Chapter 6
Industry, Technology, and the Global Marketplace

Highlights....6-4
Introduction....6-6
  Chapter Overview....6-6
  Chapter Organization....6-6
U.S. Technology in the Marketplace....6-6
  Importance of High-Technology Industries....6-7
  Share of World Markets....6-8
  Global Competitiveness of Individual Industries....6-10
  Exports by High-Technology Industries....6-11
  Global Business in Knowledge-Intensive Service Industries....6-13
  U.S. Royalties and Fees Generated From Intellectual Property....6-13
New High-Technology Exporters....6-15
  National Orientation....6-16
  Socioeconomic Infrastructure....6-16
  Technological Infrastructure....6-16
  Productive Capacity....6-16
  Findings From the Four Indicators....6-18
International Trends in Industrial R&D....6-18
  R&D Performance by Industry....6-19
Patented Inventions....6-20
  U.S. Patenting....6-21
  Trends in Applications for U.S. Patents....6-24
  Technical Fields Favored by Foreign Inventors....6-25
  Patent Activity Outside the United States....6-26
Venture Capital and High-Technology Enterprise....6-27
  U.S. Venture Capital Resources....6-28
  Boom and Bust in New Venture Capital Commitments....6-29
  Venture Capital Investments by Stage of Financing....6-30
Characteristics of Innovative U.S. Firms....6-32
  Why Study IT-Based Innovation?....6-32
  Survey Results....6-33
Conclusion....6-36
References....6-37

List of Sidebars

U.S. High-Technology Industries Add More Value During Production Than Other U.S. Manufacturing Industries....6-9
U.S. Industry Continues to Invest in IT....6-10
New Database May Help to Identify Important Inventions....6-22
Top Patenting Corporations....6-23
U.S. Government Support for Small Technology Businesses....6-31
Description of U.S. IT Innovation Survey Sample and Response....6-33

List of Tables

Table 6-1. Classification of manufacturing industries based on average R&D intensity: 1991–97 6-7
Table 6-2. Triadic patent families, by inventor and applicant (owner) place of residence and priority year: 1988–98 6-22
Table 6-3. Top patenting corporations: 1977–96 and 2001 6-23
Table 6-4. Top 15 most emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 2001 6-26
Table 6-5. Top 15 most emphasized U.S. patent classes for corporations from South Korea and Taiwan: 2001 6-27
Table 6-6. New capital committed to U.S. venture capital funds: 1980–2002 6-28
Table 6-7. Capital commitments, by limited partner type: 1990–2002 6-29
Table 6-8. Federally and privately funded early-stage venture capital 6-31
Table 6-9. Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by industry and revenue size: 2001 6-34

List of Figures

Figure 6-1. Global industry sales, average annual growth rate, by sector: 1990–2001 6-8
Figure 6-2. High-technology industry share of total manufacturing output in selected countries: 1980–2001 6-8
Figure 6-3. Value added by U.S. industries as percentage of gross output: 1980–2001 6-9
Figure 6-4. Value added in Singapore and Malaysian industries as percentage of gross output: 1990–2001 6-9
Figure 6-5. Country share of global high-technology market in selected countries: 1980–2001 6-10
Figure 6-6. Industry spending on capital equipment: 1990–2002 6-10
Figure 6-7. U.S. global market share, by high-technology industry: 1980–2001 6-11
Figure 6-8. U.S. exports as percentage of gross output: 1980–2001 6-11
Figure 6-9. High-technology exports in selected countries: 1980–2001 6-12
Figure 6-10. World exports in high-technology industries in selected countries: 2001 6-12
Figure 6-11. Global revenues generated by five knowledge-intensive service industries in selected countries: 2001 6-13
Figure 6-12. U.S. trade balance of royalties and fees: 1987–2001 6-14
Figure 6-13. U.S. royalties and fees generated from exchange of industrial processes between unaffiliated companies in selected countries: 2001 6-14
Figure 6-14. Leading indicators of technological competitiveness in selected countries: 2002 6-17
Figure 6-15. Composite scores for four leading indicators in selected countries: 1999 and 2002 6-18
Figure 6-16. U.S. industrial R&D performance: 1987–2000 6-19
Figure 6-17. Japan industrial R&D performance: 1987–2000 6-20
Figure 6-18. European Union industrial R&D performance: 1992–99 6-20
Figure 6-19. U.S. patents granted, by residence of inventor: 1986–2001 6-21
Figure 6-20. U.S. patents granted to foreign inventors in selected countries, by residence of inventor: 1986–2001 6-24
Figure 6-21. U.S. patent applications, by residence of inventor: 1989–2001 6-24
Figure 6-22. U.S. patent applications filed by selected foreign inventors, by residence of inventor: 1989–2001 6-25
Figure 6-23. Patents granted to nonresident inventors in selected countries: 1985, 1990, and 2000 6-27
Figure 6-24. Patents granted to residents of United States, Japan, and Germany in selected countries: 2000 6-28
Figure 6-25. U.S. venture capital disbursements, by industry: 1999–2000 and 2001–2002 6-30
Figure 6-26. U.S. venture capital disbursements, by stage of financing: 1992–2002 6-30

Figure 6-27. Value of average investment by venture capital funds, by stage of financing: 1992–2002 6-32
Figure 6-28. Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by sector: 2001 6-34
Figure 6-29. Type of innovation contributing most to company revenue, by sector: 2001 6-35
Figure 6-30. Internal and external factors contributing to IT-based innovation: 2001 6-35

Highlights

U.S. Technology in the Marketplace

- **High-technology industries are driving economic growth around the world.** The global market for high-technology goods is growing faster than that for other manufactured goods. Over the past 22 years (1980–2001), output by high-technology manufacturing industries grew at an inflation-adjusted average annual rate of 6.5 percent. Output by other manufacturing industries grew at just 2.4 percent.
- **The United States continues to be the leading producer of high-technology products and is responsible for about one-third of the world's production.** In 2001, U.S. high-technology industries accounted for 32 percent of world output.
- **The market competitiveness of individual U.S. high-technology industries varies, although each maintained strong market positions over the 22-year period examined.** Competitive pressure from a growing number of technology-producing nations has led to a reduction or flattening of U.S. market share in recent years. Between 1998 and 2001, U.S. industry lost world market share in computers and office machinery and communication equipment, maintained a rather stable market share in aerospace and pharmaceuticals, and gained market share in scientific instruments.
- **Technology products account for a larger share of U.S. exports than imports, thereby making a positive contribution to the overall U.S. trade balance.** U.S. high-technology industries contributed to the strong export performance of the nation's manufacturing industries. In 2001, exports by U.S. high-technology industries accounted for 17 percent of world high-technology exports.
- **Knowledge-intensive service industries fueled service-sector growth around the world.** Global sales in knowledge-intensive service industries exceeded $12.3 trillion in 2001, up from $8.0 trillion in 1990. The United States was the leading provider of knowledge-intensive services, responsible for between 32 and 34 percent of world revenue totals during the 22-year period examined.
- **The United States is a net exporter of 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 2001, U.S. receipts from the licensing of technological know-how to foreigners totaled $4.9 billion, 24.4 percent higher than in 1999.

New High-Technology Exporters

- **Based on a model of leading indicators, Ireland and Israel appear to be headed toward prominence as technology developers and exporters in the global market.** In a group of 15 small or less-advanced countries, Ireland received the highest score in three of the four leading indicators and the second-highest score in the fourth. Israel, China, and Hungary also posted strong scores on several indicators.

International Trends in Industrial R&D

- **Internationally comparable data show a resurgence in service-sector R&D in several industrialized countries.** In 2000, service-sector industries, such as those involved in computer software development, accounted for 34 percent of all R&D performed by industry in the United States—nearly double their share in 1996. Large increases in service-sector R&D are also apparent in many European Union (EU) countries, especially Italy, the United Kingdom, and France.
- **In many industrialized countries, aerospace, motor vehicle, electronic equipment, and chemical industries conduct the largest amounts of R&D.** In the United States, industries that provide computer services and manufacture electronic equipment and industrial chemicals led the nation in R&D. In Japan, the electronic equipment industry conducted the most R&D throughout the period reviewed, followed by the chemical and motor vehicle industries. Manufacturers of industrial chemicals, motor vehicles, and electronic equipment were consistently among the top five performers of R&D in the EU.

Patented Inventions

- **In 2001, more than 166,000 patents were issued in the United States, 5 percent more than a year earlier.** U.S. resident inventors received nearly 88,000 new patents in 2001, which accounted for about 53 percent of total patents granted.
- **Patenting in the United States by foreign investors remains highly concentrated by country of origin.** From 1963 to 2001, Japan and Germany accounted for 56 percent of U.S. patents issued to foreign inventors, and the top four countries—Japan, Germany, France, and the United Kingdom—accounted for 72 percent. In 2000 and 2001, residents of Taiwan were awarded more U.S. patents than residents of France or the United Kingdom.

- **Recent U.S. patents issued to foreign inventors emphasize several commercially important technologies.** Japanese patents focus on consumer electronics, photography, photocopying and, more recently, computer technology. German inventors are developing new products and processes associated with heavy industry, such as motor vehicles, printing, advanced materials, and manufacturing technologies. Taiwanese and South Korean inventors are earning more U.S. patents in communication and computer technology.

Venture Capital and High-Technology Enterprise

- **Investor commitments to venture capital funds fell sharply, especially when compared with the large amounts of money committed during the *bubble years* (1999 and 2000).** In 1999, new commitments to venture capital funds jumped to $62.8 billion, a 111 percent gain from the previous year. By 2000, new commitments reached $105.8 billion, more than 10 times the inflow of new investor money recorded in 1995. In 2001, the inflow of new money dropped by more than 64 percent, to $37.9 billion, and totaled just $7.7 billion in 2002.
- **Internet companies continued to attract more venture capital than any other technology area in the postbubble period.** In 2001 and 2002, venture capital firms disbursed $62 billion, with more than one-fourth of this total still invested in Internet firms.
- **Not all venture capital is seed money.** During the past 10 years, money invested with entrepreneurs to prove a concept or to support early product development never accounted for more than 8 percent of total venture capital disbursements by venture capital funds and most often made up only 2 to 5 percent of the annual totals. The latest data show that the share of all venture capital classified as seed financing represents just 1 percent of total disbursements in 2001 and 2002, down from about 2 percent in 1999 and 2000.

Characteristics of Innovative U.S. Firms

- **A recent survey examining innovative activities in which information technology (IT) was a significant or critical component in developing new products or processes found that nearly half (48 percent) of responding firms developed an IT-based innovation within the past year or expected to develop one within 12 months.** Surprisingly, U.S. companies providing computer-related services were more innovative than companies manufacturing computer hardware.
- **Process innovation appears to generate more revenue for innovative firms than does product innovation.** When innovative firms were asked to identify the type of innovation (product or process) that contributed most to company revenue, the number of firms identifying process innovations outnumbered the number of firms identifying product innovations by almost 60 percent.
- **R&D continues to be important to the innovation process.** According to survey respondents, 41 percent of innovators reported that in-house R&D made a large contribution to their IT-based innovation, 31 percent said that conducting R&D was a very important part of their growth strategy, and 20 percent indicated that outsourced R&D made a large contribution toward IT-based innovation.
- **Most responding firms indicated that IT was important in conducting business.** Those firms identified as innovators placed even more emphasis on IT, with nearly 74 percent of innovators saying it was very important to their business. Firms viewed IT goods and services as very important for increasing productivity, facilitating communication, and reducing costs.

Introduction

Chapter Overview

A nation's competitiveness is often judged by its ability to both produce goods that find demand in the global marketplace and to simultaneously maintain—if not improve—the standard of living among its citizens. Science and engineering and the technological developments that emerge from S&E activities enable high-wage nations like the United States to compete with low-wage nations in today's highly competitive global marketplace. Although the U.S. economy continues to rank among the world's largest, and Americans continue to enjoy a high standard of living, many other parts of the world have advanced their technological capacity and increasingly challenge U.S. prominence in many technology areas.

This chapter focuses on industry's vital role in the nation's science and technology (S&T) enterprise and how the nation develops, uses, and commercializes the investments made in S&T by industry, academia, and government. It presents various indicators tracking the U.S. industry's national activity and its standing in the international marketplace for technology products and services, technology development, and industrial research and development performance. 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.[1]

Past assessments showed the United States to be a leader in many technology areas. In the chapter prepared for *Science & Engineering Indicators – 2002*, it was shown 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 2004 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, updates to the Georgia Institute of Technology high-technology indicators model that identifies developing nations with increased technology capacities, and selected data from a recently completed survey of information technology (IT)-based innovation by the National Science Foundation (NSF).

Chapter Organization

This chapter begins with a review of industries that rely heavily on R&D, referred to herein as *high-technology industries.* No single authoritative methodology exists for identifying high-technology industries. Most calculations rely on a comparison of R&D intensities, typically determined by comparing industry R&D expenditures or the numbers of technical people employed (e.g., scientists, engineers, technicians) with the value R&D adds to the industry or the total 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 high R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also employ and help train new scientists, engineers, and other technical personnel. Thus, the market competitiveness of a nation's technological advances, as embodied in new products and processes associated with high-technology 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 industry is assessed through an examination of domestic and worldwide market share trends. Data on royalties and fees generated from U.S. imports and exports of technological know-how—sold or rented as intangible (intellectual) property—are used to gauge U.S. competitiveness. Also discussed are indicators designed to identify developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.

This chapter also explores several leading indicators of technology development by examining the changing emphases in industrial R&D in major industrialized countries and comparing U.S. patenting patterns with those of other nations. In addition, the disbursement of venture capital in the United States, which is money used in the formation and expansion of small high-technology companies, is examined by both the stage of development in which financing is awarded and the technology area receiving funds. The chapter concludes with a discussion of summary results from NSF's Information Technology Innovation Survey.

U.S. Technology in the Marketplace

Most countries acknowledge a symbiotic relationship between investment in S&T and success in the marketplace: S&T supports competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, the nation's economic health is a performance measure for the national investment in R&D and S&E.

OECD currently identifies five industries as high technology (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,

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

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

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

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

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

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

SOURCES: Organisation for Economic Co-operation and Development, ANBERD and STAN databases, May 2001.

Science & Engineering Indicators – 2004

precision, and optical) instruments.[2] These five industries, identified as the most R&D intensive by OECD, are also the most R&D intensive for the United States (table 6-1).

This section reviews the U.S. position in the global marketplace from several vantage points: its position in the high-technology product market, the competiveness of individual industries, and trends in U.S. exports and imports of technological know-how.

[2]In designating these high-technology industries, OECD took into account both direct and indirect R&D intensities 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 (PPPs) 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).

Importance of High-Technology Industries

High-technology industries are important to nations for several reasons. High-technology firms innovate, 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; and Tassey 2000). High-technology firms develop high value-added products and are successful in foreign markets, which results in greater compensation for their employees. Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business, and create high-wage jobs.

According to the Global Insight World Industry Service database, which provides production data for 70 countries that account for more than 97 percent of global economic activity, the global market for high-technology goods is growing at a faster rate than that for other manufactured goods, and high-technology industries are driving economic growth around the world. During the 22-year period examined (1980–2001), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.5 percent compared with 2.4 percent for other manufactured goods. Global economic activity was especially strong at the end of the period (1996–2001), when high-technology industry output grew at 8.9 percent per year, more than double the rate of growth for all other manufacturing industries (figure 6-1 and appendix table 6-1). Output by the five high-technology industries represented 7.7 percent of global production of all manufactured goods in 1980; by 2001, it doubled to 15.8 percent.

During the 1980s, the United States and other high-wage countries committed to increasing the resources used in the manufacture of higher value-added, technology-intensive goods, often referred to as *high-technology manufactures.* (See sidebar, "U.S. High-Technology Industries Add More Value During Production Than Other U.S. Manufacturing Industries.") During this period, the United States led the major industrialized countries in concentration on high-technology manufactures. In 1980, high-technology manufactures accounted for about 10 percent of total U.S. production. By 1984, it had increased to 13 percent and in 1989 was nearly 14 percent. By contrast, high-technology manufactures represented about 12 percent of total Japanese production in 1989, up from 7.3 percent in 1980. European nations also saw high-technology manufactures account for a growing share of their total production, although to a lesser degree. The one exception was the United Kingdom, where high-technology manufactures rose from 9 percent of total manufacturing output in 1980 to 12.5 percent in 1989.

The major industrialized countries continued to emphasize high-technology manufactures throughout the 1990s (figure 6-2 and appendix table 6-1). In 1999, high-technology manufactures were estimated to be 20.9 percent of manufacturing output in the United States, 17.0 percent in the United Kingdom, 16.2 percent in France, 15.8 percent in Japan, and 9.3 percent in Germany. The latest data through 2001 show output in high-technology industries continued to grow faster than output in other manufacturing industries in the United States, Germany, and France, while slowing somewhat in Japan and the United Kingdom.

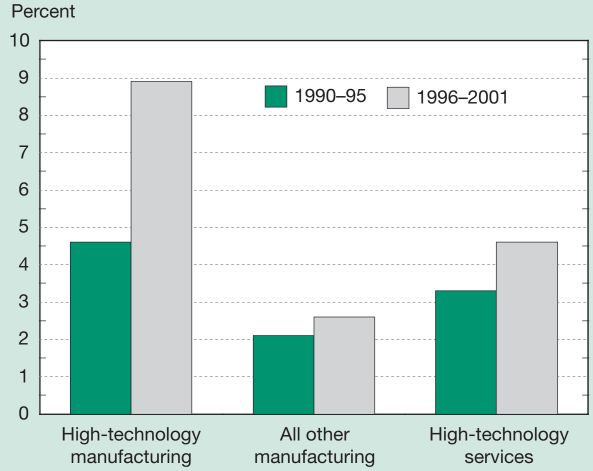
Taiwan and South Korea typify how important R&D-intensive industries are to newly industrialized economies. In 1980, high-technology manufactures accounted for 8.2 percent of Taiwan's total manufacturing output; this proportion jumped to 12.4 percent in 1989 and reached 29.2 percent in 2001. The transformation of South Korea's manufacturing base is even more striking. High-technology manufacturing in South Korea accounted for 6.1 percent of total output in 1980, 10.0 percent in 1989, and 31.0 percent in 2001.

Share of World Markets

From 1980 through 2001, the United States has consistently been the world's leading producer of high-technology products. U.S. high-technology industries' shares of world output fluctuated between 29 and 33 percent, rising slightly in the late 1990s before falling in 2000 and 2001. In 2001, U.S. high-technology industries accounted for about 32 percent of world output.

The EU lost high-technology market share gradually during the 1980s and 1990s. High-technology industries in the EU's 15 nations accounted for 22.8 percent of world output in 2001, which was a small increase from 2000 but generally reflects a persistent decline in the European share since the early 1980s. Among the four large EU countries, the United Kingdom, Germany, and Italy each recorded smaller shares,

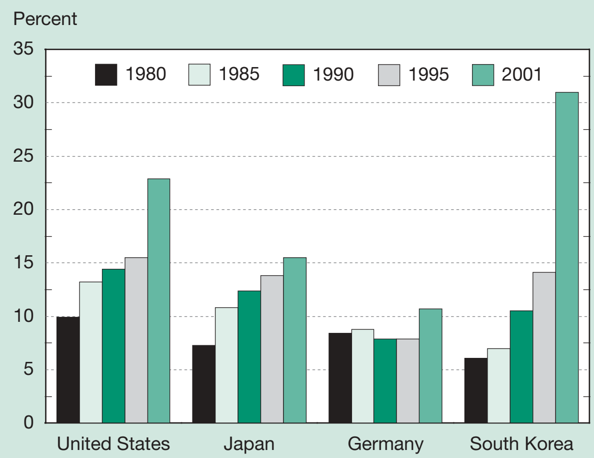
Figure 6-1
Global industry sales, average annual growth rate, by sector: 1990–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

Figure 6-2
High-technology industry share of total manufacturing output in selected countries: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

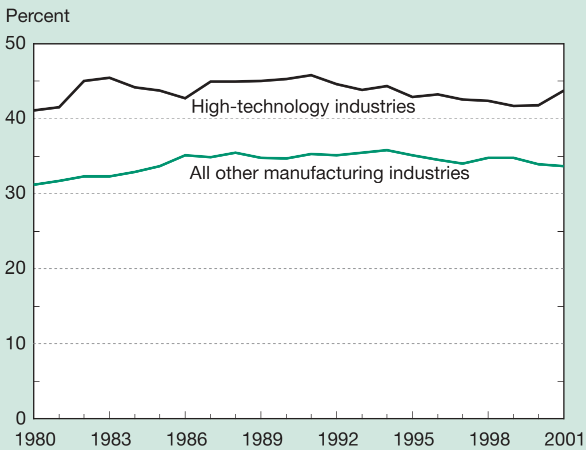
U.S. High-Technology Industries Add More Value During Production Than Other U.S. Manufacturing Industries

Historically, manufacturing has incorporated processes and production steps that occur in different locations, at different times, and in different countries. In today's highly competitive global marketplace, manufacturers in countries with high standards of living and labor costs have increasingly 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 show greater levels of "in-house" production (value added) in the final product than other manufacturing industries. In the United States, high-technology industries reported about 30 percent more value added than other manufacturing industries (figure 6-3). High-technology industries also generally pay their workers higher wages than they would receive in other manufacturing industries.

Gross value added in this summary equals gross output minus the cost of intermediate inputs and supplies. That is, value added is the amount of revenue generated by product sales that is available to pay wages, interest on loans, rents, and profits to the business owners after production costs are paid.

Value added can be an important indicator 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 corporations are transferring technological and manufacturing know-how to the host country. For example, Singapore and Malaysia have actively pursued policies that encourage foreign investment with the expectation that, over time, domestic content would grow larger. As shown in figure 6-4, the amount of value added by manufacturing industries in those two countries, as measured by value added as a percentage of the value of final output, has fluctuated over time but generally increased in both high-technology and other manufacturing industries.

Figure 6-3
Value added by U.S. industries as percentage of gross output: 1980–2001

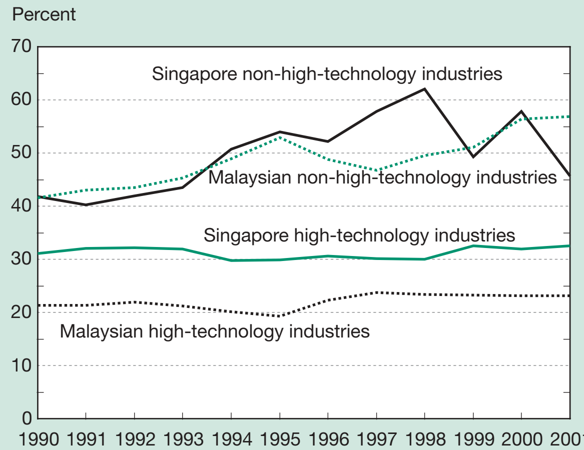


NOTE: Conceptually, value added is the value of final production less the value of purchased inputs used in the production process.

SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

Figure 6-4
Value added in Singapore and Malaysian industries as percentage of gross output: 1990–2001



NOTE: Conceptually, value added is the value of final production less the value of purchased inputs used in the production process.

SOURCE: Global Insight Inc. World Industry Service database, 2003. See appendix table 6-1.

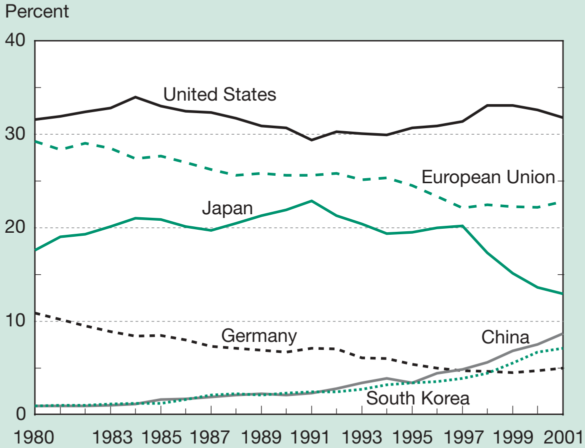
Science & Engineering Indicators – 2004

although Germany reversed its decline somewhat from 1999 to 2001. Only France gained market share over the 22-year period examined, and in 2001, it led EU countries with a 5.5 percent share. Germany accounted for 5.0 percent and the United Kingdom for 4.1 percent. Italy's shares were the lowest among the four large European economies, ranging from a high of about 3.5 percent during the mid-1980s to a low of about 1.8 percent in 2000 and 2001.

Asia's market share grew over the past 2 decades, led first by Japan in the 1980s and then by South Korea and China in the 1990s. In 1989, Japan accounted for 21.3 percent of the world's production of high-technology products, moving up 4 percentage points from its 1980 share. Japan continued to gain market share through 1991. Since then, however, its market position has deteriorated, with the steepest declines evident after 1997. In 2001, Japan's share fell to 12.9 percent, its lowest level in the 1980–2001 period examined (figure 6-5).

As Japan's dominance waned, developing Asian nations made dramatic gains. South Korea's market share more

Figure 6-5
Country share of global high-technology market in selected countries: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

than doubled during the 1980s, moving from 0.9 percent in 1980 to 2.1 percent in 1989, and then increased each year throughout the 1990s. By 2000, it had jumped to 6.5 percent, and by 2001 it measured 7.1 percent, its highest level in the 22 years examined. The growth in China's high-technology output surpassed that of South Korea. In 1980, China's high-technology industry produced just 0.9 percent of the world's output. That figure rose to 2.2 percent in 1989, 5.5 percent in 1999, and 8.7 percent in 2001.

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, market positions between 1980 and 2001. The United States is a large and mostly open market, characteristics that benefit U.S. high-technology producers in two important ways. First, supplying a market with many consumers results in scale effects for U.S. producers because there are potentially large rewards for new ideas and innovations (Romer 1996). 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.

Two U.S. high-technology industries, computers and office machinery and communication equipment, reversed downward trends resulting from competitive pressures from a growing cadre of high-technology-producing nations during the 1980s. These industries gained market share in the mid- to late 1990s in part due to increased capital investment by U.S. businesses. (See sidebar, "U.S. Industry Continues to Invest in IT.")

Since 1997, the United States has been the leading supplier of office and computer machinery in the global market, overtaking longtime leader Japan. The EU, led by Germany, was the dominant producer for most of the 1980s before relinquishing the lead to Japan in 1988. Among developing countries, China and South Korea showed rapid and consistent growth in global market share, especially in the late 1990s.

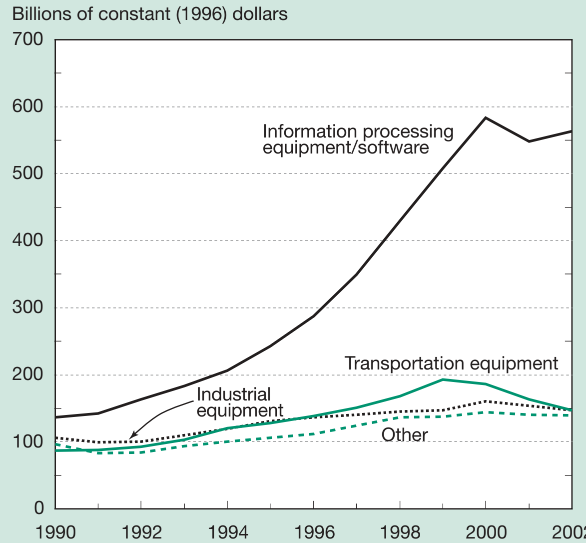
U.S. Industry Continues to Invest in IT

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

Throughout the period 1990–2002, U.S. industry purchases of IT equipment and software exceeded industry spending on all other types of capital equipment (figure 6-6). 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 it exceeded combined industry spending on industrial, transportation, and all other equipment.

Despite the economic downturn that began in spring of 2000, U.S. companies continued to invest heavily in IT. Industry spending on IT equipment and software accounted for 44 percent of all nonresidential investment (including structures and equipment) by industries in 2000, and about 48 percent in 2002.

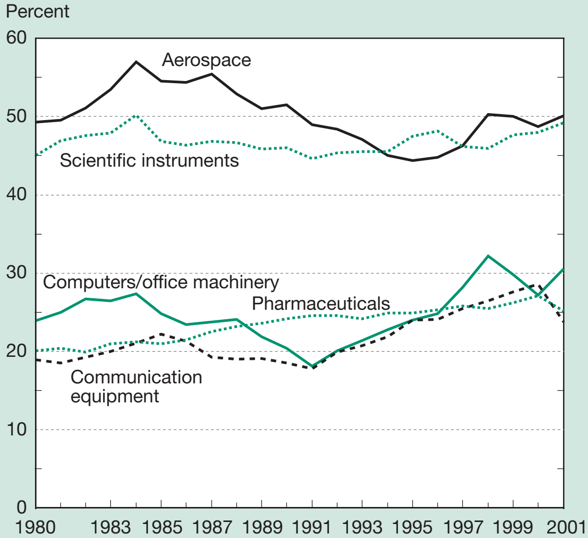
Figure 6-6
Industry spending on capital equipment: 1990–2002



SOURCE: U.S. Bureau of Economic Analysis, http://www.bea.doc.gov/bea/dn/nipaweb/TableViewFixed.asp?SelectedTable=68&FirstYear=2002&LastYear=2003&Freq=Qtr

Science & Engineering Indicators – 2004

Figure 6-7
U.S. global market share, by high-technology industry: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

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, U.S. manufacturers once again became the leading producer of communication equipment in the world and have since retained that position. In 2001, the latest year for which data are available, the United States accounted for approximately 24 percent of world production of communication equipment, down from 29 percent in 2000 (figure 6-7 and appendix table 6-1).

Aerospace, the U.S. high-technology industry with the largest world market share, was the only industry to lose market share during the 1990s. During the early 1980s, the U.S. aerospace industry consistently gained market share, peaking at 57 percent in 1984. Since then, the U.S. share of this market has generally declined, falling to 51 percent in 1989 and to about 44 percent in 1995. The industry recovered somewhat during the following 3 years, then leveled off at about a 50 percent share in 2001. European aerospace industries made some gains during this time, particularly in France. After fluctuating between 7 and 10 percent during the 1980s, the French aerospace industry slowly gained market share for much of the 1990s. In 2000, France supplied 12.8 percent of world aircraft shipments; in 2001, that figure reached 13.5 percent. The EU as a whole accounted for 30.2 percent of world aircraft shipments in 2001. China's aerospace industry also grew relatively sharply. In 1980, China's aerospace industry output accounted for less than 1 percent of world output; by 1989, its market share rose to 1.5 percent. A succession of year-to-year gains from 1992 through 1997 then lifted its market share to 5.8 percent, and in 2000 and 2001 it stood at 6.5 percent. Brazil exhibited a very different trend. Brazil accounted for 14.9 percent of world aerospace production in 1980, 10.2 percent in 1989, and 2.8 percent in 2001.

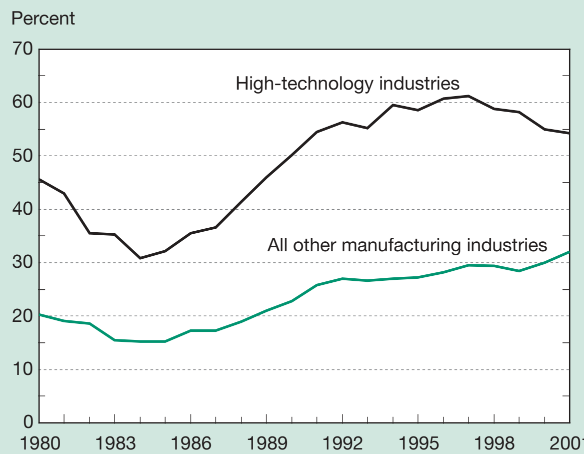
The EU was the leading producer of drugs and medicines in the world market for the entire 22-year period examined and accounted for 30–34 percent of global shipments. France is the leading producer among the four largest EU member nations. The U.S. market share grew irregularly, from 20 percent in 1980 to 24 percent in 1990, and to 25 percent in 2001. Different national laws governing the distribution of foreign pharmaceuticals make this industry unique compared with other high-technology industries. For this industry, domestic population dynamics may play a more important role than global market forces and affect the demand for a country's pharmaceutical products.

The 2001 addition of the scientific instruments industry (medical, precision, and optical instruments) to the group of high-technology industries reflects the industry's high level of R&D in advanced nations (table 6-1). From 1980 through 2001, the United States was the leading producer of scientific instruments. In 2001, the United States accounted for 49.3 percent of global industry shipments, up from 46.0 percent in 1990 and 45.1 percent in 1980. The EU, led by Germany and France, ranked second, accounting for 28–31 percent of global shipments.

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 trade deficits highlight the need to serve foreign markets as well. Traditionally, U.S. high-technology industries have been more successful exporting their products than other U.S. industries, and therefore can play a key role in returning the United States to a more balanced trade position (figure 6-8).

Figure 6-8
U.S. exports as percentage of gross output: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

Foreign Markets

Despite its domestic focus, the United States was an important supplier of manufactured products to foreign markets throughout the 1980–2001 period. Throughout the 1990s and continuing through 2001, U.S. industry supplied 13–14 percent of the world's general manufacturing exports. It ranked second only to the EU in its share of world exports. If intra-EU shipments were excluded, the United States would likely rank above the EU.

Exports by U.S. high-technology industries grew rapidly during the mid-1990s and contributed to the nation's strong export performance (figure 6-9). During the 1990s, U.S. high-technology industries accounted for between 19 and 23 percent of world high-technology exports, which at times were nearly twice the level achieved by all U.S. manufacturing industries. In 2001, the latest year for which data are available, exports by U.S. high-technology industries accounted for about 17 percent of world high-technology exports; Japan accounted for about 10 percent, and Germany nearly 8 percent.

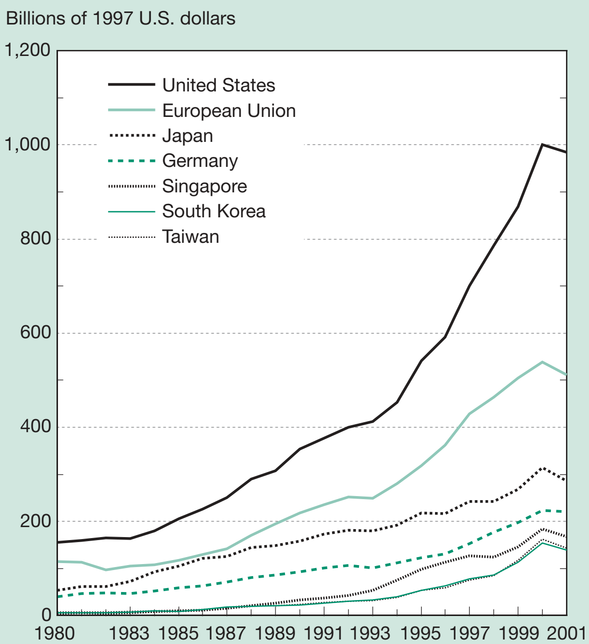
The gradual drop in the U.S. share during 1990–2001 was in part due to competition from emerging high-technology industries in newly industrialized economies, especially in Asia. High-technology industries in South Korea and Taiwan each accounted for about 2.5 percent of world high-technology exports in 1990, and data for 2001 show that each country's share nearly doubled. Singapore's share, which was 3.5 percent in 1990 and 5.7 percent in 2001, was also significant.

Industry Comparisons

Over the past 2 decades, U.S. high-technology industries were leading exporters in each of the five industries that comprise the high-technology group. The United States was the export leader in all five industries in 2001, although its shares in several categories declined.

U.S. aerospace technology, computers and office machinery, and communication equipment industries all recorded successively smaller shares of world exports in 2001 than in earlier years. U.S. exports of aerospace technologies accounted for 54 percent of world aerospace exports in 1980, 46 percent in 1990, and 38 percent in 2001. U.S. exports of computers and office machinery represented 31 percent of world exports in 1980, 22 percent in 1990, and 16 percent in 2001. The U.S. manufacturers of communication equipment's share has fluctuated in a much narrower range, 13–17 percent, reaching highs in the early 1980s and the mid-1990s before falling to lows in 2000 and 2001. U.S. exports of scientific instruments declined throughout most of the 1980s, remained stable through the mid-1990s, and have slowly climbed since then. In 2001, U.S. exports of scientific instruments accounted for approximately 22 percent of world exports (figure 6-10 and appendix table 6-1). The only U.S. industry with a higher share of world exports in 2001 than in 1980 was the pharmaceutical industry, which rose from 12 to 15 percent.

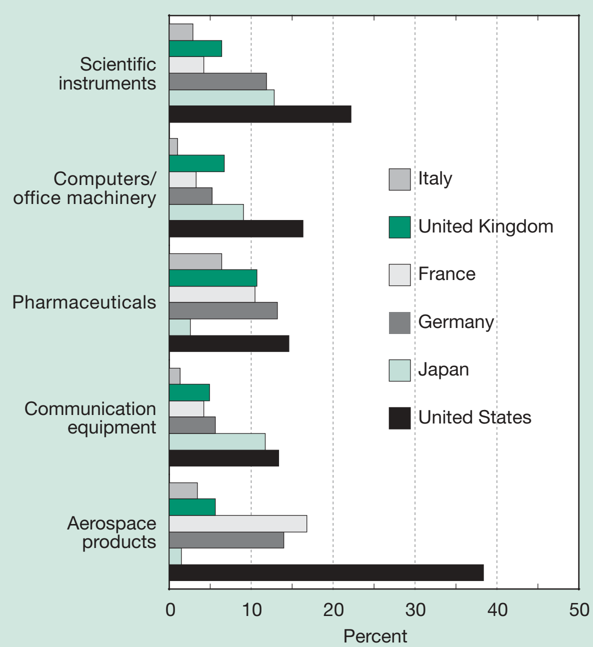
Figure 6-9
High-technology exports in selected countries: 1980–2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

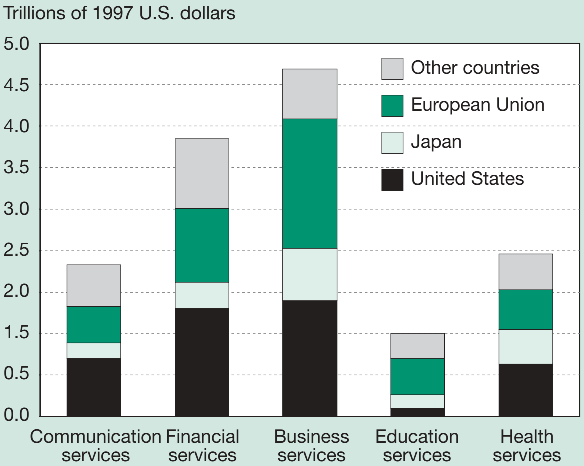
Figure 6-10
World exports in high-technology industries in selected countries: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-1.

Science & Engineering Indicators – 2004

Figure 6-11
Global revenues generated by five knowledge-intensive service industries in selected countries: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003. See appendix table 6-2.

Science & Engineering Indicators – 2004

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 percent in 1959 to 64 percent in 1997 (NSB 2000, appendix table 9-4). This growth has been fueled largely by *knowledge-intensive* industries—those that incorporate science, engineering, and technology in either their services or the delivery of their services.[3] Five of these knowledge-intensive industries are the communication, financial, business (including computer software development), educational, and health services. In the United States, these industries grew faster than the high-technology manufacturing sector discussed earlier. This section presents data tracking the overall revenues earned by these industries in 70 countries[4] (figure 6-11 and appendix table 6-2).

Combined global sales in these service-sector industries exceeded $12.3 trillion in 2001, up from $5.4 trillion in 1980 and $8.0 trillion in 1990. The United States was the leading provider of high-technology services, responsible for about one-third of total world service revenues during the 22-year period examined.

Business services, which include computer and data processing and research and engineering services, was the largest of the five service industries and accounted for 34 percent of global revenues in 2001. It was most prominent in the EU, which claimed 37 percent of business services world revenue in 2001. The United States ranked second at nearly 34 percent, followed by Japan at 15 percent. Data on individual business services by country are not available.

Financial services was the second largest service sector and accounted for nearly 27 percent of global revenues in 2001. Forty percent of industry revenues in 2001 went to the U.S. financial services industry, the world's largest. The EU was second with approximately 26 percent, followed by Japan at nearly 10 percent.

Communication services, which include telecommunication and broadcast services, was the fourth-largest service industry examined, accounting for almost 15 percent of world service industry revenues in 2001. In what many consider the most technology-driven of the service industries, the United States held the dominant position. In 2001, U.S. firms generated revenues equal to 38 percent of world revenues. The EU accounted for 24 percent, and Japan accounted for nearly 11 percent.

Because many nations' governments serve as the primary provider of the remaining two knowledge-intensive service industries, health services and educational services, and because the size of each country's population affects the delivery of these services, global comparisons based on market-generated revenues are less meaningful than they are for other service industries. The United States, with arguably the least government involvement, has the largest health services industry in the world. The EU is second, followed by Japan. If most of these services are delivered primarily to domestic customers, then, on a per capita basis, Japanese residents clearly consumed the most health services of any advanced nation. Educational services, the smallest of the five knowledge-intensive service industries in terms of revenue generated, includes governmental and private education institutions of all types that offer primary, secondary, and university education, as well as technical, vocational, and commercial schools. By comparison, fees (tuition) and income from other education service-related operations accounted for about one-fourth of the revenues generated by the business services industry worldwide. Europe generated the most revenues in this service industry, with Japan second and the United States third. Again, on a per capita basis, Japanese residents consumed more educational services than residents in any other advanced nation.

U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large trade surplus in intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate revenues in the form of royalties and licensing fees.

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

[4]Unlike the manufacturing industries, national data that track activity in many rapidly growing service sectors are limited in the level of industry disaggregation and the types of data collected.

U.S. Royalties and Fees From All Transactions

In 2001, U.S. receipts from trade in intellectual property declined for the first time since 1987. After an increase throughout the late 1980s and 1990s, total receipts peaked in 2000 at nearly $40 billion, then dropped somewhat in 2001. U.S. receipts for transactions involving intellectual property generally were four to five times larger than U.S. payments to foreign firms. This gap narrowed in the late 1990s as U.S. payments increased faster than U.S. receipts. This trend continued for 3 years and, by 2000, the ratio of receipts to payments dropped to about 2.5:1.

In 2001, U.S. trade in intellectual property produced a surplus of $22.3 billion, down 5 percent from the $23.5 billion surplus recorded a year earlier and extending a downward trend that began in 1999 (figure 6-12 and appendix table 6-3). About 75 percent of transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[5] 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.

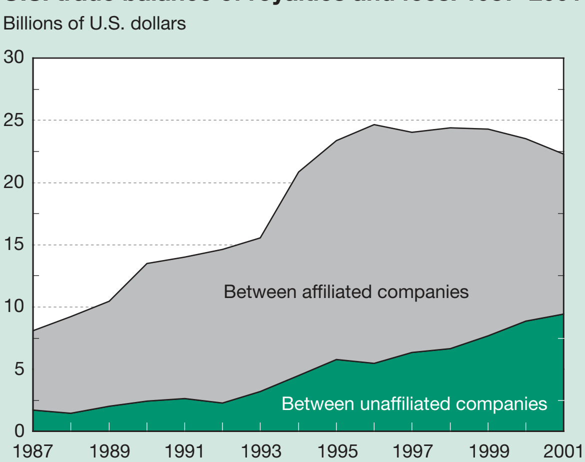
U.S. Royalties and Fees From Trade in Technical Knowledge

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. By tracking transactions between unaffiliated firms in which prices are set through market-based negotiation, these data may better reflect the value of technical know-how at a given time than data on exchanges among affiliated firms. When receipts (sales of technical 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 technical knowledge.

The United States is a net exporter of technology sold as intellectual property. The gap between imports and exports narrowed during the late 1990s, but the most recent data show a surge in receipts in 2000 that outpaced the growth in payments. During the early 1990s, royalties and fees received from foreign firms were an average of three times greater than the amount U.S. firms paid foreigners for access to their technology. U.S. receipts grew to $3.9 billion in 1999, and in 2001 totaled $4.9 billion, an increase of approximately 24 percent (figure 6-13 and appendix table 6-4). The slower growth in the most recent year may be due in part to past transfers of intellectual property to foreign affiliates of U.S. firms who in turn take the place of the U.S. parent company when dealing directly with foreign customers. Such transfers are advantageous for U.S. firms when the affiliates are located in countries with lower tax rates or when the transfers facilitate local product adaptation (Borga and Mann 2002). In transactions between unaffiliated firms, U.S. receipts for technology sold as intellectual property exceeded payments by more than $3 billion in 2000 and 2001.

The U.S. trade surplus in intellectual property is driven largely by trade with Asia. In 1995, U.S. receipts (exports) from technology licensing transactions were nearly seven times the amount of U.S. payments (imports) to Asia. That ratio closed to slightly more than 4:1 by 1997, but has since widened. The most recent data show U.S. receipts from

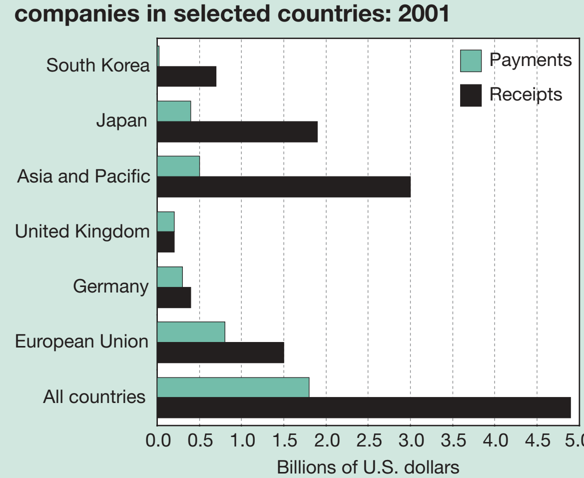
Figure 6-12
U.S. trade balance of royalties and fees: 1987–2001



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business,* 2002. See appendix table 6-3.

Science & Engineering Indicators – 2004

Figure 6-13
U.S. royalties and fees generated from exchange of industrial processes between unaffiliated companies in selected countries: 2001



SOURCE: U.S. Bureau of Economic Analysis, *Survey of Current Business,* 2002. See appendix table 6-4.

Science & Engineering Indicators – 2004

[5]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 percent or more of its voting stock; for an unincorporated business, it is an interest equal to 10 percent of voting stock.

technology licensing transactions at more than six times the amount of U.S. payments to Asia. Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property; together, these countries accounted for 54 percent of total receipts in 2001.

Japan was the single largest consumer, although its purchases declined significantly during the 1990s. At its peak in 1993, Japan's share of U.S. receipts was approximately 51 percent. Japan's purchases began to increase again in 2000 and 2001, raising its share to 35 and 39 percent, respectively. Another Asian country, South Korea, was the second largest consumer, accounting for nearly 15 percent of U.S. receipts in 2001. South Korea has been a major consumer of U.S. technological know-how since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to nearly 11 percent in 1990 and reached its highest level, 19 percent, in 2000.

Unlike its trade with Asia, U.S. trade in intellectual property with Europe fluctuated between surplus and deficit until 1994, when a sharp decline in U.S. purchases of European technical know-how led to a considerably larger surplus for the United States than in previous years. Another large surplus in 1995 resulted from an increase in receipts from the larger European countries. Receipts from EU countries have risen steadily since 1997, reaching $1.4 billion in 2001, or about 28 percent of all U.S. receipts for technology sold as intellectual property. Some of this increase can be attributed to increased licensing activity by firms in Germany, the third-largest consumer of U.S. technological know-how. In 2001, German firms spent $368 million, approximately double their expenditures in 1997. The latest data also show that U.S. receipts from exchanges with France and Switzerland rose sharply during the late 1990s and again in 2000 and 2001, leading to considerably larger U.S. surpluses from trade with Europe.

Foreign sources for U.S. firms' purchases of technical know-how varied over the years. The EU has been the biggest supplier for U.S. firms, accounting for 40–55 percent of foreign-supplied purchases of technological know-how sold as intellectual property. Germany, the United Kingdom, and Switzerland are the principal European suppliers.[6]

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

[6]France has also 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 2000 and showed a sharp drop in U.S. purchases of French technological know-how compared with 1996 data.

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&E education and R&D.[7] However, their success may depend on other factors as well, including 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:[8]

- **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, the presence of skilled labor, and the existence of innovative management practices.

This section is an analysis of 15 economies: 6 in Asia (China, India, Indonesia, Malaysia, the Philippines, and Thailand), 3 in Central Europe (Czech Republic, Hungary, and Poland), 4 in Latin America (Argentina, Brazil, Mexico, and Venezuela), and 2 others (Ireland and Israel) that showed increased technological activity.[9]

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

[8]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.

[9]See notes to appendix table 6-5 for a complete description of data used in each of the four indicators.

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 (PRS Group 2002).

Ireland and Israel posted by far the highest overall scores on this indicator (figure 6-14 and appendix table 6-5). Although Ireland scored slightly lower than Israel on each of the expert-opinion components, its rating as a much safer place for foreign investment than Israel elevated its composite score.

The national orientations of both Ireland and Israel were scored consistently and significantly higher than those of other countries examined and were well within the range of scores accorded the more advanced economies of Taiwan and Singapore. Malaysia, Hungary, Poland, the Czech Republic, China, and India also scored well, with strong scores in each indicator component.

Indonesia, Thailand, and two Latin American countries, Argentina, and Venezuela, received the lowest composite scores of the economies examined. Indonesia and Thailand were rated low on all variables but were hurt most because they were considered riskier or less attractive sites for foreign investment. Argentina and Venezuela also received consistently low scores on each variable and were hurt most by the expert perception that these three countries were not entrepreneurial.

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 survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country[10] (figure 6-14).

Ireland and Israel again received the highest scores among the emerging and transitioning economies examined. In addition to their strong records in general and higher education, Ireland's and Israel's scores reflect high ratings for the mobility of capital and encouragement of foreign businesses to invest there. Their scores were similar to those of Taiwan and South Korea.

Among remaining nations, Malaysia and the three Central European countries all posted similar high scores. The socioeconomic infrastructure score for Malaysia was bolstered by the experts' high opinion of the mobility of capital in the country, whereas the Central European countries received high scores for their strong showing in the published education data.

Indonesia received the lowest composite score of the 15 nations examined. It was held back by low marks on two of the three variables: educational attainment (particularly university enrollments) and the variable rating of its mobility of capital.

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 locally train its citizens in academic S&E, make effective use of technical knowledge, and link R&D to industry.

China and Israel received the highest scores of the group of newly industrialized or transitioning economies examined (figure 6-14). China's score 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. Israel's high score on this indicator was based on its large number of trained scientists and engineers, the size of its research enterprise, and its contribution to scientific knowledge. Indonesia and Venezuela again recorded 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.

Ireland scored highest in productive capacity among the 15 developing and transitioning nations examined, receiving high marks for each indicator component (figure 6-14). Its score was boosted by its prominence in the computer hardware manufacturing industry. China, Israel, and India followed closely, with each posting strong scores on all indicator components.

Several developing Asian economies, particularly China and Malaysia, had higher electronics production than Ireland in 1999, the reference year for the published data. However, they scored lower on indicator components rating their labor pools and management personnel. Mexico's production of

[10]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 6-5 for complete source reference.

Figure 6-14
Leading indicators of technological competitiveness in selected countries: 2002

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

SOURCE: Georgia Technology Research Co., *High Tech Statistics, Preliminary Report,* 2003. See appendix table 6-5.

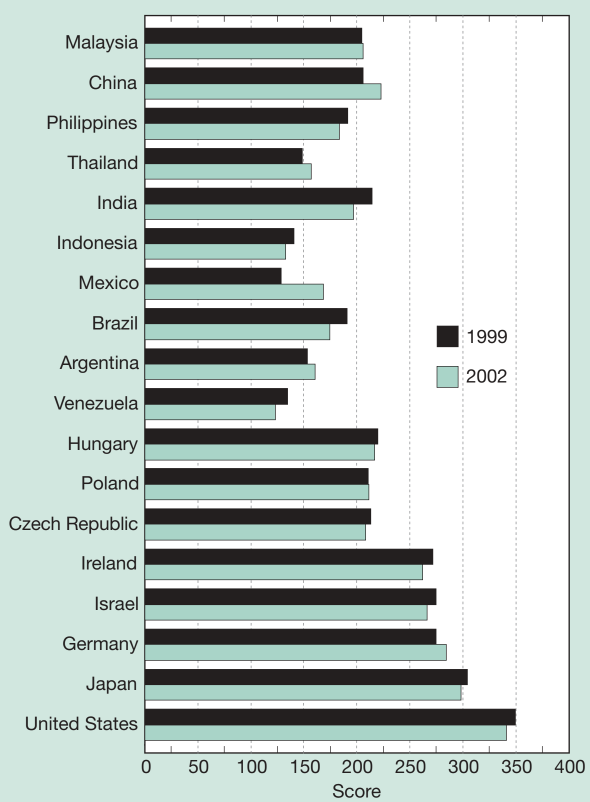
Science & Engineering Indicators – 2004

electronics products, which was this indicator's published data variable, was greater than Ireland's, but its overall score was hurt by experts' low rating of the quality of Mexican skilled labor and the existence of indigenous electronics components suppliers.

Findings From the Four Indicators

Based on this set of four leading indicators, Ireland and Israel again earned high scores and appear to be on the path to prominence as exporters of technology products in the global market. Both countries posted similar high scores when these same indicators were developed 3 years ago (figure 6-15 and appendix table 6-6). The latest results show that Ireland led the group of countries examined in two of the four leading indicators and received the second-highest score in a third, socioeconomic infrastructure. Israel ranked 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 on two of the remaining indicators and third on the other (figure 6-14).

Figure 6-15
Composite scores for four leading indicators in selected countries: 1999 and 2002



NOTE: The four leading indicators are national orientation, socio-economic infrastructures, technological infrastructure, and productive capacity.

SOURCE: Georgia Technology Research Co., *High Tech Statistics, Preliminary Report*, 2003. See appendix tables 6-5 and 6-6.

Science & Engineering Indicators – 2004

China and Hungary also posted strong scores on several indicators. Hungary ranked third on the indicator identifying nations that are taking action to become technologically competitive and fourth on both the socioeconomic and technological infrastructure indicators. China scored nearly as well and sometimes better than Hungary on the leading indicators, but its scores were not quite as balanced and were likely inflated by its large population.

These indicators provide a systematic way to compare future technological capability for an even wider set of nations than might be available using other indicators. The results highlight how the group of nations that compete in high-technology markets may broaden in the future, as well as reflect the large differences among several emerging and transitioning economies and those considered newly industrialized.

International Trends in Industrial R&D

In high-wage countries such as the United States, one of the ways industries stay competitive in the global marketplace is through innovation (Council on Competitiveness 2001). Innovation provides firms with a comparative advantage through improved products, more efficient production processes, and new product development. This allows high-wage countries to better compete with low-wage nations.

R&D activities are incubators for ideas that can lead to new products, processes, and industries. Although they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are the source of many important new ideas that have shaped modern technology.[11] Traditionally, U.S. industries that conduct large amounts of R&D meet with greater success in foreign markets than less R&D-intensive industries, and they are more willing to pay their employees higher wages. (See "U.S. Technology in the Marketplace" for discussion of recent trends in U.S. competitiveness in foreign and domestic product markets.)

Moreover, trends in industrial R&D performance are leading indicators of future technological performance. For example, the most recent data show a resurgence in service-sector research and development in the United States and several other advanced nations. The service sector share of U.S. R&D, which was less than 19 percent in 1996, rose to 34 percent in 2000. U.S. manufacturing industries collectively continue to perform nearly two-thirds of the nation's industrial R&D, but cutbacks in R&D by the U.S. aerospace and computer hardware industries mean those sectors' shares of overall R&D have declined, especially in recent years. The following section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries in the United States, Japan, and the EU.[12]

[11]For a discussion of trends in foreign direct investment in R&D facilities, see chapter 4.

[12]This section uses data from OECD's Analytical Business Enterprise R&D database (July 2002) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense-and nondefense-related) carried out in the industrial sector, regardless of funding source. Expenditures are expressed in purchasing power parity dollars ($PPP). For an examination of U.S. industrial R&D by funding source and an explanation of $PPP, see chapter 4.

R&D Performance by Industry

The United States, the EU, and Japan are the three largest economies in the industrialized world, and their industries have been leaders of innovation in the international marketplace. An analysis of each nation or region's R&D trends can explain past success, provide insight into future product development, and highlight shifts in national technology priorities.[13]

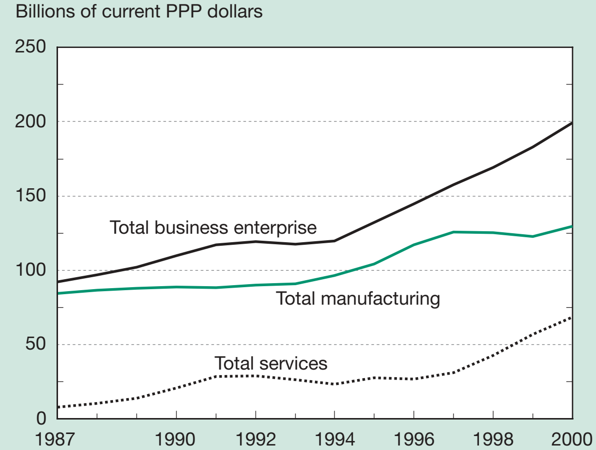
United States

In 1999 and 2000, R&D in U.S. service-sector industries grew at a faster rate than R&D in U.S. manufacturing industries. This surge was similar to the rapid growth experienced between 1987 and 1991 and was again led primarily by computer software firms and firms performing R&D on a contract basis. In 1987, service-sector industries accounted for less than 9 percent of all U.S. industrial R&D. During the next several years, the amount of R&D performed in the service sector raced ahead of that performed by other U.S. manufacturing industries until 1991, when the service sector accounted for nearly one-fourth of all U.S. industrial R&D. Manufacturers regained their position; however, their share inched back to 81 percent of total U.S. industrial R&D by 1996, led by industries making computer hardware, electronics equipment, and motor vehicles (figure 6-16 and appendix table 6-7).

The most recent data for the late 1990s and 2000 show a reemergence of the U.S. service sector as a key performer of industrial R&D. A turnaround that began slowly in 1997 was followed by large increases each year thereafter. The service sector's share of total R&D was less than 19 percent in 1996 but 34 percent by 2000.[14]

U.S. manufacturing industries collectively perform nearly two-thirds of the nation's industrial R&D and include most of the nation's top R&D-performing industries. In 2000, the latest year for which internationally comparable data are available, the industry manufacturing radio, TV, and communication equipment led the nation in industrial R&D.[15] This industry historically has been among the top five performers, but its rise to the top coincided with rapid growth in the telecommunication industry during the late 1990s. Producers of chemical products (primarily pharmaceuticals), scientific instruments, and motor vehicles were also top R&D performers in 2000, as were the industries providing computer services. Computer and office hardware manufacturers fell out of the top five. R&D performance in the U.S. aerospace industry also grew more slowly during the 1990s than in other U.S. industries. The aerospace industry accounted for 19 percent of total U.S. R&D in 1990, but its share dropped nearly every year throughout the decade. By 2000, the U.S. aerospace industry accounted for just 5 percent of total R&D.[16]

Figure 6-16
U.S. industrial R&D performance: 1987–2000



Top industrial R&D performers and share of total industrial R&D (percents)

1990		1995		2000	
Aerospace and other transport equipment	19.2	Total services	21.1	Total services	34.4
Total services	18.9	Chemicals	13.2	Electronic equipment	12.9
Chemicals	12.1	Motor vehicles	11.6	Chemicals	10.7
Computers and office machines	10.7	Electronic equipment	11.4	Instruments	9.6
Motor vehicles	9.3	Aerospace and other transport equipment	8.8	Motor vehicles	9.3

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-7.

Science & Engineering Indicators – 2004

Japan

The manufacturing sector continues to dominate Japan's industrial R&D performance, as it has throughout the period examined. From 1987 to 2000, the sector consistently accounted for 94–97 percent of all R&D performed by Japanese industry (figure 6-17 and appendix table 6-8). A small expansion in service-sector R&D first seen in the mid-1990s appears to have retreated and, in fact, has declined in recent years. In the early 1990s, Japan's service-sector industries doubled their share of total R&D, reaching 4 percent in both 1996 and 1997. However, R&D performed by Japan's service sector has declined each year since, returning to early-1990s levels. Service-sector R&D in 2000 accounted for just 2.1 percent of Japan's industrial R&D performance.

The top industrial R&D performers in Japan during 1987–2000 reflect the country's long-standing emphases on electronics technology (including consumer electronics

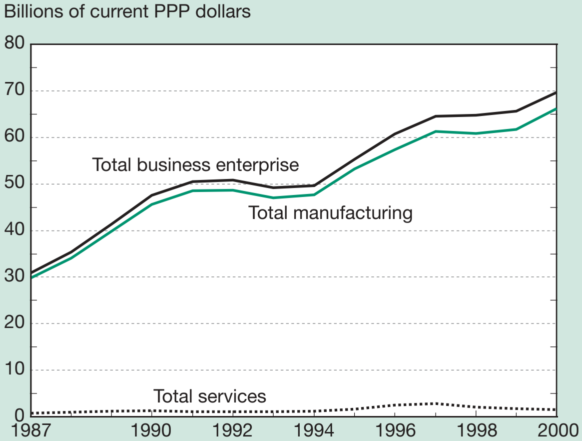
[13]Industry-level data are occasionally estimated to provide a complete time series for the 1987–2000 period.

[14]Part of the apparent growth is due to the reclassification of some firms that were previously identified as manufacturers under the SIC. Those firms have been reclassified as service industries under the NAICs.

[15]Some of the trends reported here differ from those reported in chapter 4 due to the reclassification of U.S. data to conform with the international industry classification system used by OECD.

[16]One of the recommendations made in a recent report to the President and the Congress of the United States by the Commission on the Future of the United States Aerospace Industry calls for a renewed focus on long-term research (Presidential Commission 2002).

Figure 6-17
Japan industrial R&D performance: 1987–2000



Top industrial R&D performers and share of total industrial R&D (percents)

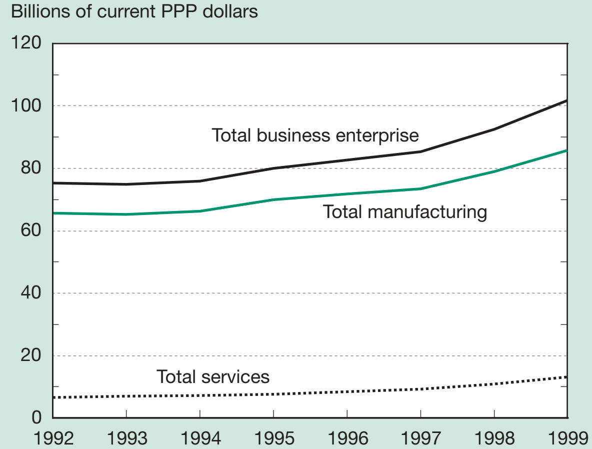
1990		1995		2000	
Electronic equipment	15.7	Electronic equipment	17.5	Electronic equipment	18.8
Chemicals	15.3	Chemicals	16.5	Chemicals	15.0
Motor vehicles	13.8	Motor vehicles	12.2	Motor vehicles	12.4
Electrical machines	10.8	Electrical machines	11.0	Computers and office machines	10.8
Computers and office machines	9.7	Computers and office machines	9.0	Electrical machines	9.8

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-8.

Science & Engineering Indicators – 2004

Figure 6-18
European Union industrial R&D performance: 1992–99



Top industrial R&D performers and share of total industrial R&D (percents)

1992		1995		1999	
Chemicals	19.7	Chemicals	20.1	Chemicals	19.9
Motor vehicles	13.8	Motor vehicles	13.8	Motor vehicles	16.1
Electronic equipment	10.8	Electronic equipment	12.0	Electronic equipment	13.5
Aerospace and other transport equipment	10.7	Aerospace and other transport equipment	9.5	Total services	13.0
Total services	8.3	Total services	9.4	Aerospace and other transport equipment	8.6

PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, 2002. See appendix table 6-9.

Science & Engineering Indicators – 2004

and audiovisual equipment), motor vehicles, and electrical machinery. Japan's electronics equipment industry was the leading R&D performer throughout most of the period, accounting for nearly 19 percent of all Japanese industrial R&D in 2000. Japan's chemical industry, also a leading performer in 2000, accounted for 15 percent of the country's industrial R&D, second only to the electronics equipment industry. Producers of motor vehicles, computer hardware, and electrical machinery round out the remaining top R&D performers. In contrast, U.S. machinery producers consistently dropped in rank among the top U.S. R&D performers since the early 1970s.

European Union

As in the United States and Japan, manufacturing industries perform the bulk of industrial R&D in the 15-nation EU. The EU's industrial R&D appears to be less concentrated in specific industries than R&D in the United States, but more so than in Japan. Manufacturers of chemicals and chemical products, electronics equipment, and motor vehicles consistently were among the top five industrial R&D performers in the EU (figure 6-18 and appendix table 6-9). The aerospace industry (other transportation) and the service sector round out the group. According to the latest data available for the EU, Germany led the EU in R&D in many of the major manufacturing industries, including chemical products, motor vehicles, communication equipment, and computer hardware. The United Kingdom led in pharmaceutical and service-sector R&D.[17]

Service-sector R&D has steadily increased each year and accounted for 13 percent of total EU industrial R&D in 1999, nearly equal to that of the EU's electronic equipment industry and almost double that of the EU's aerospace industry. Large increases in service-sector R&D are apparent in many EU countries, especially Italy, where service-sector R&D made up about 24 percent of industrial R&D from 1999 to 2001, and the United Kingdom, where it accounted for 21 percent of R&D in 1999.

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

[17]The latest calendar-year data were 2001 for Italy, 2000 for Germany and the United Kingdom, and 1999 for France.

inventors in the form of patents. These allow the inventor to exclude others from making, using, or selling the invention. Inventors obtain patents from government-authorized agencies for inventions judged to be new, useful, and not obvious.

Although the U.S. Patent and Trademark Office (PTO) grants several types of patents, this discussion is limited to utility patents, which are commonly known as patents for inventions. They include any new and 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 provide for the protection of 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.[18] 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.[19] (See sidebar, "New Database May Help to Identify Important Inventions.")

U.S. Patenting

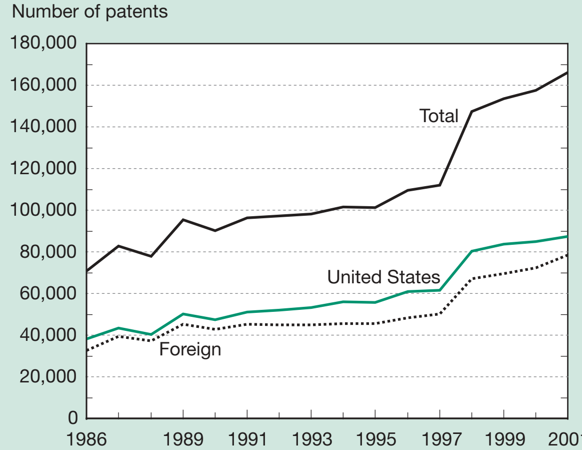
More than 166,000 patents were issued in the United States in 2001, 5 percent more than in 2000. This record number extends a period of nearly uninterrupted growth that began in the late 1980s. Since then, growth in U.S. patenting has been steady, but slower[20] (figure 6-19 and appendix table 6-10).

[18]For a survey of literature related to this point, see Z. Griliches. Patent statistics as economic indicators: A survey. *Journal of Economic Literature* 28 (December): 1661–707.

[19]It should also be noted that there is concern that patents and other forms of exclusive ownership of intellectual property may discourage research into, communication about, and diffusion of new technologies. The question arises whether, in some cases, the extension of intellectual property rights has gone too far. To provide answers and guide intellectual property right (IPR) policy over the next decade and beyond, the Science, Technology and Economic Policy Board (STEP) of the National Research Council (NRC) has undertaken a project to review the purposes of the IPR legal framework and assess how well those purposes are being served. The board will identify whether there are current or emerging problems of inadequate or over-protection of IPRs that need attention and will commission research on some of these topics. The report is due out later in 2003.

[20]The number of U.S. patents granted jumped by 32 percent 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.

Figure 6-19
U.S. patents granted, by residence of inventor: 1986–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2002. See appendix table 6-10.

Science & Engineering Indicators – 2004

Patents Granted to U.S. Inventors

Some observers have at times expressed concern that any downward trend in the number of patents issued to U.S. inventors could indicate a decline in U.S. inventiveness. However, the share of total U.S. patents granted to U.S. inventors has been fairly stable over the years, fluctuating within a very narrow range (52–56 percent). A small decline during the mid-1980s rebounded by the end of the decade as patenting by U.S. inventors increased and outpaced patenting by foreign inventors. Since peaking at 56 percent in 1996, the share of U.S. patents granted to and held by U.S. resident inventors has declined slightly. In 2001, U.S. inventors were awarded nearly 88,000 new patents, or about 53 percent of the total patents granted by the United States. The increase in U.S. patents granted to foreigners may simply reflect the attractiveness of the U.S. market for new products and the growing capacity for global technological innovation.

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. Therefore, examining patent data by the owner's sector of employment can provide a good picture of a sector's inventive work. Corporations owned 82 percent of patents granted to U.S. entities (including other U.S. organizations, the Federal Government, and independent U.S. resident inventors) in 2001.[21] This percentage has gradually increased over time. From 1987 to 1997, corporate-owned patents accounted for between 77 and 79 percent of total U.S.-owned patents. Since 1997, corporations have generally increased their share of

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

New Database May Help to Identify Important Inventions

One criticism of any attempt to analyze national inventive activity by simply counting patents is the inability of such counts to differentiate between minor inventions and highly important inventions. A new database developed through an international partnership of patent offices in the United States, Europe, and Japan provides a new tool for patent researchers that addresses this problem.* This new dataset counts only inventions for which patent protection is sought in three important markets: the United States, Europe, and Japan. Each invention that satisfies this condition forms one triadic patent family.

The high cost of filing for patents in three separate patent offices makes triadic patent families a more accurate measure of important inventions than simple patent counts. In most cases, only economically valuable inventions will justify the costs associated with filing patents in all three locations. For example, application fees alone can exceed several thousand dollars, not counting related legal costs. In total, 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.

Table 6-2 presents data generated from the new database. Counts of triadic patent families, sorted by the inventor's residence for selected countries, are listed by priority year—that is, the year of the first patent filing. It covers the period 1988–98 and shows that the United States has been the leading producer of important inventions in every year except 1988. Inventors residing in EU countries produced nearly as many important inventions as did inventors living in the United States, and they produced more than the U.S. inventors in 1988. 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 important inventions than inventors in the United States or the EU. 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 was used as the basis for comparison.

When the data are examined by the patent applicant's or owner's country of 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 stays about the same. The shift in shares between the United States and the EU is nearly identical, and 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 and tending to rely on the discoveries of native inventors.

Table 6-2
Triadic patent families, by inventor and applicant (owner) place of residence and priority year: 1988–98

Place of residence	Total	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
	Number											
World total of triadic patent families	364,335	30,814	33,360	32,919	30,677	30,669	31,454	32,243	35,161	37,679	37,630	31,729
	Percent											
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	39.1
European Union	31.6	33.5	31.7	30.2	30.5	31.3	31.8	33.6	32.7	32.8	31.0	28.3
Japan	27.5	28.3	30.2	30.3	29.1	26.7	26.8	25.3	26.5	26.9	26.6	26.2
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	42.2
European Union	27.7	29.4	28.0	26.7	26.7	27.3	27.7	29.4	28.6	28.5	27.5	25.3
Japan	27.3	28.0	30.0	29.9	28.9	26.5	26.6	24.9	26.3	26.8	26.7	26.2

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

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

Science & Engineering Indicators – 2004

*The project is a collaboration among OECD, the National Science Foundation, the European Union, 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 housed at OECD.

total patents, rising to 80 percent in 1999, 81 percent in 2000, and 82 percent in 2001.

Individuals (independent inventors) are the second-largest group of U.S. patent owners. Before 1988, individuals owned, on average, 23 percent of all patents granted to U.S. entities.[22] This figure has trended downward since then, to a low of 17 percent in 2001. The Federal Government's share of patents averaged 3 percent from 1963 to 1987, eventually falling to 1.1 percent in 1999.[23] Its share remained at about 1 percent in 2000 and 2001.[24]

Patents Granted to Foreign Inventors

Patents issued to foreign inventors represented 47 percent of all patents granted by the United States in 2001, a share that has increased slightly since 1999.[25] During much of the 1980s, growth in the number of patents issued to non-U.S. entities outpaced growth in the number of patents granted to U.S. inventors. This trend peaked in 1987 and 1988, when patents granted to foreign inventors accounted for 48 percent of all U.S. patents. (See sidebar, "Top Patenting Corporations.") From 1990 until 1996, however, the trend reversed: U.S. inventor patenting activity increased at a faster pace than did foreign inventors', which dropped the foreign share of all patents to 44 percent. Over that time, Japan and Germany accounted for about 56 percent of all U.S. patents granted to foreign inventors. The top four countries (Japan, Germany, France, and the United Kingdom) accounted for about 72 percent of U.S. patents awarded to foreign residents since 1963 (figure 6-20).

Although patenting by inventors from leading industrialized countries has leveled off or declined in recent years, some Asian economies, particularly Taiwan and South Korea, have stepped up their patenting activity in the United States and are proving to be strong inventors of new technologies.[26] Between 1963 (the year data first became available) and 1987, Taiwan

[22]Before 1988, data are provided as a total for the period 1963–87. In U.S. PTO statistical reports, the ownership category breakout is independent of the breakout by country of origin.

[23]Federal inventors frequently obtain a statutory invention registration (SIR) rather than a patent. SIR is not ordinarily subject to examination and is less costly to obtain than a patent. Also, SIR gives the holder the right to use the invention but does not prevent others from selling or using it.

[24]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 duty of 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.

[25]Corporations account for about 86 percent of all foreign-owned U.S. patents.

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

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. In 1973, no Japanese companies ranked among the top 10 corporations seeking patents in the United States. In 1983, however, 3 of the top 10 companies were Japanese, and by 1993, Japanese companies outnumbered U.S. companies. Seven of the top 10 companies were Japanese in 1996. The most recent data (2001) show 1 South Korean company (Samsung Electronics Company), 2 U.S. companies, and 7 Japanese companies among the top 10 (table 6-3). Samsung ranked fourth among foreign corporations patenting in the United States in 1999, after ranking 17th just 2 years earlier. South Korea's U.S. patent activity emphasizes computer, television and communication equipment, and power generation technologies.

IBM was awarded more patents than any other U.S. organization in 2001, the ninth consecutive year that the company earned this distinction. Micron Technology, Inc., joined the top 10 in 2000 and in 2001 was awarded 1,643 patents, nearly one-quarter more than it received just a year earlier. IBM and Micron were the only U.S. companies to make the top 10.

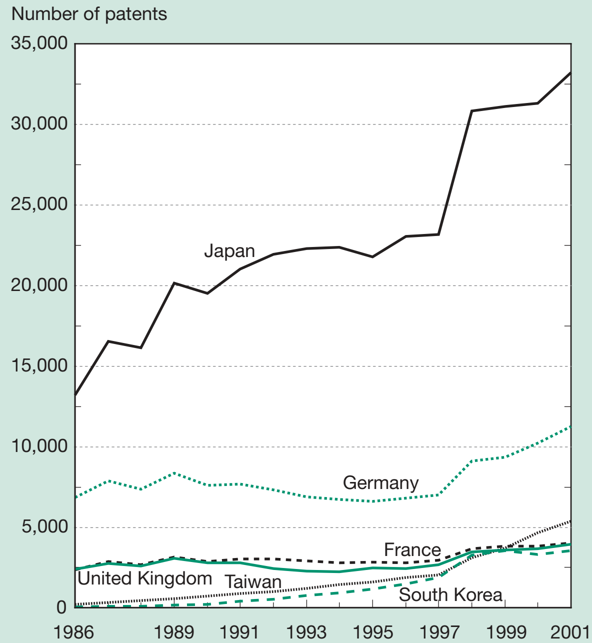
Table 6-3
Top patenting corporations: 1977–96 and 2001

Company	Patents
1977–96	
General Electric Corp.	16,206
International Business Machines Corp.	15,205
Hitachi Ltd.	14,500
Canon Kabushiki Kaisha	13,797
Toshiba Corp.	13,413
Mitsubishi Denki Kabushiki Kaisha	10,192
U.S. Philips Corp.	9,943
Eastman Kodak Co.	9,729
AT&T Corp.	9,380
Motorola, Inc.	9,143
2001	
International Business Machines Corp.	3,411
NEC Corp.	1,953
Canon Kabushiki Kaisha	1,877
Micron Technology, Inc.	1,643
Samsung Electronics Co., Ltd.	1,450
Matsushita Electric Industrial Co., Ltd.	1,440
Sony Corp.	1,409
Hitachi Ltd.	1,271
Mitsubishi Denki Kabushiki Kaisha	1,184
Fujitsu Ltd.	1,166

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, November 2002.

Science & Engineering Indicators – 2004

Figure 6-20
U.S. patents granted to foreign inventors in selected countries, by residence of inventor: 1986–2001



NOTE: Selected countries/economies are the top six recipients of U.S. patents during 2001.

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2002. See appendix table 6-10.

Science & Engineering Indicators – 2004

received just 1,293 U.S. patents. During the 14-year period since then, Taiwan was awarded nearly 29,000 U.S. patents. U.S. patenting activity among inventors from South Korea shows a similar growth pattern. Before 1987, South Korea received just 343 U.S. patents; since that time, South Korea has been awarded more than 21,000 new patents. The latest data indicate that Taiwan has moved ahead of France and the United Kingdom to become the third most active residence of foreign inventors who obtain patents in the United States. In 2000 and 2001, the top five countries receiving patents from the United States were Japan, Germany, Taiwan, France, and the United Kingdom.

Trends in Applications for U.S. Patents

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

Patent Applications From U.S. and Foreign Inventors

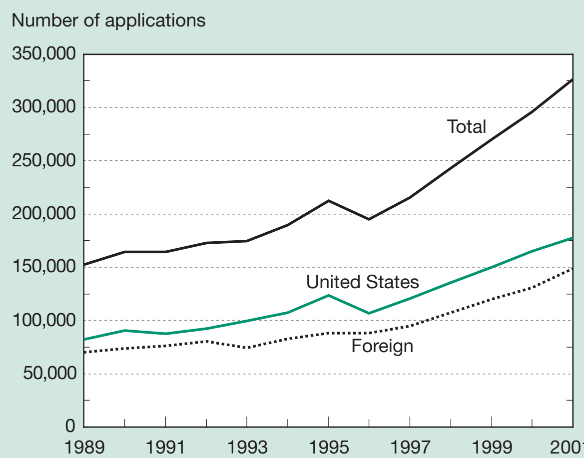
Applications for U.S. patents reached 326,500 in 2001, about 10 percent more than in 2000. Applications rose by a similar percentage in 2000. These latest data add to what has been nearly a decade of annual increases (figure 6-21 and appendix table 6-11).

Patent applications from U.S. residents made up 56 percent of all applications in 2000, a share maintained since 1997. In 2001, this share declined slightly, to 54 percent. Because patents granted to foreign inventors generally accounted for about 45–47 percent of total U.S. patents granted, the success rate for foreign applications appears to be about the same or slightly higher than that of U.S. inventor applications.[27]

Over time, residents of Japan have received more patents than residents of any other country. They accounted for 40–48 percent of U.S. patent applications made by foreign residents, more than twice that of Germany, which had the next most active group of applicants. Japan's share slipped only in the late 1990s, falling to a decade low of 40 percent in 1999. Since then, its share has increased. The German share has generally exhibited a downward trend, falling from a high of 16 percent in 1989 to about 13 percent in 2000 and 2001.

Although patent filings by inventors from the leading industrialized countries leveled off or began to decline, other countries, particularly Asian countries, stepped up their patenting activity in the United States. This is especially true for Taiwan and South Korea, and data on recent

Figure 6-21
U.S. patent applications, by residence of inventor: 1989–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2003. See appendix table 6-11.

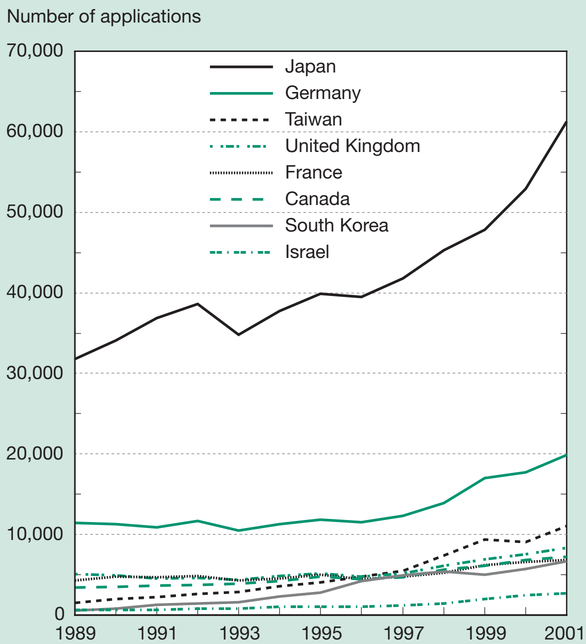
Science & Engineering Indicators – 2004

[27]This may not be surprising because the additional expenses associated with applying for a patent in a foreign market will likely discourage weak foreign applications.

patent applications indicate that the rising trend in U.S. patents granted to residents of these two Asian economies is likely to continue. Since 1997, residents of Taiwan and South Korea distinguished themselves in the number of applications submitted, applying for enough patents to replace France and Canada in the top five foreign sources seeking U.S. patents. Residents of Taiwan moved further up the list, to third, in 1998, and in 1999 applied for more than 9,000 new patents. This was an increase of 27 percent from the previous year and 2,400 more applications than were made by residents from the fourth-ranked United Kingdom. U.S. patent applications by Taiwanese inventors dropped by about 4 percent in 2000 but resumed double-digit growth in 2001. If recent patents granted to residents of Taiwan are indicative of the technologies awaiting review, many of these applications will be for new computer and electronic inventions. After slowing somewhat in 1999, U.S. patent applications from South Korean inventors picked up, increasing by 13 percent in 2000 and 18 percent in 2001 (figure 6-22).

Equally impressive was growth in patent applications by inventors from Israel, India, Finland, Belgium, and China. Data show dramatic increases over the past several years and provide yet another indication of the ever-widening community of nations active in global technology development and diffusion.

Figure 6-22
U.S. patent applications filed by selected foreign inventors, by residence of inventor: 1989–2001



SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, special tabulations, 2003. See appendix table 6-11.

Science & Engineering Indicators – 2004

Technical Fields Favored by Foreign Inventors

A country's inventors and the distribution of its patents by technical area is a reliable indicator of both the country's technological strengths and its focus on product development. Patent activity in the United States by inventors from foreign countries can be used to identify a country's technological strengths as well as U.S. product markets likely to see increased competition. This 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.[28]

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

Although U.S. patent activity encompasses a wide spectrum of technology and new product areas, corporate patenting patterns reflect activity in several technology areas that have already contributed much to the nation's economic growth. In 2001, for example, corporate patent activity indicated U.S. technological strengths in business methods, medical and surgical devices, electronics, telecommunication, and biotechnology (table 6-4).

The 2001 data also show Japan's continued emphasis on photocopying, photography, 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 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 have traditionally maintained a strong presence. The 2001 U.S. patent activity index shows that Germany emphasizes inventions for motor vehicles, printing, switches, and material-handling equipment.

In addition to inventions for traditional manufacturing applications, British patent activity is high in aeronautics, biotechnology, and chemistry (appendix table 6-12). Like the British, the French are quite active in patent classes associated with manufacturing applications and aeronautics (appendix table 6-13). They share the emphasis of U.S. and British inventors in biotechnology.

As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. By the 1990s, Taiwan was active in communication technology, semiconductor manufacturing processes, and internal combustion engines. Data from 2001 show that

[28]Information in this section is based on U.S. PTO's 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 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. Because U.S. patenting data reflect a much larger share of patenting by individuals without corporate or government affiliation than do data on foreign patenting, only patents granted to corporations are used to construct the U.S. patenting activity indices.

Table 6-4
Top 15 most emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 2001

Rank	United States	Japan	Germany
1	Business practice, data processing	Photocopying	Clutches and power-stop control
2	Surgery: light, thermal, and electrical applications	Information storage and retrieval	Rotary shafts
3	Computers and digital processing systems	Television signal processing	Brake systems
4	Surgery instruments	Photography	Printing
5	Data processing, file management	Electrophotography	Winding, tensioning, or guiding devices
6	Digital processing systems	Liquid crystal cells	Machine element or mechanism
7	Computer memory	Facsimile	Land vehicles, bodies and tops
8	Data processing software	Incremental printing of symbolic information	Magnetically operated switches
9	Surgery (medicators and receptors)	Electric lamp and discharge devices	Metal forming
10	Prosthesis	Typewriting machines	Brakes
11	Wells	Electrical generators	Land vehicles
12	I/O digital processing systems	Radiation imagery chemistry	Joints and connections
13	Boring or earth penetrating apparatus	Ceramic compositions	Internal combustion engines
14	Multicellular living organisms	Wave transmission lines and networks	Fluid sprayers
15	Digital processing, support	Optics systems, including communication	Electrical transmission systems

I/O input/output

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

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, 2002.

Science & Engineering Indicators – 2004

Taiwan's inventors also became active in other areas, adding electrical systems, semiconductors, and computer hardware technologies to their technology portfolio.

U.S. patenting by South Korean inventors also reflects that country's rapid technological development. The 2001 data show that South Korean inventors are currently patenting heavily in television technologies and a broad array of computer technologies that include devices for dynamic and static information storage, data generation and conversion, error detection, and display systems (table 6-5).

Patent Activity Outside the United States

In most countries, nonresident (foreign) inventors account for a much larger share of total patent activity than is true in the United States.[29] When foreign patent activity in the United States is compared with that in nine other countries, only Japan and Russia consistently showed lower activity levels (figure 6-23 and appendix table 6-14). Data from the patent offices in Brazil, Italy, and the United Kingdom all show that about 80 percent of patents granted in those countries go to nonresident inventors.[30] Even higher levels of nonresident patenting occur in Canada and Mexico (more than 90 percent in 1999 and 2000). Although much attention is given to the level of nonresident patent activity in the United States, it has remained farily stable over the past 10 years, accounting for about 44–47 percent of all U.S. patents issued.

Data from the World Intellectual Property Organization (WIPO), which includes patent data from most patent-granting countries, show the global reach of U.S., Japanese, and German inventors who patent their inventions in other countries. In 1999 and 2000, U.S. inventors made up the largest group of foreign inventors seeking patents in the countries neighboring the United States and in major markets in Asia, Europe, and Latin America. U.S. inventors also received more patents than other nonresident inventors in Japan, India, Brazil, Mexico, France, Germany, Italy, and the United Kingdom (figure 6-24). Japanese-resident inventors, who consistently account for the largest percentage of U.S. patents granted to nonresident inventors, also patent successfully in other parts of the world. In addition to their success patenting in the United States, Japanese-resident inventors lead all foreign inventors patenting in China and South Korea, and they follow only U.S. inventors in the United Kingdom and Canada. Germany, whose inventors also have a long tradition of patenting new inventions in the United States, actively patent in India, Japan, Brazil, Mexico, and other large European markets.

These data underscore the importance that corporations and other owners of new technologies—through seeking to protect their intellectual property—place on national patent systems. They also show the extent to which both advanced and developing nations depend on the diffusion of new technologies from around the world.

[29]Patents granted for an invention in one country do not offer any protection under another country's intellectual property laws.

[30]This discussion is based on data from the World Intellectual Property Organization in Geneva, Switzerland, which includes patenting data from most patent granting countries. These data were compiled by Mogee Research & Analysis, LLC.

Table 6-5
Top 15 most emphasized U.S. patent classes for corporations from South Korea and Taiwan: 2001

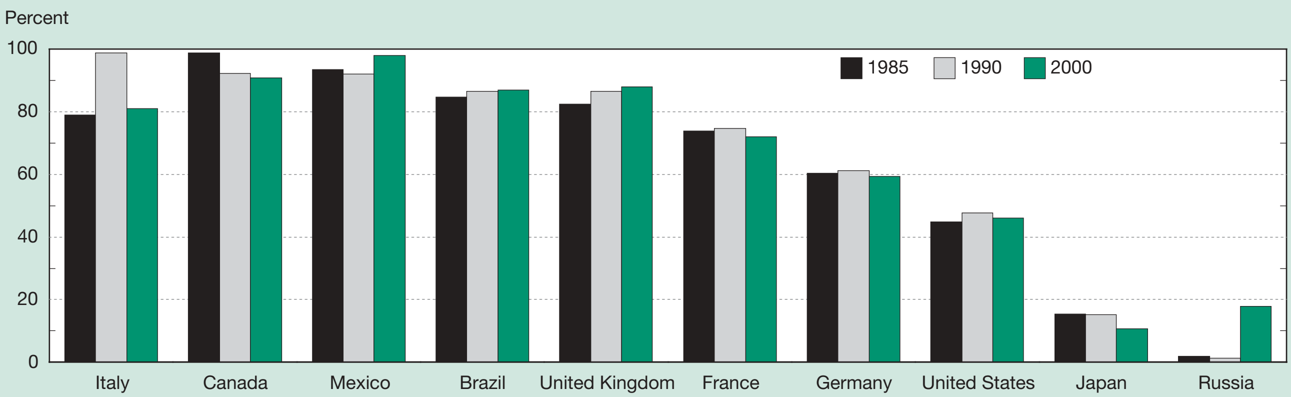
Rank	South Korea	Taiwan
1	Liquid crystal cells, elements, and systems	Semiconductor device manufacturing process
2	Static information storage and retrieval	Electrical connectors
3	Electric lamp and discharge systems	Circuit makers and breakers
4	Television	Electrical systems and devices
5	Semiconductor device manufacturing process	Active solid-state devices
6	Dynamic magnetic information storage or retrieval	Supports
7	Television signal processing for recording	Heat exchange
8	Miscellaneous active electrical nonlinear devices	Abrading
9	Electric lamp and discharge devices	Rotary expansible chamber devices
10	Pulse or digital communications	Special receptacle or package
11	Electrophotography	Typewriting machines
12	Active solid-state devices	Radiation imagery chemistry
13	Computers	Brushing, scrubbing, and general cleaning
14	Electronic digital logic circuitry	Cleaning
15	Computer graphics	Battery or capacitor charging

NOTE: Rank is based on patenting activity of nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology Assessment and Forecast Branch, 2002.

Science & Engineering Indicators – 2004

Figure 6-23
Patents granted to nonresident inventors in selected countries: 1985, 1990, and 2000



NOTE: Data for Russia in 1985 and 1990 reflect data for the Soviet Union.

SOURCE: World Intellectual Property Organization, industrial property statistics, http://www.wipo.org/ipstats/en, selected years. See appendix table 6-14.

Science & Engineering Indicators – 2004

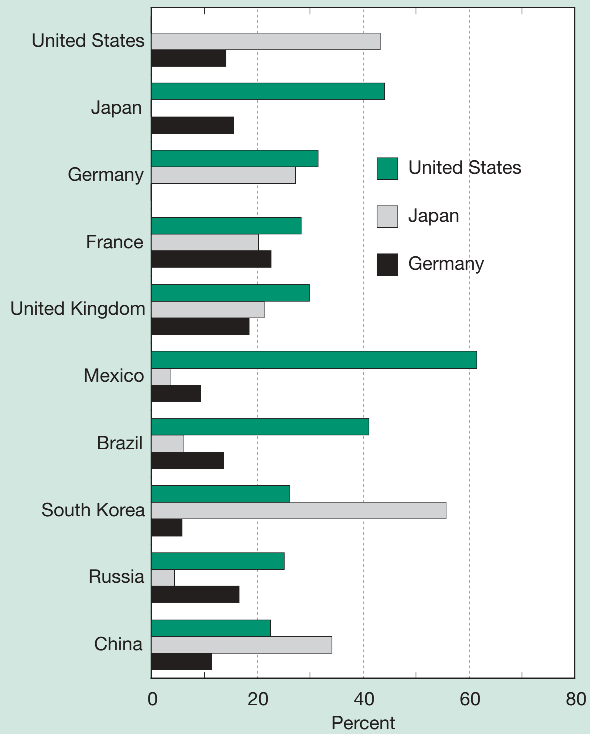
Venture Capital and High-Technology Enterprise

Venture capitalists typically make investments 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. This money can aid the growth and development of small companies and new products and technologies, and it is often an important source of funds used in the formation and expansion of small high-technology companies. This is of special interest to the S&E field, as small businesses play a vital role in the U.S. economy and have become important employers of recent S&E graduates (National Venture Capital Association 2002).

For most of the 1990s, computer technology businesses engaged in hardware or software production and related services and medical and health care companies were the leading recipients of venture capital in the United States. This pattern changed significantly in 1999, when Internet-specific businesses emerged in the marketplace.

This section examines venture capital investment patterns in the United States since 1980, with special emphasis given to a comparison of trends in 1999 and 2000 (hereafter called the *bubble years*) with trends in 2001 and 2002 (hereafter

Figure 6-24
Patents granted to residents of United States, Japan, and Germany in selected countries: 2000



NOTES: Data represent inventor share of all foreign-resident patents granted. Data for Brazil are from 1999.

SOURCE: World Intellectual Property Organization, industrial property statistics, selected years. See appendix table 6-14.

Science & Engineering Indicators – 2004

Table 6-6
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 Venture Economics, special tabulations, June 2003.

Science & Engineering Indicators – 2004

called the *postbubble period*). It discusses changes in the overall level of investment, the technology areas U.S. venture capitalists find attractive, and the types of investments made.[31]

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 that new commitments rose vigorously each year from 1996 through 2000, with the largest 1-year increase in 1999 (table 6-6). Investor commitments to venture capital funds jumped to $62.8 billion that year, a 111 percent gain from 1998. By 2000, new commitments reached $105.8 billion, more than 10 times that recorded in 1995. Quickly, venture capital emerged as a key source of financing for small innovative firms. Evidence of a slowdown emerged in 2001 when new commitments declined for the first time in 10 years.[32] Commitments fell by more than 64 percent that year, to $37.9 billion. Still, this sharply reduced total was quite large when compared with capital investments during the prebubble 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.[33] In fact, pension funds became the single largest supplier of new funds. During the entire 1990–2002 period, pension funds supplied about 44 percent of all new capital. Endowments and foundations were the second-largest source, supply-

[31]Data presented here are compiled by Thomson Venture Economics 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.

[32]According to recent reports from the National Venture Capital Association, 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 "Venture Capital Fundraising Slows in Fourth Quarter, But Hits New Record for the Year," NVCA February 22, 2001.

[33]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 men balance both income and safety as they choose investments. The web site www.investorwords.com describes the Prudent Man Rule as the fundamental principle for professional money mangement 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."

ing 17 percent of committed capital, followed closely by financial and insurance companies at 16 percent (table 6-7). California, New York, and Massachusetts together account for about 65 percent of venture capital resources, as 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).

Boom and Bust in New Venture Capital Commitments

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, leading to a large pool of money available for investments in new or expanding firms. As early as 1990, firms producing computer software or providing computer-related services began receiving large amounts of venture capital (appendix table 6-15). Software companies received 17 percent of all new venture capital disbursements in 1990, more than any other technology area. This figure fluctuated between 12 and 21 percent thereafter. Communication companies also attracted large amounts of venture capital during the 1990s, receiving from 12 to 21 percent of total disbursements. Medical and health care-related companies received a high of almost 21 percent of venture capital in 1992 before dropping to just 5 percent in 1999.

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. They collected more than 40 percent of all venture capital funds invested in each of those years. Software and software services companies received 15–17 percent of disbursed venture capital funds. Communication companies (including telephone, data, and wireless communication) were a close third with 14–15 percent.

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. In 2001 and 2002, Internet companies received far less venture capital, 28 and 21 percent, respectively, of the total dollars disbursed. This was a sharp drop from the previous 2 years but still more than the amount received by any other industry area. Companies involved primarily in computer software, communication, and medical and health care also continued to attract venture capital-backed investments during this period (figure 6-25).

The decline in enthusiasm for Internet companies seems to have benefited other technology areas, because their shares of total venture capital disbursements increased during a time when venture capitalists were sharply curbing their activity. A comparison of venture capital disbursements in 1999 and 2000 with those in the 2001 and 2002 shows that medical and health care-related and biotechnology companies attracted much higher percentages in the latter period. Medical and health care-related companies received 11 percent of total investments in 2001 and 2002, nearly triple their share of 4 percent received in 1999 and 2000. Biotechnology companies doubled their share, from 3 to about 6 percent. Other industries attracting larger shares of the smaller pool of investment funds in 2001 and 2002 were software companies, semiconductor and other electronics companies, and industrial and energy companies.

Table 6-7
Capital commitments, by limited partner type: 1990–2002
(Billions of U.S. dollars)

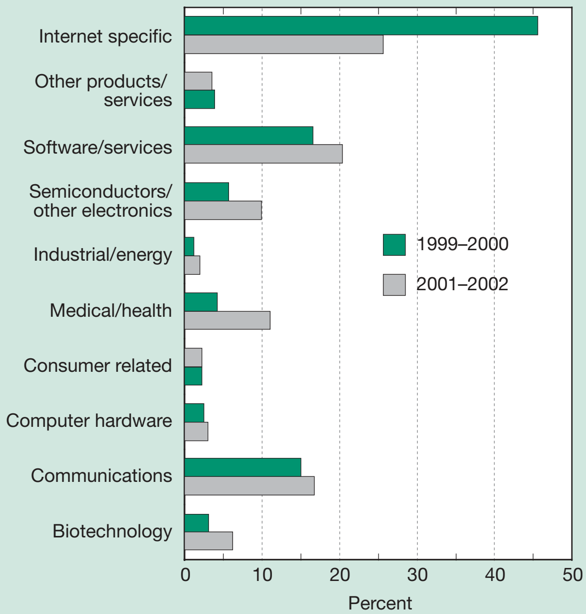
Limited partner type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
All types	2.55	1.48	3.39	4.12	7.35	8.42	10.47	15.18	25.29	60.14	93.44	2.81	2.54
Pension funds	1.34	0.63	1.41	2.43	3.36	3.12	5.74	5.77	15.03	26.16	37.47	0.83	1.12
Banks and insurance	0.24	0.08	0.49	0.43	0.70	1.62	0.30	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 Venture Economics, special tabulations, June 2003.

Science & Engineering Indicators – 2004

Figure 6-25
U.S. venture capital disbursements, by industry: 1999–2000 and 2001–2002



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-15.

Science & Engineering Indicators – 2004

Venture Capital Investments by Stage of Financing

The 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.
- ♦ **Startup financing** provides funds to companies for product development and initial marketing. This type of financing usually is provided to companies just organized or to those that have been in business just a short time but have not yet sold their product in the marketplace. Generally, such firms have already assembled key management, prepared a business plan, and made market studies.
- ♦ **First-stage financing** provides funds to companies that 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 months to 1 year.
- ♦ **Acquisition financing** provides funds to finance the purchase of another company.
- ♦ **Management and leveraged buyout** includes 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*.

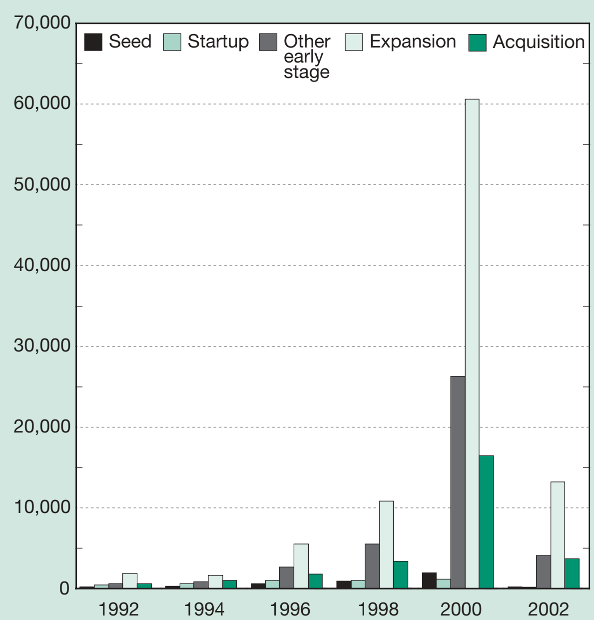
Two patterns stand out in an examination of venture capital disbursements by financing stage: (1) most of the funds' investment dollars are directed to later-stage investments, and (2) during the postbubble period, venture capital funds directed more money to later-stage investments than ever before. (See appendix table 6-16 and sidebar, "U.S. Government Support for Small Technology Businesses.")

Later-stage investments ranged from 60 to 79 percent of total venture capital disbursements, with both the highest and lowest points reached in the 1990s. In 1999 and 2000, later-stage investments made up 72 percent of total disbursements, rising to 77 percent in the postbubble period. Although early-stage, venture-backed investments as a share of total disbursements have gradually declined over time, during the 2001–02 period they fell to their lowest level ever (figure 6-26).

The postbubble trend toward later-stage investing is also evident when analyzing the three early-stage categories. Most of the postbubble venture capital that previously went to early-stage investments shifted to the most mature of the early-stage companies—those companies that had exhausted

Figure 6-26
U.S. venture capital disbursements, by stage of financing: 1992–2002

Millions of U.S. dollars



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-16.

Science & Engineering Indicators – 2004

U.S. Government Support for Small Technology Businesses

In contrast to profit-driven venture capital, U.S. Government programs support the development of new technologies to better address broader national interests and scientific needs. Two Federal programs are prominent in this effort: (1) The Small Business Innovation Research Program administered by the U.S. Small Business Administration, and (2) the Advanced Technology Program, administered by the U.S. Department of Commerce.

The Small Business Innovation Research Program (SBIR) sprang from the 1982 Small Business Innovation Development Act and was reauthorized in 1992 with an explicit emphasis on commercialization. Each Federal agency with extramural research programs greater than $100 million is required to set aside a fixed percentage of funding (currently 2.5 percent) for SBIR projects. Small businesses submit proposals to each of the agencies describing projects that meet an agency's research needs and have commercial potential.

The Advanced Technology Program (ATP) has funded the development of enabling technologies since 1990. In this program, companies, nonprofit institutions, and universities submit proposals that undergo a peer review process that evaluates the technical and economic potential of the project.

Table 6-8 shows the annual funding for these two programs since 1990. SBIR's set-aside mechanism has led to a gradual expansion of funds available to small technology-oriented firms, as opposed to the highly variable ATP appropriations.

Table 6-8
Federally and privately funded early-stage venture capital
(Millions of U.S. dollars)

Year	Federal SBIR	Federal ATP	Private early-stage venture capital
1990	461	46	1,148
1991	483	93	826
1992	508	48	1,186
1993	698	60	2,100
1994	718	309	1,581
1995	835	414	2,143
1996	916	19	2,658
1997	1,107	162	3,373
1998	1,067	235	4,700
1999	1,097	110	10,995
2000	1,190	144	20,260
2001	1,294	164	764
2002	NA	156	1,813

ATP Advanced Technology Program
NA not available
SBIR Small Business Innovation Research

NOTE: Data reflect disbursements funded publicly through Federal SBIR and ATP and privately through U.S. venture capital funds.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Indicators – 2002*, p. 4-36 through 4-38; and Thomson Venture Economics, special tabulations, June 2003.

Science and Engineering Indicators – 2004

their initial capital and were in need of funds to initiate commercial manufacturing and sales. During a period when venture capital became increasingly scarce, the more high-risk early-stage projects suffered.

Expansion financing has typically been favored by venture capital funds, with this stage alone accounting for more than half of all venture capital disbursements since 1997. In 2000, the amount of venture capital invested to finance company expansions reached 57 percent of total disbursements. This upward trend continued into the postbubble period, with the share rising to 62 percent in 2002. About one-quarter of the $36.3 billion disbursed to finance expansions of existing businesses during 2001 and 2002 went to Internet companies.

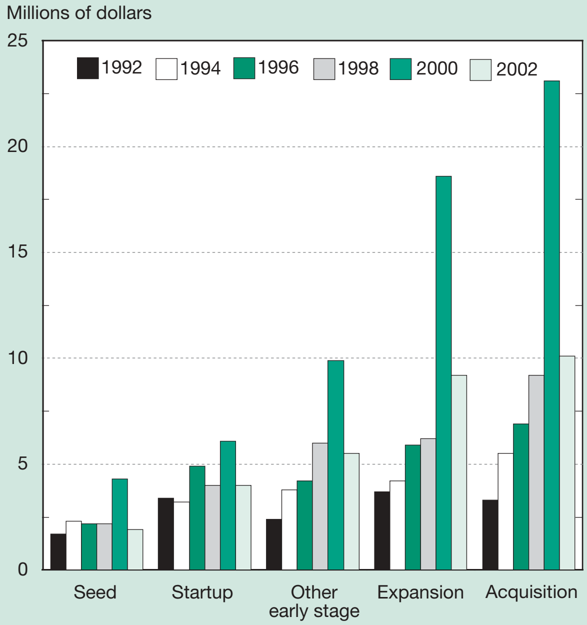
Venture Capital as Seed Money

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 never accounted for more than 8 percent of all disbursements over the past 23 years and most often represented between 2 and 5 percent of the annual totals. The latest data show that seed financing represented just 1 percent of all venture capital in 2001 and 2002, falling from just 2 percent in 1999 and 2000. Over the past 23 years, the amount invested in a seed-stage financing has averaged about $1.8 million per disbursement. The average peaked at $4.3 million per disbursement in 2000 before falling in 2001 and 2002 (figure 6-27). In 2002, the average seed-stage investment was about $1.9 million.

The same three technologies, Internet, communication, and computer software, attracted the bulk of seed financing during the past 4 years. They were the largest recipients of venture capital seed financing during the 1999 and 2000 bubble years, with Internet companies the preferred investment destination. Internet companies received 58 percent of all disbursements in 1999 and 43 percent in 2000 (appendix table 6-17). In 2001 and 2002, seed investments going to Internet companies fell off considerably but still represented 21 percent of all such investments in 2001 and 7 percent in 2002.

As dot.com panic replaced dot.com mania, other technology areas attracted more attention. Medical and health care-related companies received 10 percent of seed money in 2001 and 20 percent in 2002, up from 4 and 5 percent during the bubble years. The share going to biotechnology companies rose to 5 percent in 2001 and to 15 percent in

Figure 6-27
Value of average investment by venture capital funds, by stage of financing: 1992–2002



SOURCE: Thomson Venture Economics, special tabulations, June 2003. See appendix table 6-16.

Science & Engineering Indicators – 2004

2002. Semiconductor companies received 8 percent in 2001 and 15 percent in 2002, up from 4 percent in 1999.

Over the past 23 years, venture capital investment showed consistent support for technology-oriented businesses, particularly companies and industries that develop and rely on information technologies. And, despite the recent reduction in new money invested in venture capital funds, information technologies continue to attract the largest shares of total U.S. venture capital.

During the late 1990s, venture capitalists increasingly favored later-stage investments over early-stage investments that are more likely to support exploratory R&D and product development. That trend continued in the postbubble years of 2001 and 2002. If this trend continues, U.S. Government programs like the Small Business Innovation Research program and Advanced Technology Program may become more important sources of early-stage funds for new technology-oriented businesses.

Characteristics of Innovative U.S. Firms

The need for better information about innovative activities at U.S. firms, the innovative process, and the factors that affect innovation led NSF to conduct a new survey in 2001 that systematically examined innovative activities in selected U.S. industries. To accomplish this, and to better understand how IT affects innovation, 4,000 firms were surveyed with the following three goals in mind:

- To develop nationally representative profiles of corporate IT innovators and users
- To facilitate analyses of similar national studies conducted by other countries
- To provide policymakers with data to better understand how industry uses and develops IT in the pursuit of innovation

Data collected from this survey were designed to serve both public and private researchers and provide an important resource for NSF, policymakers, and other stakeholders interested in understanding the multidimensionality of IT-based innovation within U.S. companies. These data are limited in scope and depth but nevertheless provide useful insight into the process and characteristics of IT-based industrial innovation. (See sidebar, “Description of U.S. IT Innovation Survey Sample and Response.”)

Why Study IT-Based Innovation?

In the late 1990s, IT was recognized by the U.S. Department of Commerce as an area of growing importance within the U.S. economy (DOC 1998 and DOC/ESA 1999). This growth was evident by the impact of IT on the labor market in the form of rising demand for IT workers and the shortage of trained IT professionals (DOC/ESA 1999, DOC/OTP 1998, and Meares and Sargent 1999). During this time, IT and IT innovation was recognized as a major contributor to the service sector. It was reported that about 80 percent of IT investment was directed to the service sector in both the United States and United Kingdom (Evangelista, Sirilli, and Smith 1998).

IT-based innovation was viewed as both leading to new products and services and revitalizing the way most traditional services were produced and delivered (Evangelista, Sirilli, and Smith 1998). The introduction of IT and IT-based innovations reduced costs in production- and scale-intensive sectors, whereas specialized technology suppliers and science-based sectors used IT to focus on R&D and software development (Evangelista, Sirilli, and Smith 1998). IT was especially important to supplier-dominated industries that relied on technologies developed by other sectors. Furthermore, in a review of U.S. policy on investment in innovation, Branscomb and Keller (1998) found that assumptions about the way companies innovate have not kept pace with structural changes in the high-technology sector of the economy, particularly as they relate to:

- Sources of technology and funding for innovation
- Challenges to competitiveness in the global marketplace
- The nature of relationships between companies, government, and the academic community
- Decentralization of technology management responsibilities and corporate decisionmaking

Description of U.S. IT Innovation Survey Sample and Response

In 1999, NSF contracted with the PricewaterhouseCoopers Survey Research Center (now IBM Business Consulting Services) to develop and conduct the Information Technology Innovation Survey. The survey was designed to systematically examine business characteristics and activities in U.S. industry related to IT-based innovation. The survey went to approximately 4,000 for-profit, single-location firms (or to the corporate headquarters for multilocation businesses) with 25 or more employees and annual sales of at least $2.5 million.

The target population was limited to firms associated with developing information technologies (IT strata) and industries in which IT-based innovation may have had an impact (non-IT strata). The four non-IT strata included select companies from the remaining manufacturing standard industrial classifications (SICs); the transportation and public utilities sector; the service sector; and the finance, insurance, and real estate sectors. The IT sector industries were grouped into three IT strata composed of industries specializing in computer equipment, electronic and electrical equipment, and measuring, analyzing, and controlling instruments; communication (telephone, radio, television, etc.); and computer-related business services from the service sector. None of the four-digit SIC codes within the finance, insurance, and real estate sector were identified as part of the IT strata.

Based on an analysis of existing sources from which to draw the sample, Dun & Bradstreet's "Marketplace" database software was selected and licensed as the source for the sample frame. The database is a comprehensive listing of more than 10 million business establishments covering all industries in the United States.

A total of 2,005 companies responded to the survey, representing an estimated population of 72,406 companies. Of the 2,005 respondents, 66 percent responded by telephone (computer-assisted telephone interview), 22 percent by Web, and 12 percent by paper.

After adjusting the sample for companies determined to be out-of-frame and out-of-scope, the final adjusted response rate was 57.2 percent. The highest response rate (65.4 percent) was recorded for the non-IT services stratum, and the lowest response rate (50.3 percent) was for the non-IT manufacturing stratum. Response among companies in the IT and non-IT sectors was the same (57 percent). Item nonresponse was minimal.

- Managing risk and determining returns on investment in education, research and development, and organizational change

New patterns in private-sector innovation are assumed to reach across companies in the form of increased partnerships, alliances, and other forms of collaboration, although quantitative data are not available to support this assumption (Branscomb and Keller 1998).

Survey Results

For the purposes of the NSF study, innovation was defined as the development of technologically new or significantly improved products or processes. Respondents were instructed to consider innovation IT-based if IT was a significant or critical component in the development of new products or processes. Changes to existing products that were purely aesthetic, involved only minor modifications, or were implemented to accommodate Y2K issues were not considered IT-based innovation.

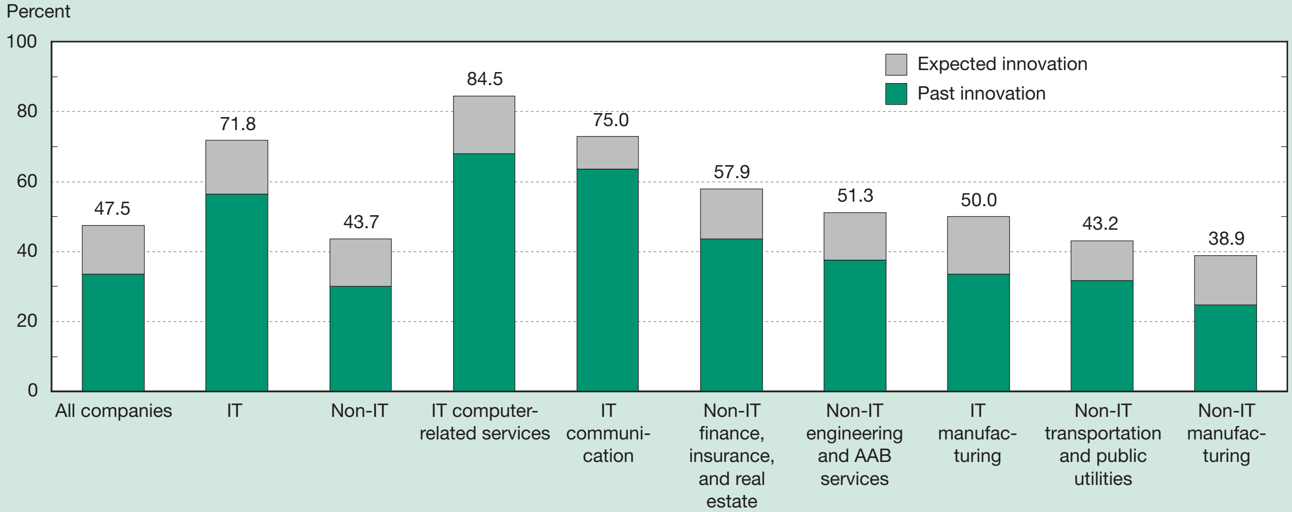
The survey found that nearly half (48 percent) of responding firms developed an IT-based innovation within the past year or expected to develop one within 12 months. This 48 percent is an estimated national average rate of IT-based innovation for the collection of industries surveyed. Not surprisingly, certain industries reported above-average levels of innovation. For example, IT companies reported higher levels of innovation (72 percent) than non-IT companies (44 percent), and IT computer-related services (84 percent) were the most innovative of the three IT sectors surveyed. The lowest rate of innovation was reported in the non-IT manufacturing sector (figure 6-28 and table 6-9).

Process innovation was more prevalent and may be more important for innovative firms than product innovation (appendix tables 6-18 through 6-21). When innovative firms were asked to identify the type of innovation (product or process) developed during the past year that contributed most to company revenue, process innovations outnumbered product innovations by almost 60 percent (figure 6-29). The number of firms that said they expected to have an IT-based process innovation within 12 months outnumbered firms expecting a product innovation by more than 2 to 1 (appendix table 6-21). This survey defined *product innovation* as the development of improved goods or services in which IT was a significant or critical component, and *process innovation* as the development of an improved operation, or function associated with manufacturing, production, or business services in which IT was a significant or critical component.

The survey identified several characteristics of innovative U.S. companies. Larger companies were more likely to report higher rates of innovation than smaller companies. Using annual revenue as a proxy for size, 63 percent of companies with more than $50 million in sales revenue reported they had developed an IT-based innovation in the past 12 months or expected to do so within the next 12 months, compared with 43 percent of the smallest firms, those with annual company revenues between $2.5 million and $4.9 million.

Innovative firms did not appear to be statistically more likely to export their products than noninnovtive firms. Sixteen percent of companies that introduced a new IT-based innovation reported serving foreign customers compared with 14 percent of noninnovative firms.

Figure 6-28
Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by sector: 2001



IT information technology
AAB accounting, auditing, and bookkeeping

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix tables 6-18 and 6-19.

Science & Engineering Indicators – 2004

Table 6-9
Companies reporting IT-based innovation in past 12 months or expected innovation in next 12 months, by industry and revenue size: 2001
(Percent)

Characteristic of innovator[a]	Total	Past	Expected
All industries	48	34	14
IT	72	57	15
Manufacturing	50	33	17
Communications	75	63	13
Computer-related services	84	67	18
Non-IT	44	30	14
Manufacturing	39	25	14
Transportation and public utilities	44	32	12
Finance, insurance, and real estate	58	44	14
Engineering and AAB services	52	38	14
Revenue size (millions of dollars)			
2.5–4.9	43	29	14
5–9.9	46	33	13
10–24.9	48	34	14
25–50	58	35	23
More than 50	63	56	7

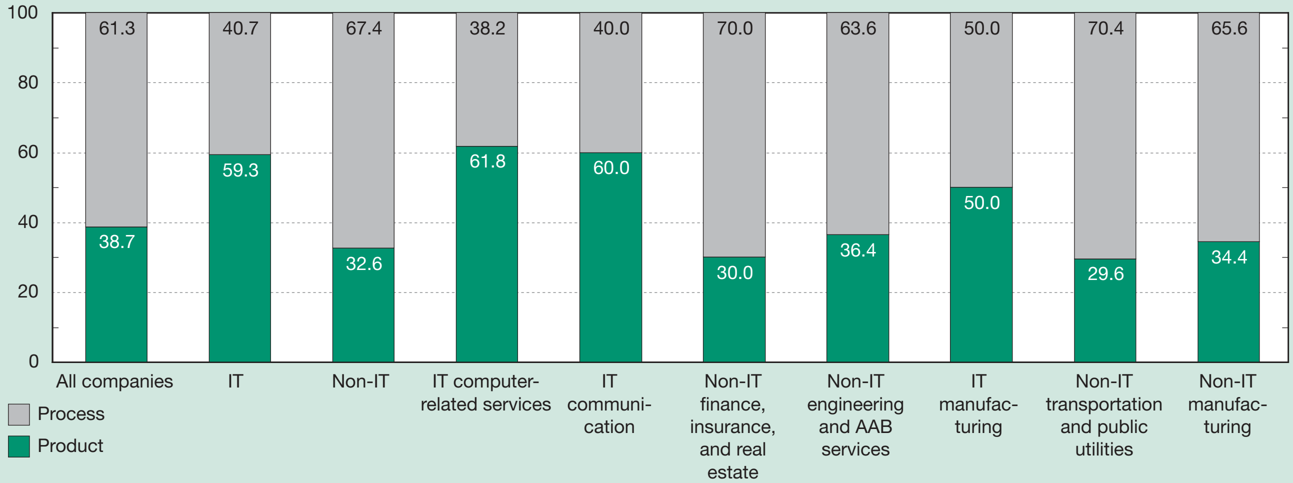
AAB accounting, auditing, and bookkeeping
IT information technology

[a]To be classified as innovator, the company had to have developed a product or process in the past 12 months or believed it would develop a product or process in the next 12 months as a result of IT-based innovation. The survey was conducted during the period July 2001 to April 2002.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix tables 6-18 and 6-19.

Science & Engineering Indicators – 2004

Figure 6-29
Type of innovation contributing most to company revenue, by sector: 2001



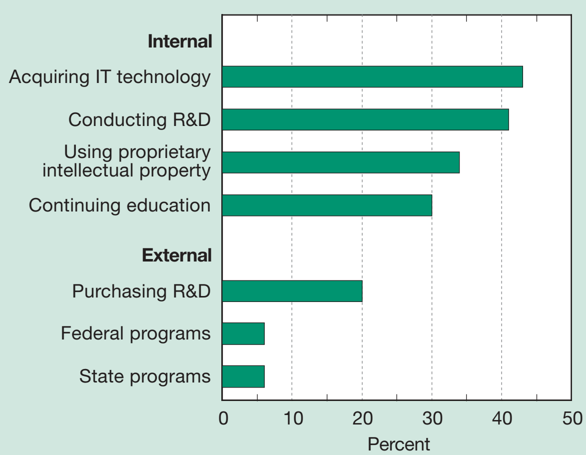
IT information technology
AAB accounting, auditing, and bookkeeping

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001. See appendix table 6-20.

Science & Engineering Indicators – 2004

Innovative companies were asked about various internal and external factors that contributed to their IT-based innovation. Among the internal factors cited, respondents considered acquiring IT and conducting R&D to be the most important. Forty-three percent of innovative firms said acquiring IT made a large contribution to their IT-based innovation, and 41 percent said the same about conducting in-house R&D (figure 6-30).

Figure 6-30
Internal and external factors contributing to IT-based innovation: 2001



IT information technology

NOTE: Data represent those who said factor was very important.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Information Technology Information Survey, 2001.

Science & Engineering Indicators – 2004

With respect to the other internal factors posed to respondents, 34 percent of innovators said using proprietary intellectual property made a large contribution to innovation, and 30 percent cited continuing education. Sector differences on this question are worth noting. Conducting R&D was cited as an important contributor to innovation by more IT companies (58 percent) than non-IT companies (37 percent), whereas acquiring IT technology meant more to non-IT companies (44 percent) than to IT companies (39 percent). This suggests that purchasing technology during the innovation process may be an effective substitute for developing technology through internal R&D. These results demonstrate how technology that is developed in one company or industry and acquired by others plays an important role in the acquiring company's innovation process.

External factors appear to have a lesser impact on innovative companies than internal factors. Among the seven factors posed to respondents, purchasing external R&D was the most highly valued, and it garnered this response from only 20 percent of respondents. Federal and state programs were the least valued; only 6 percent of innovative firms identified these programs as having made a large contribution to the firm's IT-based innovation.

The IT innovation survey answered several other questions as well:

- **What did innovators say provided incentive for IT-based innovation?** The availability of skilled IT personnel and favorable timeframes for realizing a return on investment were each considered an incentive by 45 percent of firms. R&D-associated costs were seen neither as an incentive nor a deterrent; the same was true for current tax policy, access to capital, and the existence of environmental regulations.

- **What did innovators see as strategically important for their firm's growth? Were their views different from those held by noninnovators?** Innovators viewed being the first to market as strategically very important, were more focused on expanding into new geographic regions, and placed a higher importance on conducting R&D than noninnovators. Innovators also viewed forming alliances, partnerships, or joint ventures as a more important business strategy than noninnovators. Innovators were more concerned about retaining skilled IT personnel (47 percent felt it was very important versus 24 percent of noninnovators) and viewed it as strategically very important for their business. Somewhat surprisingly, venture capital was not an overriding concern for innovators and noninnovators. Seventeen percent of innovators saw it as very important compared with 12 percent of noninnovators.
- **How important is IT hardware and software relative to other elements for conducting business?** Almost 60 percent of responding firms viewed IT hardware and software as very important for conducting business. Innovators weighted it even more, with nearly 74 percent reporting it as very important to their business.
- **How did firms view the utility of IT goods and services?** Firms saw IT goods and services as very important for reducing costs (54 percent of all respondents gave this answer, as did 67 percent of innovators and 43 percent of noninnovators), increasing productivity (64 percent overall, 77 percent of innovators, and 52 percent of noninnovators), and facilitating communication (61 percent overall, 75 percent of innovators, and 49 percent of noninnovators). Firms did not view IT goods and services as very important for attracting investment.
- **How important is R&D to the innovation process?** Forty-one percent of innovators said in-house R&D made a large contribution to IT-based innovation, 31 percent said that conducting R&D was a very important part of a growth strategy, and 20 percent said outsourced R&D made a large contribution toward IT-based innovation.

The development of innovation theory and the collection of data go hand in hand. This latest data collection effort by NSF drew on myriad experiences of related innovation surveys conducted in Europe, Asia, and Latin America, but it broke new ground by focusing exclusively on IT-based innovation. By designing the data collection process for a narrower set of innovations and industries, this survey strived to address practitioner concerns about the usefulness of national innovation data while trying to understand the innovation process in specific industries. The focus on IT-based innovation sought to improve the data currently available and to investigate the innovation process in this critical technology area.

Conclusion

Despite signs of a slowing economy, the United States continues to rank among the leaders in all major technology areas. Advances in U.S. aerospace, 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 bears this out and may suggest a level of optimism by U.S. and foreign inventors in the U.S. economy.

The United States also continues to be a leading provider of knowledge-intensive services, but it 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.

Though strong, U.S. high-technology industries have struggled in the shrinking economy and in the aftermath of the September 11 terrorist attacks. Declining investment in IT has clearly affected the bottom line in U.S. firms producing computer hardware and software. Firms involved in all aspects of communication, along with those in the U.S. aerospace industry, may be facing the greatest challenges. Airlines have sharply cut back orders due to declines in travel and tourism, and they face tougher competition in their struggle to retain market share while addressing the challenges raised by the events of September 11 and the still evolving societal and economic reactions to them. The event itself affected the nation in myriad ways, but it set an already struggling U.S. aerospace industry on its heels, and the industry continues to lose world market share.

Asia's status as both a consumer and developer of high-technology products has been enhanced by development in many Asian economies, particularly Taiwan, South Korea, and China. Several smaller European countries also exhibit growing capacities to develop new technologies and to compete in global markets.

The United States continues to be a leading developer and supplier of high-technology both at home and abroad. This success has likely been influenced by a combination of factors: the nation's long commitment to investments in S&T; the scale effects derived from serving a large, demanding domestic market; and the U.S. market's willingness to adopt new technologies. These same market dynamics already show signs of benefitting Asia and a more unified Europe and will likely enhance the value of their investments in S&T.

References

Borga and Mann. 2002. U.S. international services, cross-border trade in 2001 and sales through affiliates in 2000. *Survey of Current Business* October: 76–77.

Branscomb, L. M., and J. H. Keller. 1998. *Investing in Innovation: Creating a Research and Innovation Policy that Works*. Cambridge: MIT Press.

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

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

Meares, C. A., and J. F. Sargent, Jr. 1999. *The Digital Work Force: Building Infotech Skills at the Speed of Innovation.* Washington, DC: U.S. Department of Commerce, Office of Technology Policy.

National Research Council (NRC), Hamburg Institute for Economic Research, and 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. DRI-WEFA, A Global Insight Company, "The Economic Impact of the Venture Capital Industry on the U.S. Economy." http://www.nvca.org. Accessed February 2003.

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

Porter, A. L., and J. D. Roessner. 1991. Indicators of national competitiveness in high technology industries. Final report to the Science & Engineering Indicators Studies Group, National Science Foundation, two volumes. Atlanta: GA.

Presidential Commission. 2002. Final report of the Commission on the Future of the United States Aerospace Industry, November 2002. http://www.ita.doc.gov/aerospace/aerospacecommission. Accessed May 2003.

PRS Group. 2002. Political risk letter. Political and economic forecast table. http://www.prsgroup.com. Accessed March 2002.

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

Romer, P. M. 1996. Why, indeed in America? Theory, history, and the origins of modern economic growth. *American Economic Review* 86(2)(May): 202–206.

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.

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

U.S. Department of Commerce (DOC). 1998. *The Emerging Digital Economy.* Report on electronic commerce and society. Washington, DC.

U.S. Department of Commerce (DOC), Economics and Statistics Administration (ESA). 1999. *The Emerging Digital Economy II.* Washington, DC.

U.S. Department of Commerce (DOC), Office of Technology Policy (OTP). 1998. America's new deficit: The shortage of information technology workers. Washington, DC: DOC, National Technical Information Service.

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