, "A fiduciary must discharge his or her duties in a prudent fashion." For pension fund managers, the standard emphasizes how prudent investors balance both income and safety as they choose investments. The website www.investorwords.com describes the Prudent Man Rule as the fundamental principle for professional money management stated by Judge Samuel Putnam in 1830 *(Supreme Court of Massachusetts in Harvard College* v. *Armory):* "Those with responsibility to invest money for others should act with prudence, discretion, intelligence, and regard for safety of capital as well as income."

Glossary

Activity index: Proportion of corporate patents in a particular class granted to inventors resident in a specific country divided by the proportion of all patents granted to inventors resident in that country.

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Gross value-added: Gross output minus the cost of purchased intermediate inputs and supplies.

Intellectual property: Intangible property that is the result of creativity; the most common forms of intellectual property include patents, copyrights, trademarks, and trade secrets.

"Not obvious": One criterion (along with new and useful) on which an invention is judged to determine its patentability.

Triadic patent family: An invention for which patent protection is sought in the United States, Europe, and Japan.

References

Aerospace Industries Association (AIA). 2005. *Aerospace Facts and Figures 2004/2005*.

Allison JR, Lemley MA, Moore KA, Trunkey RD. 2003. *Valuable Patents*. Research Paper No. 03–31, Social Science Research Network Electronic Paper Collection. Arlington, VA: George Mason University School of Law. http://papers.ssrn.com/abstract=426020. Accessed 22 June 2005.

Borga M, Mann M. 2004. U.S. international services: Cross-border trade in 2003 and sales through affiliates in 2002. *Survey of Current Business* October:25–31.

Borga M, Mann M. 2002. U.S. international services: Cross-border trade in 2001 and sales through affiliates in 2000. *Survey of Current Business* October:76–7.

Branscomb LM, Keller JH. 1998. *Investing in Innovation: Creating a Research and Innovation Policy that Works.* Cambridge, MA: MIT Press.

Council on Competitiveness. 2001. *U.S. Competitiveness 2001: Strengths, Vulnerabilities and Long-Term Priorities.* Washington, DC.

Evangelista R, Sirilli G, Smith K. 1998. Measuring innovation in services. Paper series 6, Board on Science, Technology, and Economic Policy, Washington, DC: National Research Council.

Godin B. 2004a. The New Economy: What the concept owes to the OECD. *Research Policy* 33:679–90.

Godin B. 2004b. The obsession for competitiveness and its impact on statistics: The construction of high-technology indicators. *Research Policy* 33:1217–29.

National Research Council (NRC). 2004. *A Patent System for the 21st Century.* Merrill SA, Levin RC, Myers MB, editors. Committee on Intellectual Property Rights in the Knowledge-Based Economy. Washington, DC: National Academies Press.

National Research Council (NRC), Hamburg Institute for Economic Research, Kiel Institute for World Economics. 1996. *Conflict and Cooperation in National Competition for High-Technology Industry*. Washington, DC: National Academy Press.

National Science Board (NSB). 2002. *Science and Engineering Indicators 2002.* NSB–02–1. Arlington, VA: National Science Foundation.

National Venture Capital Association. 2002. *The Economic Impact of the Venture Capital Industry on the U.S. Economy.* DRI-WEFA, A Global Insight Company. http://www.nvca.org. Accessed February 2003.

Organisation for Economic Co-operation and Development (OECD). 1996. *Structural Analysis Database for Industrial Analysis.* Paris: Directorate for Science, Technology, and Industry/Economic Analysis Statistics.

Organisation for Economic Co-operation and Development (OECD). 2001. *Knowledge-Based Industries.* Paris: Directorate for Science, Technology, and Industry/Economic Analysis Statistics.

Porter AL, Roessner JD. 1991. *Indicators of National Competitiveness in High Technology Industries.* Final Report to the Science and Engineering Indicators Studies Group, two volumes. Atlanta: National Science Foundation.

PRS Group. 2002. Political and economic forecast table. *Political Risk Lette*r. http://www.prsgroup.com. Accessed March 2002.

Roessner JD, Porter AL, Xu H. 1992. National capacities to absorb and institutionalize external science and technology. *Technology Analysis & Strategic Management* 4(2).

Tassey G. 2000. *R&D and Long-Term Competitiveness: Manufacturing's Central Role in a Knowledge-Based Economy.* Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology.

Tassey G. 2004. Policy issues for R&D investment in a knowledge-based economy. *Journal of Technology Transfer* 29:153–85.

Thomson Financial Venture Economics. 2002. *2002 National Venture Capital Association Yearbook.* New York.

Venture Economics Information Services. 1999. *1999 National Venture Capital Association Yearbook.* Arlington, VA: National Venture Capital Association.