Industry & Trade Summary

Semiconductors

USITC Publication 2708
December 1993

OFFICE OF INDUSTRIES
U.S. International Trade Commission
Washington, DC 20436

UNITED STATES INTERNATIONAL TRADE COMMISSION

COMMISSIONERS

Don E. Newquist, Chairman
Peter S. Watson, Vice Chairman
David B. Rohr
Anne E. Brunsdale
Carol T. Crawford
Janet A. Nuzum

Robert A. Rogowsky
Director of Operations

Vern Simpson
Director of Industries

This report was prepared principally by

Andrew F. Malison

Electronic Technology and Equipment Branch
Services and Electronics Division

Address all communications to
Secretary to the Commission
United States International Trade Commission
Washington, DC 20436

PREFACE

In 1991 the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of the basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on semiconductors covers the period 1986 through 1992 and represents one of approximately 250 to 300 individual reports to be produced in this series during the first half of the 1990s. Listed below are the individual summary reports published to date on the electronic equipment and technology sector.

USITC publication number	*Publication date*	*Title*
2445	January 1992	Television Receivers and Video Monitors
2648	July 1993	Measuring, testing, controlling, and analyzing instruments
2674	September 1993	Medical goods
2708	December 1993	Semiconductors

[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

CONTENTS

CONTENTS—*Continued*

Page

Tables

INTRODUCTION

Semiconductors are important to almost all electronic products and are found principally in computers, consumer electronics goods, transportation equipment, telecommunications apparatus, industrial machinery, and military hardware (figure 1). Semiconductors account for only 12.5 percent of the total value of electronic equipment sales.[1] However, since their invention in 1948, these devices have driven dramatic advances in the performance and manufacture of electronic equipment.[2] As a result, improvements in semiconductors usually spur innovation in the electronics industry, an industry that in the United States had 1992-sales of $260 billion.[3]

The semiconductor industry is often considered critical to the strength and development of the U.S. economy.[4] The industry accounts for only about 1 percent of U.S. employment in manufacturing industries, 1 percent of U.S. shipments of manufactured goods, and 3 percent of both U.S. imports and exports of manufactures.[5] However, manufacturing and service sectors in the United States and other major industrialized countries are quickly becoming more "electronics intensive." As a result, the ability of these countries to develop new products and services is becoming more dependent on the timely availability of leading-edge and competitively priced semiconductor devices.[6]

Semiconductor devices are electronic circuit components or combinations of these components produced within or on a crystal capable of controlling the flow of electrons. These devices can be subdivided into groups based on type, manner of processing electronic signals, technology, function, and design (figure 2). There are three types of semiconductor devices: discretes, integrated circuits (ICs), and hybrids. A discrete is an individually packaged semiconductor circuit component. ICs are combinations of two or more semiconductor components that are often put together with other electronic components arrayed on a single piece of silicon or other similar substrate. Hybrids are special packaging arrangements of either a combination of ICs or ICs with the addition of discrete components.

Discretes are usually soldered along with other electronic components on printed circuit boards (PCBs) used in electronic equipment. ICs can incorporate the equivalent of thousands of these PCBs and components in a miniaturized form.[7] Since the invention of ICs in 1958, technological improvements have continually increased the number of electronic components and interconnections that ICs can incorporate. As a result, one IC today can embody, for example, a large portion of the circuitry of a television set or computer.

ICs are classified according to whether they process electronic signals in a digital or an analog manner or combine these two manners of processing. Digital semiconductors store and manipulate data using the binary numerical system that represents values with 0's and 1's. Digital semiconductors represent these numbers using two levels of energy, one to represent the digit "0" and another to represent the digit "1." On the other hand, analog semiconductors store or manipulate data with a continuous functional relationship between input and output signal. For example, in an analog IC amplifier the output is a magnified version of the input. In recent years, as electronic equipment has become more sophisticated, ICs combining analog and digital circuits, called mixed signal or digital signal processing (DSP) ICs, are becoming increasingly common.

ICs are principally constructed using metal oxide semiconductor (MOS) or bipolar technologies.[8] In 1992 about 78 percent of the value of the world's IC production was based on MOS technologies and only about 19 percent of this value was based on bipolar technologies.[9] Until the early 1980s bipolar technologies were preferred to MOS technologies in the construction of ICs because bipolar ICs could provide greater processing speeds for electronic signals. However, MOS became preferred in IC construction as techniques were perfected to manufacture these devices. Compared with bipolar semiconductors, MOS ICs can be produced in fewer processing steps and with a greater density, and, thus, have significantly lower fabrication costs.[10] Moreover, compared with bipolar ICs, MOS ICs generally can

---

[1] Integrated Circuit Engineering (ICE), *Status 1993: A Report on the Integrated Circuit Industry* (Scottsdale, AZ: ICE, 1993), p. 1-5.

[2] "Controlling Our Own Destiny in Critical Technologies," a presentation of the Semiconductor Industry Association, Mar. 15, 1991, San Jose, CA, and U.S. International Trade Commission (USITC), *Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Semiconductor Manufacturing and Testing Equipment* (investigation No. 332-303), USITC publication 2434, Sept. 1991, pp. 1-8.

[3] Estimates based on data from Electronic Industries Association, *Electronic Market Databook* (Washington, DC: EAI, 1993), pp. 2 and 98.

[4] See for example NACS, *Toward a National Semiconductor Strategy*, vols. I and II, Feb. 1991.

[5] U.S. Department of Commerce, U.S. Bureau of the Census, Economics and Statistics Administration, *Statistical Abstract of the United States, 1992* (Washington, DC: GPO, 1992), table 1244, and official trade statistics of the U.S. Department of Commerce.

[6] See for example *EC Council Resolution of November 18, 1991*, concerning electronics, information, and communications technologies, and *Council Directive 165/90, Official Journal of the European Communities*, No. L 20 (Jan. 23, 1990), p. 5.

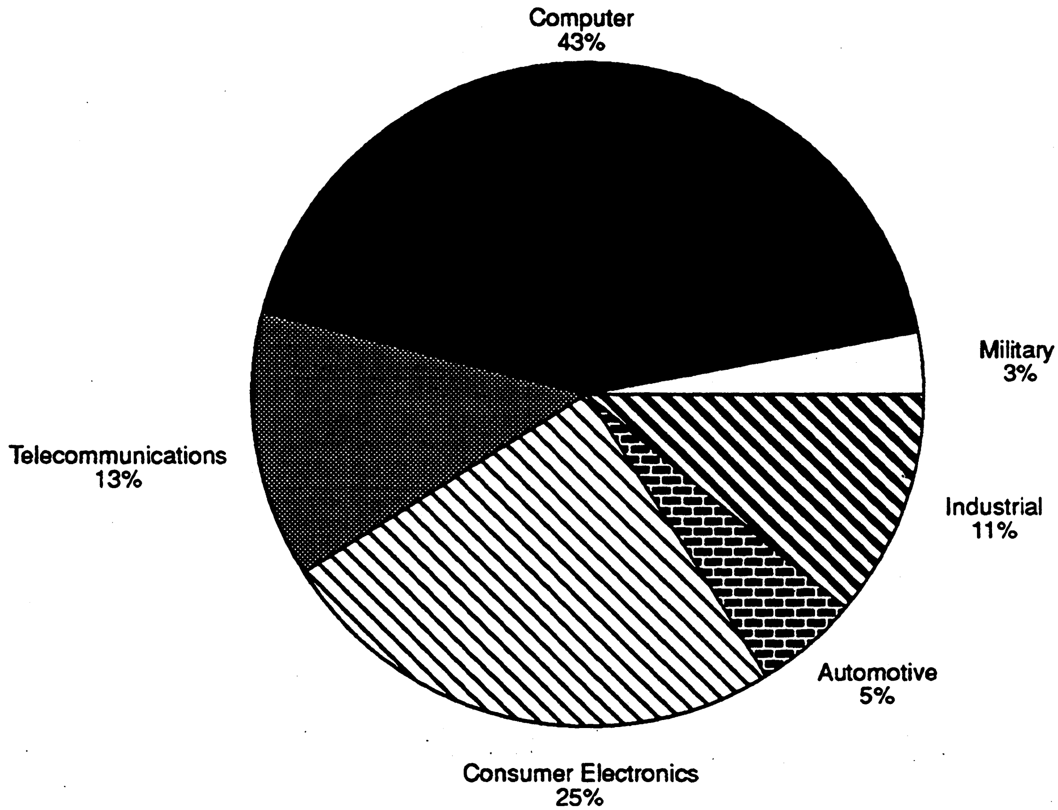
[7] ICs are box-shaped and usually have sides of less than 10 millimeters and heights of less than 1 millimeter.

[8] The explanation of semiconductor technologies and functions in this section draws heavily on Peter Van Zant, *Microchip Fabrication: A Practical Guide to Semiconductor Processing*, 2d ed. (New York: McGraw-Hill, 1990). See Appendix C for a glossary of technical terms.

[9] The remaining 3 percent consisted of ICs combining bipolar and MOS technologies or devices produced on substrates other than silicon. ICE, *Status 1993*, p. 5-3.

[10] See discussion below on manufacturing semiconductors.

Figure 1
Semiconductors: Principal world markets by end-use sector, 1992



Source: Integrated Circuit Engineering Corporation.

function with less power. This feature makes MOS ICs less prone to heat buildup and better suited for the portable electronic equipment applications that have proliferated during the past two decades. Heat buildup in semiconductors can cause circuit malfunctions and is the reason that computers with bipolar semiconductors are often installed in air-conditioned rooms. Low power requirements are advantageous in reducing the size of otherwise bulky power sources needed in laptop computers, video camera recorders, and other portable electronic equipment. The advantages of MOS technologies have been particularly beneficial for memory IC development because these devices usually have lower speed requirements and higher power requirements than microprocessors or logic circuits.

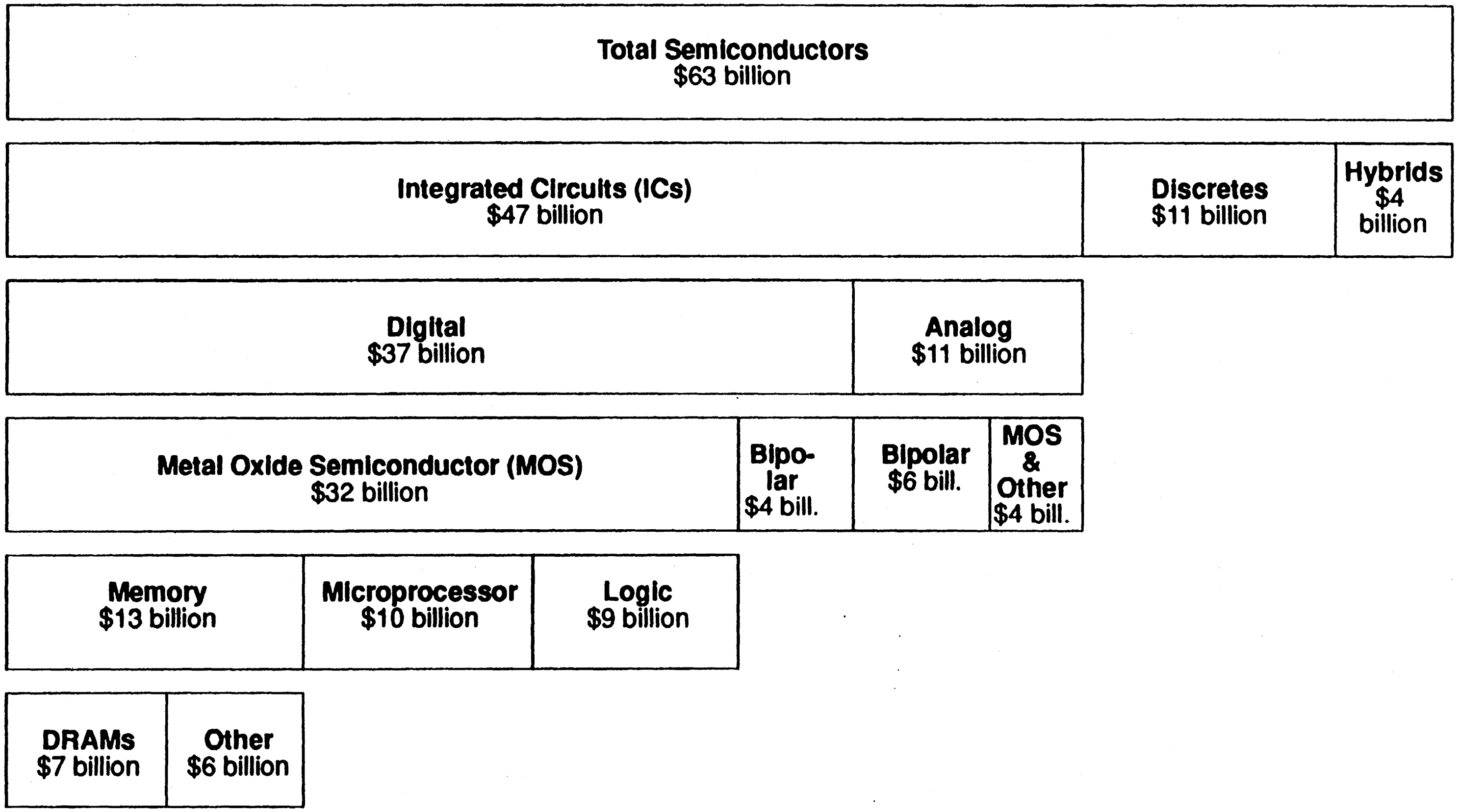
Recently producers began to combine MOS and bipolar technologies in the construction of ICs. In these ICs, MOS technologies are used for parts of the device that require less speed but are more sensitive to heat buildup, and bipolar technology is used for portions of the device that need to perform fast logic functions.

ICs fall into three functional classes: logic, memory, and logic combined with memory (microprocessors). Using electronic signals, logic ICs perform specified logical operations on data, such as adding two numbers. Memory ICs store and return information in the same form in which it is entered. For example, a memory IC in a calculator can store the value of pi (3.14) and provide it on request. Microprocessors can be programmed to perform many different functions fostering development of powerful personal computers, digital watches, and other sophisticated electronic equipment.

Semiconductors are also differentiated into two additional groups: commodity and noncommodity. The distinction between commodity and noncommodity devices is useful because, as the semiconductor industry has matured, several trends and factors governing the industry differ in these two segments. The commodity group encompasses semiconductors that compete primarily on a cost basis, enjoy relatively large markets, and, most importantly, are based on technological know-how that is relatively accessible to major producers in the industry. Commodity semiconductors principally include (1) discrete devices, except for some photosensitive semiconductors; (2) 4- to 8-bit logic circuits; and (3) memory ICs, except for high-speed memory ICs.

On the other hand, the noncommodity group consists of semiconductors that have higher profit margins. These semiconductors also are generally more

Figure 2
Semiconductors: Estimated worldwide market by product groups, 1990[1]



[1] The areas of the blocks in the figure are approximations of the relative market size of each major group of semiconductors. Each row represents a subgroup of the preceding row. The dollar shares of some subgroups may not add up to the total of the group because of rounding. The market for mixed signal ICs is not shown in this figure because it is less than $500 million, a relatively small portion of the semiconductor market.

Source: World Semiconductor Trade Statistics, Office of Microelectronics of the U.S. Department of Commerce, and estimates by the staff of the USITC.

specialized, and have smaller markets. Noncommodity semiconductors are based on technological know-how that, either because it is specialized or enjoys patent protection, is relatively inaccessible to most producers in the industry. Noncommodity semiconductors principally include (1) application-specific ICs (ASICs), (2) gate arrays, (3) high-end microprocessors and logic circuits, and (4) most mixed-signal ICs. Noncommodity semiconductors usually become commodities as markets grow, patent terms expire, or know-how becomes more widespread.

Semiconductors are manufactured in three main stages; design, wafer fabrication, and assembly and testing.[11] The design and development of new semiconductors requires highly skilled technical and engineering personnel as well as significant investment in capital equipment, such as sophisticated computers and software. Fabricating semiconductors is a complex process that is highly automated and capital intensive. Fabrication requires large investments in plant and equipment as well as skilled production workers. Compared with fabrication, assembly and testing of semiconductors is usually more labor-intensive, and it is often conducted in developing countries with low-cost labor. Although physics and electronic engineering are the underlying technologies of semiconductors, the manufacture of semiconductors also requires skills in chemistry, chemical engineering, and metallurgy.

Many compounds and elements are used in the production of semiconductors. By far the most significant of these materials are those used as the substrate or base on which semiconductor devices are built. For nearly 40 years silicon has been the overwhelmingly preferred substrate used in the manufacture of semiconductors. Silicon is relatively inexpensive, can operate at relatively high temperatures, and has an insulating, protective oxide property that eases batch production, a requirement for producing semiconductor devices at low costs. Other substrates used in the production of semiconductors include germanium, gallium arsenide, and indium phosphide. Whereas these substrates can provide better performance in some applications, at present their cost, heat tolerance, or durability usually makes them less suited than silicon for constructing most semiconductors.

Semiconductor manufacturers usually purchase their substrate materials as wafers from chemical producers.[12] Batches of these wafers are then subject to a multistep process involving lithography and the introduction of electrically active impurities into narrowly defined regions of the substrate. On each wafer anywhere from about 6 to 800 identical miniature circuits, known as chips, dice, or pellets, are produced simultaneously. After the chips are separated, they are usually assembled. Assembly involves mounting each chip onto a plastic or ceramic package, connecting the chip to metal leads, and enclosing the device for protection from mechanical shock and the external environment. Although most semiconductors are sold assembled, semiconductor customers are increasingly purchasing unassembled chips and incorporating them into hybrid circuits of their own manufacture.

The semiconductor fabrication process involves high-purity materials, minute circuit dimensions, and chemical concentrations, and other conditions that make measurement and control difficult. As a result, semiconductor manufacturing is characterized by a steep learning curve and is subject to an initially low ratio of working (as opposed to defective) chips. This yield[13] of nondefective chips can be considerably increased through knowledge and control of the production process and is largely a function of experience and research and development (R&D) efforts. Yields of working chips typically range from 25 percent for new, complex devices to more than 90 percent for mature products.

This summary of industry and trade information on semiconductors covers the period 1986 to 1992. The report is organized into three major sections: U.S. and foreign industry profiles and competitiveness, tariff and nontariff measures, and U.S. industry performance in domestic and foreign markets. In addition appendices include definitions of tariff and trade agreement terms, a list of U.S. International Trade Commission (USITC) reports pertaining to semiconductors, and a glossary of technical terms.

U.S. INDUSTRY PROFILE[14]

Industry Structure

From its beginning until the mid-1980s, the U.S. semiconductor industry was the world's dominant supplier of semiconductors and the undisputed leader in innovation. The semiconductor industry originated in the United States when the transistor was invented in 1948. In the late 1950s the U.S. industry developed the IC, which by the end of the 1960s revolutionized the world's electronics industry. Since then the U.S. industry has generally sustained high growth rates in output and continued as the world's leader in innovation. However, in the mid-1970s, although domestic production continued to grow rapidly, the U.S. share of total world output declined as U.S.-headquartered firms expanded manufacturing operations abroad and as the industries of Japan and

[11] The explanation of the production of semiconductor devices in this section draws on the following: USITC, *Semiconductor Manufacturing and Testing Equipment*, USITC publication 2434, pp. 1-8., and U.S. Department of Commerce, National Institute of Standards and Technology, *Semiconductor Technology for the Non-Technologist*, 2d ed. (Sept. 1990), by Robert I. Scace, NIST publication 4414.

[12] Wafers are produced from extremely pure substrate materials formed into long rods having a diameter from about 10 centimeters to about 30 centimeters. Manufacturers cut the rods into thin cross-sections which are polished to create wafers that are essentially flat and defect-free. USITC, *The U.S. Polysilicon Industry in its Global Context*, unpublished staff paper, May 25, 1990.

[13] Yields represent the number of working chips produced on a wafer as a percent of the total number of chips fabricated on this wafer.

[14] Semiconductors are reported in Standard Industrial Classification (SIC) 3674, Semiconductors and Related Devices.

other countries grew. By the mid-1980s the U.S. industry had been overtaken by the Japanese industry as the world's largest supplier of semiconductors, and during the remainder of the 1980s it continued to lose market share in the world (figure 3). This loss of market share subsided in 1991 and was reversed the following year as demand for noncommodity semiconductor product lines, which are dominated by U.S. producers, rose and major foreign electronic producing-areas entered into recessions.[15]

About 100 of the roughly 750 firms in the U.S. semiconductor industry operate fabrication lines and account for most of the industry's shipments.[16] The remaining firms principally supply semiconductor parts such as mounts for semiconductors or produce special packaging arrangements of semiconductors such as single in-line memory modules (SIMMs). The Herfindahl Index for the industry was .046 in 1990, suggesting a negligible concentration among the top companies of the industry.[17]

In 1992 the U.S. semiconductor industry employed roughly 175,000 workers. Although the industry's domestic shipments almost doubled in value during 1986-92, employment in the industry remained almost unchanged.[18] U.S. firms increased output without increasing employment by adopting new technologies that made U.S. semiconductor manufacturing more capital-intensive and productive and by transferring labor-intensive manufacturing abroad.[19] Labor productivity in the U.S. semiconductor industry, measured by value added per employee, not adjusted for inflation, increased annually during 1986-92 by an estimated 13 percent.[20]

U.S. semiconductor producers consist of both merchant firms that primarily sell their output on the open market and captive firms that primarily manufacture semiconductors for internal consumption (figure 4). Many merchant producers, such as Intel Corp. and Motorola, produce semiconductors for both internal and external consumption. However, these firms are generally considered to be merchant rather than captive producers because they sell a large portion of their production on the open market with a primary goal to serve this market rather than in-house needs.

In 1992 about 84 percent of U.S. semiconductor consumption was supplied by merchant producers and the remainder by captive producers. That year International Business Machines Corp. (IBM), a captive producer and the largest U.S. producer of semiconductors, supplied an estimated 71 percent of U.S. captive consumption.[21] The remainder of captive consumption was supplied by a small number of firms.

In 1992 Intel, Motorola, Texas Instruments (TI), and National Semiconductor, all merchant producers, were the largest U.S. semiconductor producers after IBM. Together these four merchant producers accounted for an estimated 33 percent of the U.S. merchant market (figure 5). Though there are some notable exceptions, such as American Telephone & Telegraph Corp. (AT&T), Motorola, and TI, most of the top 100 U.S. semiconductor firms are not diversified.

The U.S. industry is concentrated in California, New York, and Texas,[22] locations generally near primary users, engineering know-how, transportation routes, and good utility and telecommunications infrastructures. During 1986-92 Texas, Oregon, and Colorado attracted a relatively large proportion of new capital investments made by semiconductor producers.[23] Semiconductor producers were attracted by the relatively low tax rates, land values, and energy prices in these states. Moreover, semiconductor producers chose these locations knowing that many of their workers would welcome relocation to the relatively uncongested and economical living environments of these states.[24]

During 1986-92, the U.S. industry became more integrated with the global semiconductor industry as foreign producers increased their operations in the United States and as U.S. producers increased their operations abroad. Although the U.S. industry continues to be dominated by U.S.-headquartered firms, foreign-headquartered firms significantly increased their equity in the U.S. industry to serve the U.S. market better, tap into advanced skills of U.S. semiconductor industry personnel, and, in the case of some Japanese firms, reduce potential trade friction.[25] In 1986 foreign firms owned or partially

---

[15] Market share data in this report is based on production by geographical location and, therefore, is different from that reported by ICE, Dataquest, The World Semiconductor Trade Statistics (WSTS) Committee of the Semiconductor Industry Association (SIA), Electronics International Corporation (EIC), and other sources reporting such data based on the national affiliation of producing firms.

[16] Estimated from data from Dataquest and U.S. Department of Commerce, U.S. Bureau of the Census, *U.S. Census of Manufacturers: Industry Series, Electronic Components* (Washington, DC: GPO, 1987), MC87-I, p. 36E-7.

[17] This index ranges from 0.0 in a perfectly competitive marketplace with hundreds or thousands of producers to 1.0 in a monopolistic marketplace. A high index indicates a greater degree of concentration in the industry.

[18] U.S. Department of Commerce, *1989 U.S. Industrial Outlook* (Washington, DC: GPO, 1989), p. 30-2, and U.S. Department of Commerce, *1992 U.S. Industrial Outlook* (Washington, DC: GPO, 1992), p. 16-2.

[19] U.S. industry officials, interviews by USITC staff, 1991-92.

[20] Estimated from data in U.S. Department of Commerce, *Annual Survey of Manufacturers*, 1986 to 1991 issues.

[21] Estimated by the staff of the USITC based on data from ICE, *Status 1993*.

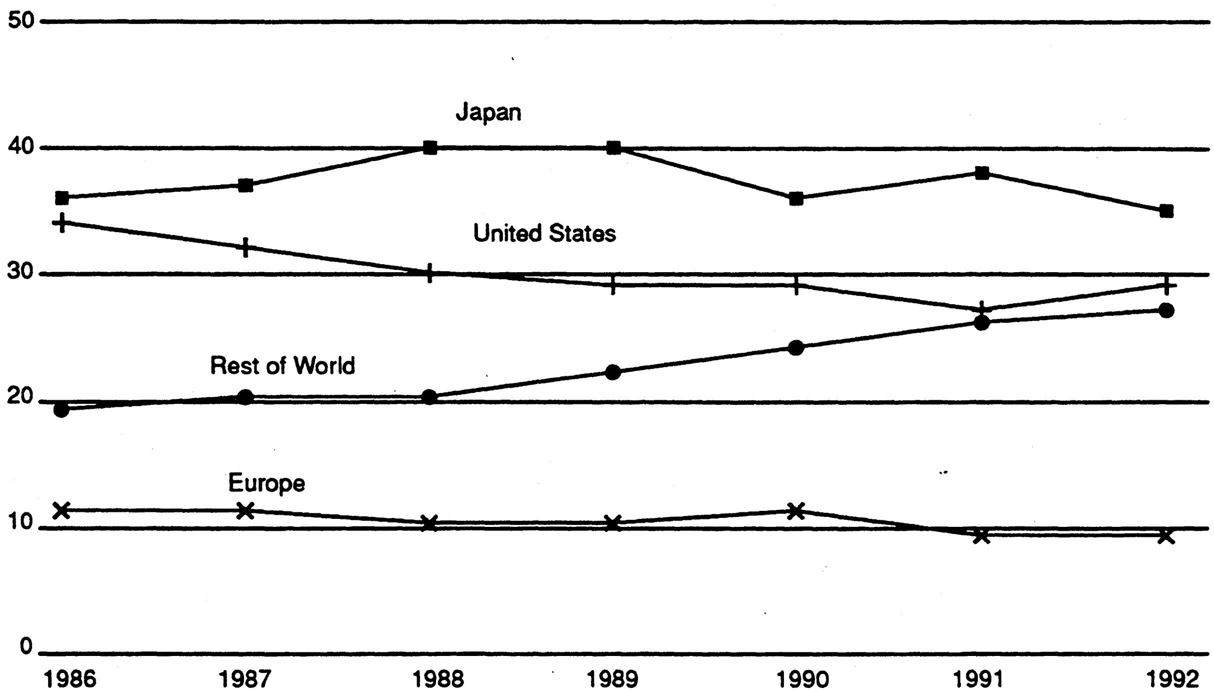
[22] U.S. Department of Commerce, *U.S. Census of Manufacturers*, p. 36E-12.

[23] U.S. industry officials, interviews by USITC staff, 1991-92, and estimates based on data from U.S. Department of Commerce, *U.S. Census of Manufacturers*, and U.S. Department of Commerce, *Annual Survey of Manufacturers*, 1986 to 1991 issues.

[24] U.S. industry officials, interviews by USITC staff, 1991-92.

[25] U.S. Department of Commerce, Economics and Statistics Administration and Technology Administration, *Japanese Direct Investment in U.S. Manufacturing* (Washington, DC: GPO, Aug. 1991), p. 29.

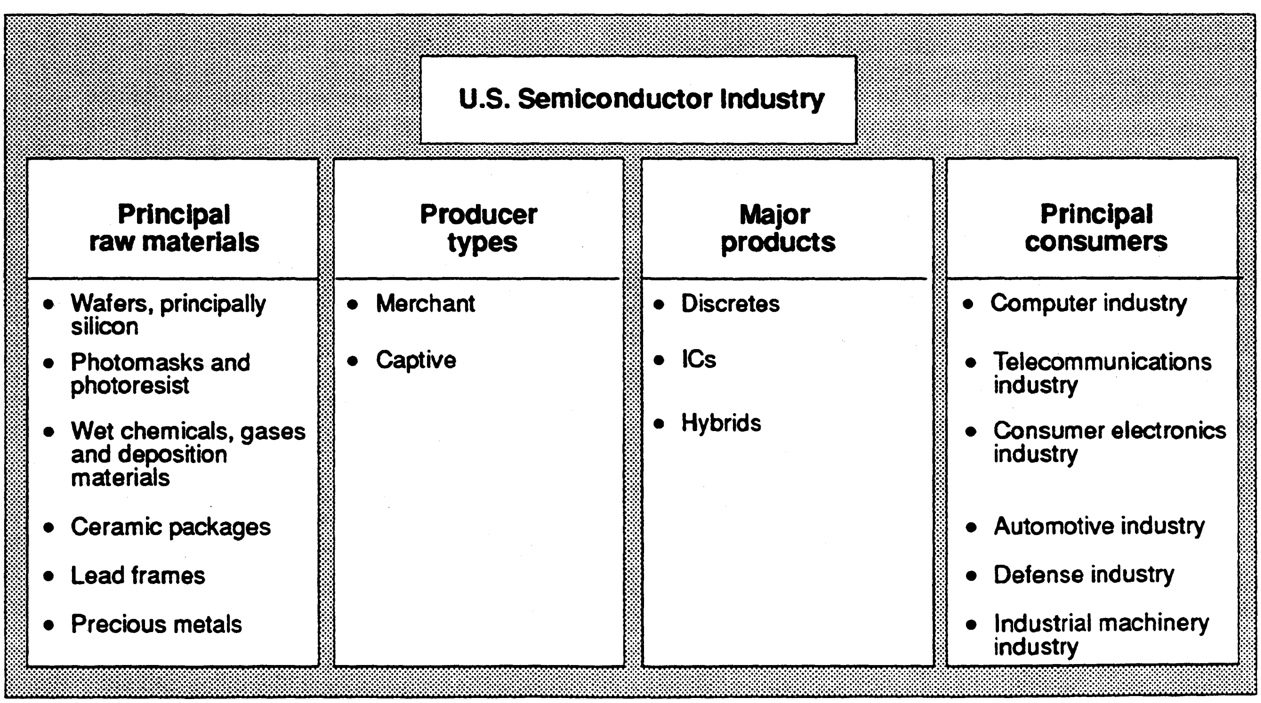
Figure 3
Semiconductors: Share of world output by selected geographical regions, 1986-92[1]



[1] These data exclude wafers, parts, and modules classified in SIC 3674 and are in current dollars for 1986-91 and projected in constant 1991-dollars for 1992.

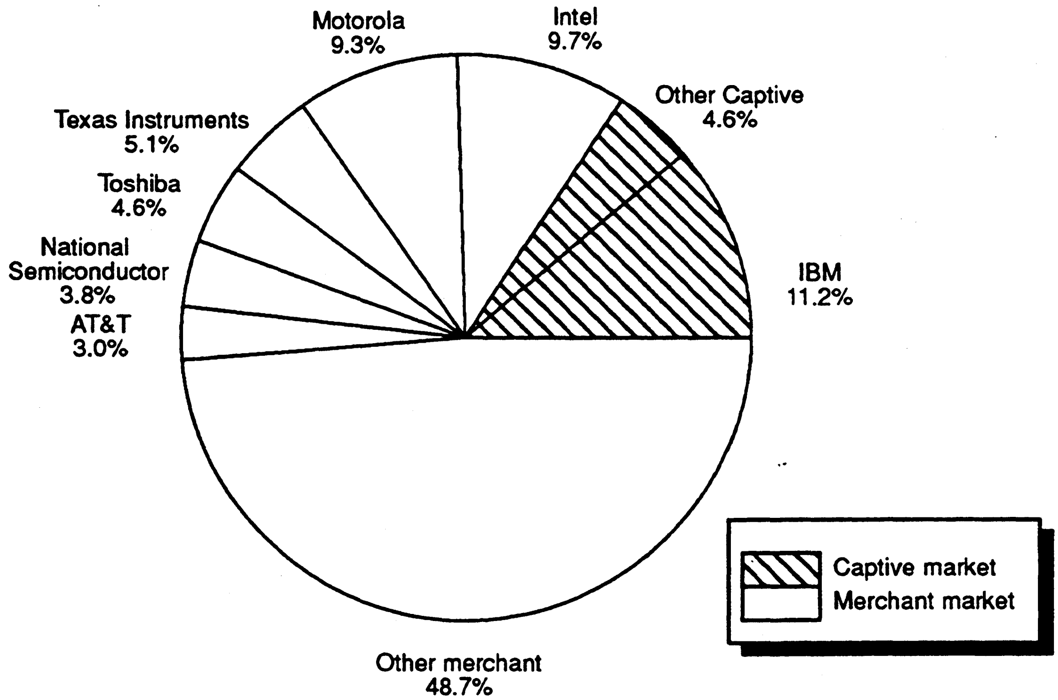
Source: Elsevier Advanced Technology, Oxford, United Kingdom.

Figure 4
U.S. semiconductor industry: Principal raw materials, producer types, major products, and principal consumers



Source: Compiled by USITC staff.

Figure 5
Semiconductors: North American market share estimates of principal suppliers, 1991



Source: USITC staff estimates based on data from Dataquest and ICE.

owned only a negligible portion of U.S. fabrication lines in the United States. By 1990 foreign producers owned or partially owned 39 of the 293 fabrication lines in North America. The principal foreign semiconductor firms operating semiconductor facilities in the United States are from Japan: Fujitsu, Ltd., Matsushita Electronics Corp., NEC Corporation, Oki Electric Industry Corp. Ltd., Mitsubishi Electric Corp., Sony Corporation, and Toshiba Corporation; and from the EC: Philips Semiconductor, and Siemens AG.

During 1986-92 U.S. producers of semiconductors expanded production more rapidly abroad than in the United States for several reasons. U.S. firms increased their production abroad to serve better the electronics industries of the EC, Asia, and Japan, all of which grew considerably faster during most of the 1986-92 period than the U.S. electronic equipment industry.[26] U.S. firms also increased semiconductor production in Japan and the EC during this period to access more favorable financing available in those markets. Some U.S. semiconductor firms established fabrication plants in the EC responding to changes in EC government procurement practices, rules of origin, and local-content requirements.[27] During 1986-92, foreign government investment incentives and lower transportation and communications costs also helped accelerate the expansion of U.S. firms abroad.[28]

In addition, further global integration of the U.S. industry during 1986-92 occurred because U.S. and foreign producers increasingly entered into alliances (figure 6). Some U.S. semiconductor firms entered into these business relations with European and Japanese producers to access foreign producer capital markets. These capital markets allegedly offered U.S. semiconductor firms cheaper and more available capital.[29] Other firms entered into alliances to share or develop technologies jointly to reduce R&D cost burdens and technology decision risks. Among the most notable associations of this type is an alliance entered in 1991 between IBM and Siemens to develop and produce dynamic random access memories (DRAMs), one of the largest and fastest growing segments of the world's semiconductor market.[30]

[26] U.S. industry officials, interviews by USITC staff, fall 1992.

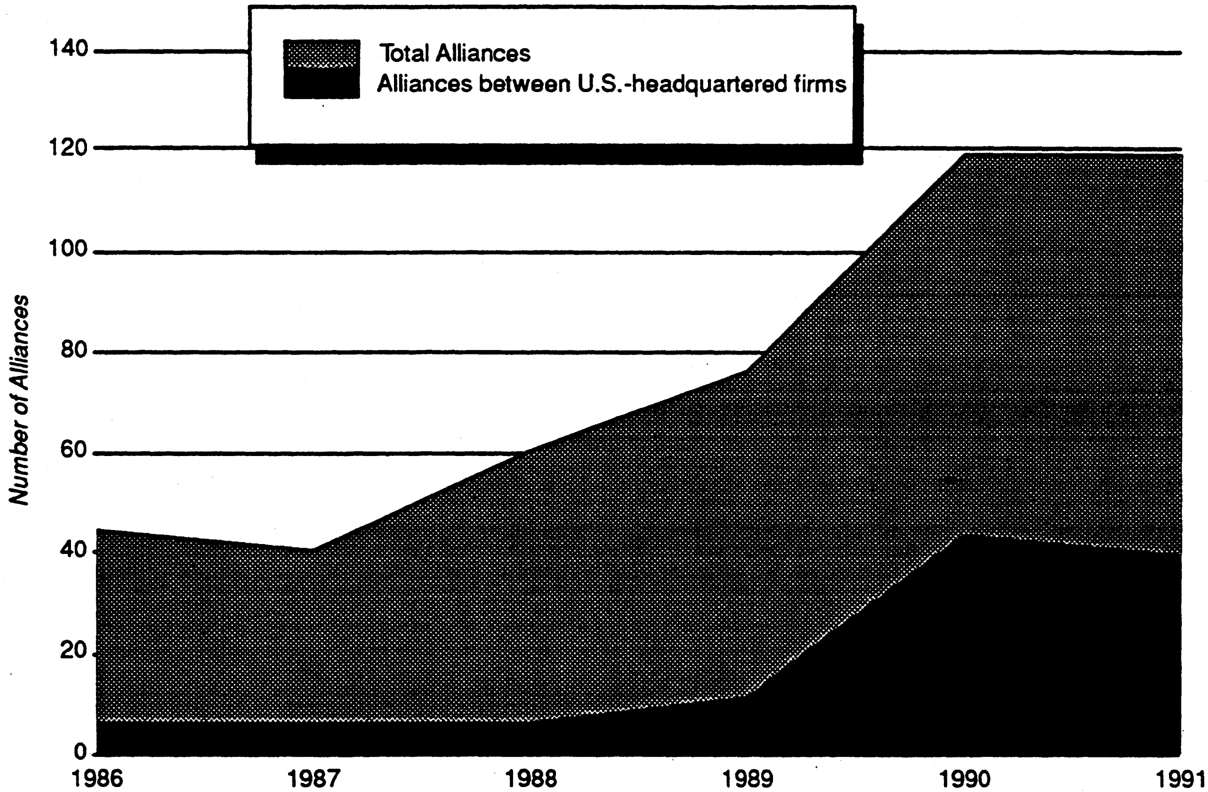
[27] See section on foreign nontariff measures later in this report.

[28] Charles R. Taylor, *Global Presence and Competitiveness of U.S. Manufacturers*, The Conference Board, 1991; U.S. industry officials, interviews by USITC staff, 1991 and 1992.

[29] H. Garrett DeYoung, "Piecing Together Successful World-Class Partnerships," *Electronic Business*, May 28, 1990, pp. 32-36, and "Bruce C.P. Rayner, "Shift in Focus for Strategic Alliances," *Electronic Business*, Mar. 19, 1990, pp. 58-60.

[30] Siemens is one of the top semiconductor producers in the EC.

Figure 6
National and international alliances entered into by semiconduct or firms, 1986-91[1]



[1] Total alliances comprise all alliances among semiconductor firms in the world during the period. An alliance is broadly defined to include any agreement between two or more firms concerning marketing, joint research and development efforts, manufacturing, and technology licensing.

Source: Venture Economics/Securities Data Co.

Firms also entered into alliances to bring products to market more quickly and meet the escalating cost of establishing semiconductor fabrication facilities. One such venture is between Hewlett-Packard, TI, Canon of Japan, and the Singapore Economic Development Board and includes plans to build a $330 million wafer fabrication facility in Singapore.[31]

It is essential that semiconductor firms invest in R&D in order to maintain their competitiveness. These expenditures can significantly reduce production costs in manufacturing.[32] R&D expenditures also can enhance the ability of firms to develop and keep up with the latest generation of products and decrease the time required to bring these products to market. In this industry, time-to-market has become increasingly important. With the early introduction of an improved semiconductor, firms can command relatively high profit margins. With time, these margins diminish significantly as the number of suppliers of similar products in the market increases and the product becomes a commodity.

The U.S. semiconductor industry is among the most R&D-intensive of all U.S. manufacturing industries.[33] During 1986-90, R&D expenditures as a share of sales averaged about 3 percent for all U.S. manufacturing firms compared with 13 percent for U.S. semiconductor firms; the latter represents an increase over the 11 percent share of 1981-85. Semiconductor producers increased their R&D expenditures during 1986-90 to reduce production costs, accelerate new product development, and shorten the time-to-market of these products.

There are three R&D consortiums of U.S. producers of semiconductors: the Microelectronics and Computer Technology Corp.

[31] Integrated Circuit Engineering (ICE), *Status 1992: A Report on the Integrated Circuit Industry* (Scottsdale, AZ: ICE, 1992), p. 2-7. The cost of setting up a semiconductor fabrication facility has been rising rapidly and presently ranges from under $100 million to $1 billion.

[32] The impact of R&D on manufacturing costs is discussed in the introduction to this report.

[33] USITC, *Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study* (investigation No. 332-294), USITC publication 2319, Sept. 1990, p. 6.

(MCC), the Semiconductor Research Corp. (SRC), and Sematech. These consortiums are generally believed to have increased the competitiveness of the U.S. industry. However, the extent of this contribution is disputed.[34]

MCC is a privately funded, for-profit research organization created in 1982 to maintain U.S. leadership in microelectronics and computer sciences. In 1986 MCC had 27 members, a $50 million annual budget, and 400 employees. During 1986-92, MCC's budget and employment did not change appreciably. However, its membership rose appreciably during this period as members were no longer required to participate in the consortium as a whole but were allowed to limit their participation to targeted projects.[35]

SRC was formed in 1982 by the Semiconductor Industry Association (SIA) as a subsidiary to fund U.S. university R&D and students specializing in semiconductor technologies. In 1986 SRC had 35 members and total operating revenues of $16.5 million. During 1986-92 awareness of the consortium's benefits increased and the organization assumed the management of Sematech's external research services. As a result, by 1992 SRC's membership and budget increased to 71 and $35 million, respectively.[36]

Sematech, also an initiative of the SIA, was created in 1987 by 14 major U.S. semiconductor firms and the U.S. Government to sponsor and conduct R&D aimed at assuring U.S. leadership in semiconductor manufacturing processes, materials, and equipment. Half of Sematech's $200 million annual budget is funded by the consortium's participating firms, and the remainder is funded by the Advanced Research Projects Agency (ARPA, formerly the Defense Advanced Research Projects Agency, DARPA) through a matching funds program.[37] The consortium contracts out about half of its R&D projects to a group of 140 equipment and materials manufactures, funds research at 11 university-based centers and several national laboratories, and conducts in-house research using its 700-person staff. Since it was founded, Sematech's budget has remained unchanged and membership has dropped to 11.

In the semiconductor industry, royalties for licenses of patented technologies have historically been nominal.[38] However, during 1986-92 U.S.-headquartered firms increasingly sought to protect their intellectual property rights and seek compensation for violations. This change has been attributed to several factors, including the industry's increased product development costs and maturity, the creation in 1982 of a U.S. Federal Appeals Court dedicated to intellectual property disputes, and the Omnibus Trade and Competitiveness Act of 1988.[39] During 1986-92 a large portion of the income of some semiconductor firms, most notably TI, came from collecting these types of royalties.[40] Other firms such as Intel Corp., significantly increased their profit margins during this period by restricting competing firm's ability to copy or imitate their products.[41]

In the United States merchant semiconductor firms sell primarily through two distribution channels, each serving different-sized customers. Large original equipment manufacturers (OEMs) are usually served directly with negotiated contracts. Smaller semiconductor users are usually served through independent wholesalers, who usually stock a variety of other electronics parts as well. Captive producers often enter the open market as purchasers when they are unable to satisfy their internal demand.[42]

Consumer Characteristics and Factors Affecting Demand

The major consumers of semiconductors in the United States are producers of data processing equipment, industrial equipment, communications apparatus, military hardware, transportation equipment, and consumer electronics goods.[43] These producers are known collectively as the U.S. electronic equipment industry and are dispersed across the nation.[44] Like the U.S. semiconductor industry, the U.S. electronic equipment industry is part of a global industry, and U.S.-headquartered producers of electronic equipment are major employers and manufacturers in the electronics industries of Europe, Canada, members of the Association of South East Asian Nations (ASEAN), Mexico, and several other developing countries.

Demand for semiconductors is closely linked to the growth of the electronic equipment industry,[45] whose growth, in turn, is largely influenced by capital equipment expenditures. During the latter part of the 1980s, following a trend that had begun earlier, production of electronic equipment in the United States

[34] For a discussion of these views see Peter Burrows, "Consortia: Are They Getting Better," *Electronic Business*, May 18, 1992, pp. 46-52.

[35] MCC representative, telephone conversation with USITC staff, Oct. 1992.

[36] SRC representative, telephone conversation with USITC staff, Jun. 1993.

[37] Sematech, "Sematech: Innovation For America's Future," a brochure published by Sematech, Austin, TX.

[38] U.S. industry officials, interviews by USITC staff, fall 1991.

[39] Section 301 of the Trade and Competitiveness Act of 1988, 19 U.S.C. 2901, strengthened the enforcement of international agreements governing intellectual property rights, and section 337 relieved U.S. firms challenging the importation of foreign products violating U.S. intellectual protection laws from having to show (a) "injury" and (b) that the domestic industry was efficiently and economically operated.

[40] ICE, *Status 1993*, p. 2-3.

[41] U.S. industry officials, interviews by USITC staff, 1992.

[42] Ibid.

[43] Ibid.

[44] Some concentration of these producers exists in the Santa Clara Valley in California, Research Triangle in North Carolina, the Boston area, and certain areas in Texas and New York. Based on data from U.S. Department of Commerce, *Annual Survey of Manufacturers* (1986-90 issues), and staff of U.S. Department of Commerce, U.S. Bureau of the Census, Economic Surveys Division, telephone conversation with USITC staff, Nov. 1991.

[45] ICE, *Status 1993*, p. 1-4 to 1-7.

grew at a slower rate than did production in other regions of the world. As a result, the U.S. share of the world's production of electronic equipment decreased from about 41 percent in 1986 to about 29 percent in 1992 (figure 7).[46]

The reduced U.S. share of world electronic equipment production during the second half of the 1980s may be attributable in part to the increased ability of Japan and countries such as the Republic of Korea (Korea), Singapore, and Taiwan, to develop export-oriented manufacturing capabilities in both electronic components and finished equipment.[47] The slower growth in U.S. electronic equipment production also reflects an increase in foreign manufacturing by U.S.-headquartered firms. Several factors have contributed to this development. In some foreign markets U.S. firms established or expanded foreign production facilities to circumvent high duties and nontariff barriers.[48] In other markets, particularly those large enough to provide significant economies of scale in manufacturing, U.S. firms set up local production to be closer to customers and improve their competitive position in these markets.[49] Moreover, U.S. electronic producers increasingly shifted labor-intensive manufacturing to Mexico, Singapore, Malaysia, Korea, Taiwan, and other countries with relatively low labor rates to reduce production costs.[50]

There are no close substitutes for semiconductors; therefore, users usually insist on multiple sources of supply and on devices produced to industry standards. Price, performance, availability, and quality are the primary marketing factors, with price regarded as the principal factor, particularly for commodity products. For noncommodity products, price is less of a factor, and users must often rely on only one or a few sources of supply. Imported semiconductors, including those from producers not affiliated with U.S. firms, are expected to meet domestic quality and performance specifications and are interchangeable with those produced in the United States.

FOREIGN INDUSTRY PROFILE

Until the late 1970s the United States was indisputably the world's leader in semiconductor production. However, by the mid-1980s, Japan had surpassed the United States as the dominant world producer of these devices. Japanese manufacturers developed superior manufacturing techniques that reduced commodity semiconductor manufacturing costs.[51]

Producers in the Japanese semiconductor industry have a significantly different concentration and structure than U.S. producers. Ten producers in Japan accounted for about 90 percent of the country's semiconductor production in 1991.[52] These producers were NEC, Toshiba, Hitachi Ltd., Fujitsu, Mitsubishi, Matsushita, Sharp Corp., Sony, Sanyo Electric Co., and Oki. Unlike most U.S. semiconductor producers, Japanese semiconductor producers are mainly diversified firms that produce electronic components and equipment for both internal consumption and outside sales. In 1989, for example, 9 of Japan's top 10 semiconductor producers were among Japan's top 10 producers of electronic equipment.[53] Moreover, on average, the semiconductor sales of the top 10 semiconductor firms accounted for only an estimated 16 percent of these firms' total sales.[54]

Like the United States, Japan exports a large portion of its semiconductor production. However, unlike the United States, Japan is not a large importer of semiconductors. In 1989, for example, Japan exported an estimated 37 percent of the value of its semiconductor production and imported an estimated 13 percent of the value of its consumption of these devices.[55] That same year, the United States exported 42 percent of the value of its semiconductor production and imported 51 percent of the value of its consumption.[56]

Japan's superior competitiveness over the United States and other semiconductor producers in manufacturing is derived in part from several technological strengths. A 1991-report of the Japanese Technology Evaluation Center (JTEC) on the use of computer-integrated manufacturing (CIM) found that Japan had a 5-year lead over the United States in the application of CIM technologies in the production of ICs.[57] Also that year, the U.S. National Critical Technologies Panel reported that Japan lead in some new semiconductor manufacturing technologies including the following: microwave plasma processing; radiation sources for lithography; electron and ion microbeams; laser-assisted processing; compound semiconductor processing; and three-dimensional device structures. Whereas the United States led in a number of semiconductor

[46] Elsevier Science Publishing Ltd., *Yearbook of World Electronics Data*, (formerly the *Mackintosh Yearbook of International Electronics Data*) (Oxford, England: Elsevier, 1989-93).

[47] U.S. industry officials, interviews by USITC staff, 1991 and 1992.

[48] Ibid.

[49] Ibid.

[50] For example, see USITC, *Potential Impact on the U.S. Economy and Selected Industries of the North American Free-Trade Agreement*, (investigation No. 332-337), USITC publication 2596, Jan. 1993, p. 5-1.

[51] Federal Interagency Staff Working Group, *The Semiconductor Industry*, National Science Foundation, Nov. 16, 1987, pp. 1-2.

[52] Dempa Publications, *Japan Electronics Almanac 1991* (Tokyo: Dempa, Inc., 1991), p. 308.

[53] Dempa, *Japan Electronics Almanac 1991*, p. 308.

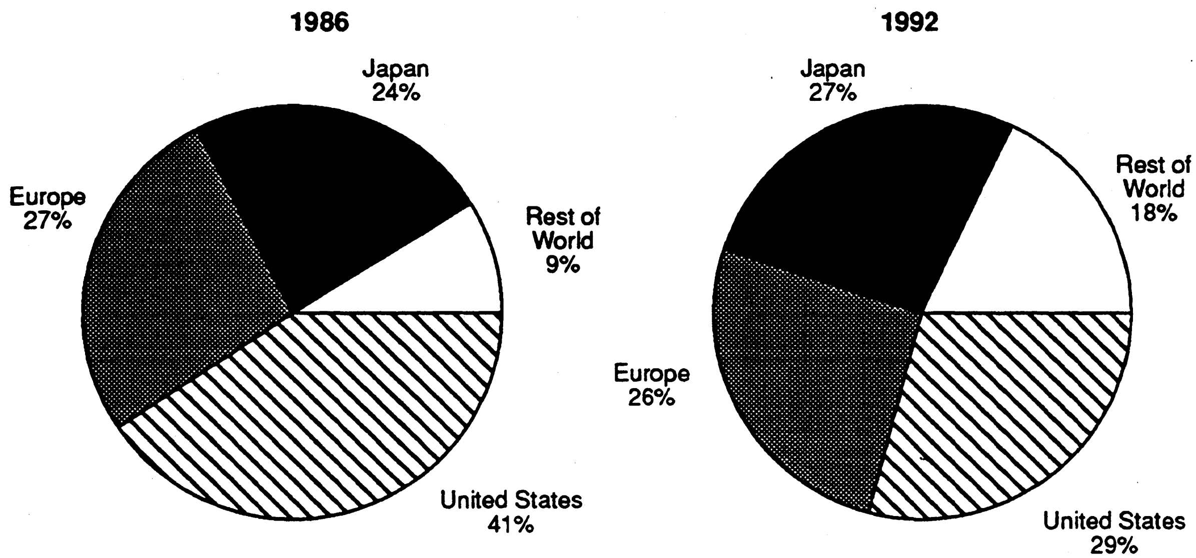
[54] Estimated by the staff of the USITC from sales data in ICE, *Status 1991*, p. 2-31, and Dempa, *Japan Electronics Almanac 1991*, p. 308.

[55] Estimated by the staff of the USITC from data in Dempa, *Japan Electronics Almanac 1991*, p. 92.

[56] Derived from official statistics of the U.S. Department of Commerce and Dempa, *Japan Electronics Almanac 1991*.

[57] Patricia N. Rogers, ed., *JTEC Program Summary*, coordinated by Loyola College in Baltimore, MD, Sept. 1991, p. 32.

Figure 7
Electronic Equipment: Production by geographical location for major producing areas in the world, 1986 and 1992[1]



[1] Because of rounding, percentages may not total 100.

Source: Elsevier Advanced Technology, Oxford, United Kingdom.

manufacturing technologies, such as ion implantation, thin-film epitaxy, thin-film deposition, and etching, this panel also pointed out that Japan led in lithography, materials purity, and ceramic packaging.[58] During the last two years, U.S. firms have made significant improvements in their manufacturing capabilities, though reportedly continue to lag behind Japanese producers.[59]

Europe is highly dependent on semiconductor imports and exports a relatively small proportion of its semiconductor production. Moreover, foreign-headquartered firms, particularly U.S.-headquartered firms, account for a large portion of Europe's production. Europe imports about half of its semiconductor requirements. In 1989 European-headquartered semiconductor firms supplied only 37 percent of their home market, U.S.-headquartered firms supplied 41 percent of this market, and Japanese companies, 20 percent.[60] Concentration in the European market is relatively high, with about 81 percent of the market supplied by 20 firms.[61]

The principal European semiconductor producers are Philips N.V. of the Netherlands, SGS-Thomson Microelectronics (STM), which was formed in 1987 from the merger of the French Thomson-CSF and the Italian SGS-Ates, and Siemens AG of Germany.[62] In 1989 Philips and STM were the largest and second-largest suppliers of semiconductors in Europe, and Siemens ranked fifth. The remaining firms among the top 10 suppliers of Europe's market include five U.S.-headquartered firms—TI, Motorola, Intel, National Semiconductor, and Advanced Micro Devices (AMD)—and two Japanese-headquartered firms—NEC and Toshiba.[63]

Since the mid-1980s producers in several countries in Asia, most notably Korea, have increased their production and share of the world's semiconductor market significantly. U.S.-headquartered semiconductor producers, which historically have had assembly operations in these Asian countries, continued to expand their operations to include some fabrication plants. Domestically owned producers in Asian countries, usually with the help of their governments, developed indigenous capabilities as fabrication and assembly subcontractors for U.S. and other foreign firms. Moreover, some of these Asian

[58] National Critical Technologies Panel, *Report of the National Critical Technologies Panel* (Arlington, VA: 1991), prepared pursuant to title VI of Pub. L. 94-282, as amended by sec. 841 of Pub. L. 101-189, p. 61.

[59] U.S. industry officials, interviews by USITC staff, 1993.

[60] Association of Computing Machinery (ACM), "The Semiconductor Market in the European Community," *Communications of the ACM*, ACM, vol. 33, No. 4 (Apr. 1990), p. 418.

[61] Roger Chiarodo and Judee Mussehl, "The Semiconductor Market in the European Community," quoted from Dataquest Corp., p. 418.

[62] Kenneth Flamm, *Europe 1992: An American Perspective*, The Brookings Institution, Oct. 1989, revised Jan. 1990, pp. 30-33.

[63] Dataquest Corp.

producers developed indigenous design, manufacturing, and global marketing capabilities.[64] Like Japanese producers, these Asia-Pacific producers have been especially successful in commodity markets, competing primarily on price. In addition, they are entering noncommodity markets as their technical skills and knowledge of the industry increase.[65]

GLOBAL COMPETITIVENESS OF THE U.S. INDUSTRY

From 1986 to 1992 the value of world production of semiconductors grew from $38 billion to $71 billion (figure 8). During this period, the U.S. industry's share of this production decreased from 34 percent to 29 percent (figure 3). This lost market share was gained primarily by emerging producers who increased their share of world production from about 19 percent to 27 percent. These countries successfully attracted foreign wafer fabrication and assembly and testing operations and some developed indigenous production capabilities and global marketing and distribution networks.[66]

Japanese manufacturers' share of world semiconductor production rose from 36 percent to 40 percent from 1986 to 1989 as demand and prices for DRAMs and other commodity semiconductors dominated by these producers rose. However, these manufacturers' share of the world's semiconductor production fell in 1990 with the softening of prices for DRAMs and, after some recovery in 1991, slid to 35 percent in 1992 when Japan entered into a recession. European firms' share of the world's production fell from 11 percent in 1986 to 10 percent in 1992.

The Semiconductor Industry Association and many academic and industry observers have argued that the U.S. industry's loss of worldwide market share during 1986-92 reflects a decline in the competitiveness of the U.S. industry.[67] Others have argued that this loss of market share is merely a result of changes in currency rates and does not reflect any major shift in the competitiveness of U.S. firms.[68] It is also argued that the loss of U.S. market share should not be construed to be a loss of competitiveness because most of the lost market share has been in commodity semiconductors that command a large portion of market revenues but whose manufacture is generally less profitable and more risky than noncommodity semiconductors.[69]

There is no consensus on which factors explain the competitiveness of foreign semiconductor producers compared with U.S. producers.[70] Below is a discussion of some of the principal competitive advantages and disadvantages that appear to have been most pertinent to the U.S. industry's performance during 1986-92.

Many industry officials conclude that, compared with U.S. semiconductor producers, Japanese firms and, to a lesser extent, other major foreign competitors benefitted during the first part of the 1986-92 period from lower capital costs.[71] Allegedly this advantage gave foreign producers an edge over U.S. producers in meeting the increasingly high costs of R&D and capital equipment necessary to compete in world semiconductor markets. It is thought as well that the capital advantage also enhanced foreign firms' ability to buy U.S. semiconductor firms and technology and better support themselves during downturn in demand.[72]

By the end of the decade, the gap between the cost of capital in the United States and in other major semiconductor-producing nations appeared to diminish greatly as interest rates converged.[73] However, some industry analysts still alleged that foreign semiconductor producers continued to have a considerable cost of capital advantage. In particular, it was argued that the cost of raising capital for semiconductor firms in the U.S. equity markets was still significantly higher than in the equity markets of countries such as Japan and Germany.[74]

Some industry analysts argue that Japanese, Korean, and, to a lesser extent, European firms have a competitive advantage over U.S. firms because most of these foreign firms are usually more vertically and horizontally integrated. Specifically, it is alleged that this integration can provide (1) greater economies of scale and reduced risks by assuring producers a captive market, (2) better market information to improve products, (3) more information on manufacturing techniques, and (4) greater financial resources to

[64] ICE Corp., *Status 1991*, p. 2-63.

[65] Sheridan Tatsuno, "The Asia Pacific Role in Semiconductors," lecture given at the Annual Semiconductor Conference of the Semiconductor Industry Association, Oct. 2, 1991.

[66] Market share data in this report is based on production by geographical location and, therefore, is different from that reported by ICE, Dataquest, The WSTS Committee of the SIA, EIC, and other sources reporting such data based on the national affiliation of producing firms.

[67] NACS, *Attaining Preeminence in Semiconductors: Third Annual Report to the President and the Congress*, (Washington, DC: NACS, Feb. 1992).

[68] "Some Concrete Proposals to Make the Semiconductor Industry More Competitive," statement of Dr. T.J. Rodgers, President and CEO of Cypress Semiconductor Corp., House Committee on Science, Space, and Technology, Subcommittee on Technology and Competitiveness, July 23, 1992.

[69] U.S. industry officials, interviews by USITC staff, 1992.

[70] For a discussion of some of these positions see USITC, *Semiconductor Manufacturing and Testing Equipment*, USITC publication 2434, pp. 2-1 to 2.16.

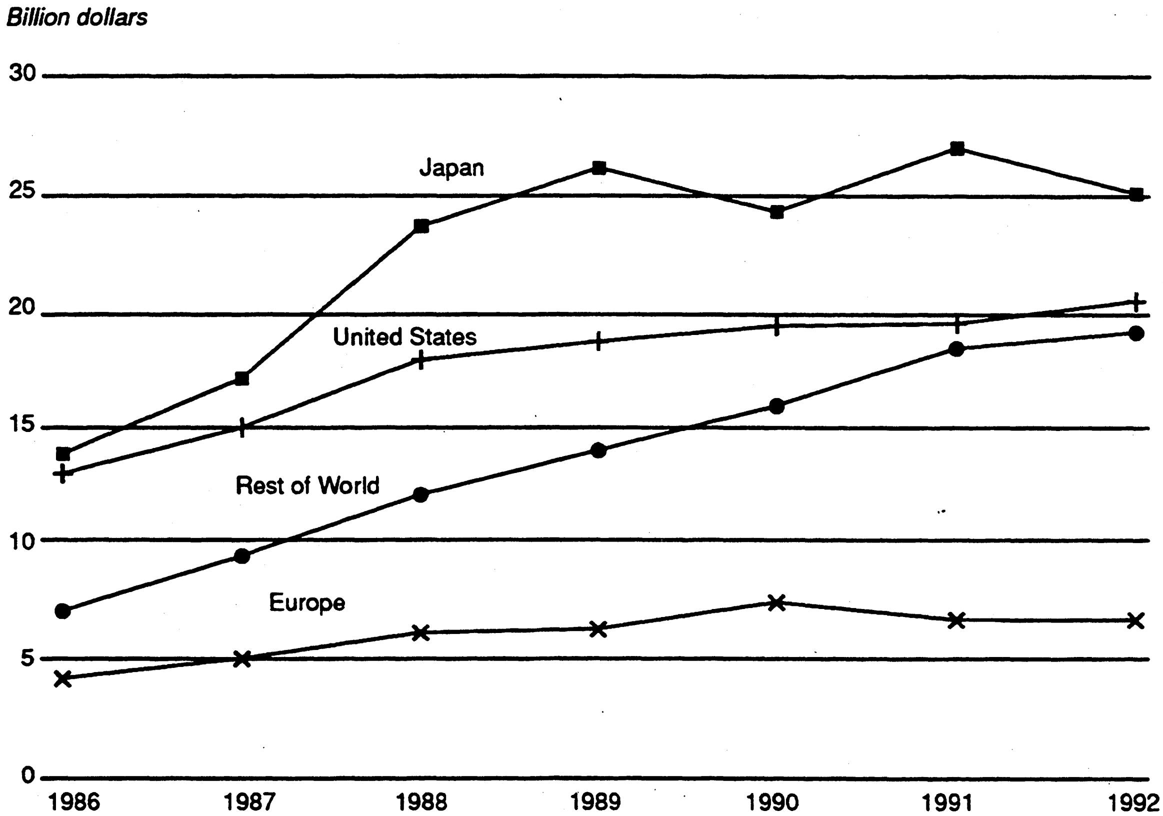
[71] NACS, *Capital Investment in Semiconductors, the Lifeblood of the U.S. Semiconductor Industry*, Sept. 1990, p. 8, and U.S. industry officials, interviews by USITC staff, 1991-92.

[72] U.S. industry officials, interviews by USITC staff, 1991-92.

[73] For a discussion of trends in differences in cost of capital, see "Explaining International Differences in the Cost of Capital," *Federal Reserve Bank of New York Quarterly Review* (summer 1989); "Capital Conflict," *The Economist*, Aug. 10, 1991, p. 69; and "Capital Punishment," *The Economist*, May 23, 1992, p. 71.

[74] Elizabeth B. Baatz, "Cost of Capital Is Still a Threat to High Tech," *Electronic Business*, Nov. 4, 1991, pp. 40-43.

Figure 8
Semiconductors: Production by major producing areas, 1986-92[1]



[1] These data exclude wafers, parts, and modules classified in SIC 3674 and are in current dollars for 1986-91 and projected in constant 1991-dollars for 1992.

Source: Elsevier Advanced Technology, Oxford, United Kingdom.

endure downturns in price and to meet the industry's escalating costs of R&D and capital outlays.[75]

U.S. industry officials also attribute the success of Japanese producers—particularly in competing against foreign producers in Japan—to coordinated behavior by the country's large corporate groups called Keiretsu. Six of Japan's major semiconductor firms are reportedly members of Keiretsu.[76] Firms within a Keiretsu usually have equity cross-holdings and preferential business relations among themselves and are closely associated with a common major bank.

Differences in Government policy between the United States and other countries, particularly concerning intellectual property rights, have also reportedly contributed to the loss of competitiveness of the U.S. industry.[77] Although the U.S. semiconductor industry is not among the U.S. industries regarded as being most affected by foreign intellectual property violations, a survey done by the USITC in 1987 indicated that many U.S. semiconductor firms believed that their patents had been infringed.[78]

Industry observers also argue that many foreign semiconductor producers, most notably Japanese firms, increasingly have a competitive advantage over U.S. producers in supplying the world's semiconductor markets because these foreign firms are in or closer to the world's fastest growing markets for electronic parts.[79] Proximity to customers is important to increase responsiveness and access to these customers and reduce transportation costs. Japanese firms, in particular, dominate the global consumer electronics market, which consumes a high proportion of commodity semiconductors compared with the computer and telecommunications markets.[80]

[75] For example, see Gregory Tassey, "Structural Change and Competitiveness: The U.S. Semiconductor Industry," *Technological Forecasting and Social Change*, vol. 37 (1990), pp. 85-93.

[76] For a discussion on Keiretsu and their impact on the U.S. semiconductor industry, see Clyde V. Prestowitz, Jr., *Trading Places: How We Allowed Japan to Take the Lead* (New York: Basic Books, 1988), p. 43.

[77] NACS, *A Strategic Industry at Risk*, advanced ed. (Washington, DC: NACS, Nov. 1989), p. 16.

[78] USITC, *Foreign Protection of Intellectual Property Rights and the Effect of U.S. Industry and Trade* (investigation No. 332-245), USITC publication 2065, Feb. 1988, pp. 3-1 and 3-10.

[79] Semiconductor Industry Association, "Controlling Our Own Destiny in Critical Technologies," presentation, 1991.

[80] U.S. industry officials, interviews by USITC staff, 1991-92.

U.S. firms' strategy of pursuing noncommodity semiconductors, as compared with Japanese and Korean firms' strategy of concentrating on higher volume commodity semiconductors is also believed to have placed U.S. firms at a competitive disadvantage. It is argued that producing commodity semiconductors successfully provides firms with superior production efficiencies allowing these firms to gain market share in noncommodity segments.[81] On the other hand, the increased market share and exceptional performance of the U.S. industry in 1992 have been attributed to the strength of U.S. firms in producing noncommodity products.[82]

U.S. TRADE MEASURES

Tariff Measures

Table 1 shows the pre-Uruguay Round column 1-general rate of duty and preferential rates of duty as of July 7, 1992, for each 8-digit Harmonized Tariff Schedule (HTS) semiconductor subheading. This table also lists U.S. exports and imports in 1992 for these HTS subheadings. In 1992 about 97 percent of semiconductor imports entered the United States duty-free.[83] Only a few types of semiconductors are subject to tariffs. Moreover, U.S. imports of semiconductors subject to tariffs are relatively small and often eligible for duty-free treatment under the Generalized System of Preferences, Automotive Products Trade Act, United States-Canada Free-Trade Agreement, Caribbean Basin Economic Recovery Act, the United States-Israel Free-Trade Area, and the Andean Trade Preference Act (Appendix A includes an explanation of tariff and trade agreement terms). The aggregate U.S. trade weighted-average duty for semiconductors based on 1992 data is less than 0.1 percent ad valorem and remained essentially unchanged during 1986-92.[84]

There were few classification criteria adjustments or substantive changes for semiconductors as a result of the conversion from the Tariff Schedules of the United States (TSUS) to the HTS. However, in 1990 the U.S. Government expanded several 10-digit breakouts to gather more detailed information on the types of semiconductors imported into the United States.[85]

[81] Richard N. Langlois, ed., *Microelectronics: An Industry in Transition* (Unwin Hyman, Winchester, MA, 1988), and Daniel I. Okimoto, Takuo Sugano, and Franklin B. Weinstein, eds., *Competitive Edge: The Semiconductor Industry in the U.S. and Japan* (Stanford, CA: Stanford U. Press, 1984).

[82] U.S. industry officials, interviews by USITC staff, 1993.

[83] Calculated from official statistics of the U.S. Department of Commerce.

[84] Calculated from official statistics of the U.S. Department of Commerce.

[85] In particular, the new breakouts identify (1) ICs constructed on silicon, (2) the primary types of volatile and nonvolatile memory devices, (3) more of the memory capacities of memory devices, (4) microprocessors by bit size, (5) ICs that combine MOS and bipolar technologies, and (6) analog and mixed-signal ICs by function.

U.S. Nontariff Measures

During 1986-92 U.S. trade in semiconductors was affected by an agreement between the Governments of Japan and the United States concerning trade in semiconductors. Also during this period the U.S. Government maintained limitations on the transfer of semiconductor technology to Communist countries.

In September 1986, the Governments of Japan and the United States entered into an agreement that is known as the Semiconductor Arrangement.[86] In the Arrangement, the Government of Japan (GOJ) agreed to monitor the costs and prices of Japanese semiconductor exports to the United States and third-country markets to prevent these exports from being sold at less than fair market value (LTFV).[87] In addition, the GOJ agreed in the Arrangement to improve foreign access to the Japanese semiconductor market. The GOJ also recognized in a side letter "the U.S. semiconductor industry's expectation that semiconductor sales in Japan of foreign-affiliated companies (would) grow to at least slightly above 20 percent" by the time the Arrangement was scheduled to expire in September 1991.[88]

During the 5-year period covered by the first Semiconductor Arrangement, the foreign share of Japan's semiconductor market reportedly increased from 9.27 percent to 13.85 percent.[89] Under the new Arrangement, the date to reach the 20-percent target was extended to the end of 1992. This 20-percent market-access goal was achieved in the fourth quarter of 1992 as expected. The U.S. Trade Representative (USTR) and the SIA welcomed this achievement but emphasized that the Arrangement called for continued improvement beyond the 20-percent target.[90]

Historically, trade and investment relations between U.S. producers of semiconductors and Communist countries have been limited to avoid transfers of technology that could significantly enhance the military capabilities of these countries. Limits on the transfer of technologies have been accomplished

[86] Arrangement between the Government of Japan and the Government of the United States of America Concerning Trade in Semiconductor Products, Office of the United States Trade Representative, Washington, DC (Sept. 1986).

[87] In general terms, fair market value refers to a value equivalent to the home market value of the import. For a specific explanation of the definition of fair market value, see *Trade Agreements Act of 1979*, Pub. L. 96-39, July 26, 1979, subtitle D, "General Provisions," secs. 771 to 778.

[88] "Text of Secret Semiconductor Letter," *Inside U.S. Trade*, vol. 6, No. 46 (Nov. 18, 1988).

[89] U.S. Department of Commerce and World Semiconductor Trade Statistics Committee data used by the Government of the United States to monitor progress of market access provisions of the Semiconductor Arrangement.

[90] Market share data collected under the new arrangement are not directly comparable with those collected under the old arrangement because they are computed using a different methodology. The foreign share of Japan's semiconductor market was 19.6 in the first quarter of 1993 and 19.2 in the second quarter of 1993.

Table 1
Semiconductors: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jul. 7, 1992; U.S. exports, 1992; and U.S. imports, 1992

HTS subheading	Description	Col. 1 rate of duty As of Jul. 7, 1992		U.S. exports, 1992	U.S. imports, 1992
		General	Special[1]		
				— Million dollars —	
8541.10.00	Diodes, other than photosensitive or light-emitting diodes	Free[2]		223	349
8541.21.00	Transistors, other than photosensitive transistors with a dissipation rate of less than 1 W	Free		131	187
8541.29.00	Transistors, other than photosensitive transistors, with a dissipation rate of 1 W or more	Free		286	363
8541.30.00	Thyristors, diacs and triacs, other than photosensitive	Free		20	74
8541.40.20	Light-emitting diodes	2.0%	Free (A,CA,E,IL,J)	39	131
8541.40.60	Photosensitive diodes, other than light-emitting diodes	Free		86	78
8541.40.70	Photosensitive transistors	Free		6	44
8541.40.80	Optical coupled isolators	4.2%	Free (A,B,CA,E,IL,J)	12	42
8541.40.95	Photosensitive semiconductor devices, nesi	4.2%	Free (B,CA,E,IL,J)	18	64
8541.50.00	Semiconductor devices other than those listed above	1.0%[2]	Free (B,CA,E,IL,J)	192	21
8541.90.00	Parts of discrete semiconductors and pizeoelectric crystals	Free		150	40
8542.11.00	Digital monolithic electronic integrated circuits	Free		7,796	11,411
8542.19.00	Analog and mixed signal monolithic electronic integrated circuits	Free		1,368	1,529
8542.20.00	Hybrid electronic integrated circuits	Free		450	425
8542.80.00	Electronic integrated circuits and microassemblies other than monolithic	3.9%	Free (A,B,CA,E,IL,J)	304	91
8542.90.00	Parts of electronic integrated circuits and microassemblies	Free		384	428

[1] Programs under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A); Automotive Products Trade Act (B); Agreement on Trade in Civil Aircraft (C); United States-Canada Free-Trade Agreement (CA); Caribbean Basin Economic Recovery Act (E); United States-Israel Free-Trade Area (IL), and Andean Trade Preference Act (J).
[2] Duty temporarily suspended on metal oxide varistors provided for in subheading 8541.10.00 and 8541.50.00 until Jan. 1, 1993.

Source: U.S. exports and imports compiled from data of the U.S. Department of Commerce.

mainly through the Paris-based Coordinating Committee for Multilateral Export Controls (CoCom). This organization restricts technological transfers from the United States and most other technologically advanced non-Communist nations by requiring its 17 members to approve unanimously exports of military-sensitive technologies to Communist countries.

For more than a decade, pressure has mounted within CoCom for the relaxation of export restrictions on many products. Many spokespersons from industry and academia increasingly questioned the criteria used by CoCom for defining what technologies were militarily-sensitive. In 1989 a report prepared under the auspices of the National Research Council found that many of CoCom's restrictions that would not compromise the West's security were limiting business opportunities.[91] Since, several of these restrictions have been lifted as countries in Eastern Europe and elsewhere have abandoned communism.[92]

Government Trade-Related Investigations

In 1985 three separate dumping petitions, respectively concerning 64 Kilobit (K) DRAMs, 256K DRAMs, and erasable programmable read only memories (EPROMs) were filed at the USITC and the U.S. Department of Commerce (See appendix B for a list of reports of the USITC pertaining to semiconductors). The petitions charged that Japanese producers were selling these products in the United States at LTFV. The petition on 64K DRAMs was filed in June 1985 by Micron Technology, Inc., of Boise, ID; the petition on EPROMs was filed in September 1985 by three other U.S. semiconductor firms; and the petition on 256K DRAMs was initiated in December 1985 by the U.S. Department of Commerce on its own motion.

In June 1986 the U.S. Department of Commerce found that U.S. imports of 64K DRAMs from Japan had been sold in the United States at LTFV and the USITC determined that these imports had materially injured the U.S. industry producing these devices.[93] Accordingly, the U.S. Department of Commerce issued an order directing the U.S. Customs Service to assess antidumping duties on these devices from Japan. In July 1986, as part of the Semiconductor Arrangement (see U.S. Nontariff Measures above), the U.S. Government suspended the antidumping cases on EPROMs and 256K DRAMs, and no antidumping duties related to these cases were imposed.

In October 1992, Micron Technology, Inc., filed a dumping petition concerning DRAMs of 1 megabit and above from Korea. In April 1992, the USITC made an affirmative final determination that the U.S. industry producing these products was materially injured by reason of LTFV imports of these DRAMs from Korea,[94] and later that month the U.S. Department of Commerce determined antidumping margins ranging from 0.82 percent to 11.45 percent.[95]

FOREIGN TRADE MEASURES

Tariff Measures

The major U.S. trading partners in semiconductors, both imports and exports, are Japan, Malaysia, Korea, Canada, Singapore, and the EC. In Japan, though tariffs are 4.2 to 4.3 percent ad valorem on imports from members of the General Tariff and Trade Agreement (GATT), U.S. semiconductors enter free of duty under that country's temporary customs regime.[96] U.S.-produced semiconductors enter Malaysia generally at 2 percent ad valorem for finished devices and 5 percent ad valorem for parts.[97] U.S. semiconductors enter Korea at 10 percent ad valorem.[98] U.S. semiconductors enter Canada free of duty under the U.S.-Canada Free-Trade Agreement and also enter Singapore free of duty.[99] On the other hand, tariffs on U.S.-produced semiconductors range from 4.6 to 14.0 percent ad valorem in the EC.[100]

Nontariff Measures

During the 1980s the GOJ, under pressure from the Governments of the United States and other nations, eliminated most formal barriers to semiconductor imports. However, nontariff barriers on U.S. exports to Japan allegedly remain. According to the U.S. Department of State, these barriers are "diffuse and deeply rooted in Japan's insular, non-Western traditions."[101] Most notably, U.S. semiconductor firms

[91] National Research Council, *Global Trends in Computer Technology and Their Impact on Export Controls* (Washington, DC: National Academy Press, 1988).

[92] In October 1993, CoCom reached an interim agreement to lift all restrictions on computers up to 67 million theoretical operations per second (MTOPS), the speed of Intel's Pentium chip, to countries such as Russia and China. As part of this agreement, CoCom member nations may allow sales of computers up to 100 MTOPS at their discretion and clear exports of machines of up to 194 MTOPS with only limited review by Cocom nations. The U.S. administration is reportedly seeking a comprehensive proposal for relaxing limits up to 500 MTOPS.

[93] USITC, *64K Dynamic Random Access Memory Components From Japan* (investigation No. 731-TA-270 (final)), USITC publication 1862, June 1986.

[94] The affirmative determination resulted from a tie vote, 3-3. Under current U.S. trade law, a tie vote is a victory for the domestic petitioner. USITC, *DRAMs of One Megabit and Above From the Republic of Korea* (investigation No. 731-TA-556 (final)), USITC publication 2629, May 1993.

[95] The margins were as follows: Goldstar Electronic Co. 4.97 percent, Hyundai Electronics 11.45 percent, Samsung 0.82 percent, and all others 3.89.

[96] Custom Tariff Schedule of Japan, 1991.

[97] Custom Tariff Schedule of Malaysia, 1988.

[98] Custom Tariff Schedule of Korea, 1990.

[99] Singapore Trade Classification and Customs Duties, 1989.

[100] Custom Tariff Schedule of the EC, 1990.

[101] U.S. Senate, Committee on Foreign Relations and Committee on Finance, and U.S. House, Committee on Foreign Affairs and Committee on Ways and Means, *Country Reports on Economic Policy and Trade Practices*, report prepared by the Department of State in accordance with section 2202 of the Omnibus Trade and Competitiveness Act of 1988 (Washington, DC: GPO, 1990), p. 284.

have found that, even with competitive price, quality, and service, it can be extraordinarily difficult to change long-established relationships between Japanese suppliers and buyers.[102] The Governments of the United States and Japan sought to address this problem in the Semiconductor Arrangement through several measures, such as setting a target market share for foreign producers in Japan and promoting long-term relationships between Japanese semiconductor purchasers and foreign producers.[103]

Besides the high European tariffs discussed earlier, U.S. exports to the EC are hindered by EC rulings relating to the use of national preferences in government procurement and the rules of origin for semiconductors.[104] The EC's 1992 agenda on rules governing public procurement mandates that public water, energy, transport, and telecommunications procurers provide a 3-percent price preference to EC bids over equivalent non-EC offers and allows them to reject bids with contracts containing less than 50 percent EC origin.[105] As a result, producers of electronic equipment for these purchasers are biased in favor of semiconductors and other electronic components produced in the EC over those produced abroad.[106]

The adverse effect of these government procurement regulations on U.S. and other foreign exports to the EC is aggravated by the EC's rule of origin on semiconductors.[107] This rule was enacted in February 1989 and established that the country of origin of ICs was determined by where the ICs were fabricated, as opposed to where they were assembled. Before this rule came into effect, ICs fabricated abroad and assembled in the EC were designated as having an EC country of origin. As a result, many foreign producers had EC assembly facilities to meet the preference for EC-made ICs of electronic equipment suppliers in the EC. EC assembly facilities were also advantageous to foreign producers because tariffs on unassembled semiconductors in the EC were about 9 percent whereas tariffs on finished semiconductors were generally 14 percent.[108] The new ruling, which was enacted without previous announcement or a period of adjustment, was contested by U.S. and other foreign governments and is alleged by some foreign producers to have been an important factor in attracting foreign firms to establish fabrication facilities in the EC.[109]

During 1986-92, the EC instituted three dumping cases. One case, initiated in April 1987, concerned imports of EPROMs from Japan;[110] another, initiated in July 1987, concerned imports of DRAMs from Japan;[111] and the third, initiated in March 1991, concerned imports of DRAMs from Korea.[112] The cases regarding imports of EPROMs and DRAMs from Japan were terminated in March 1991[113] and in January 1990,[114] respectively; and the case regarding imports of DRAMs from Korea was terminated in March 1993.[115] In all three cases, the EC found the existence of dumping and injury in the form of material retardation to EC industries. The cases were terminated when the EC Commission accepted 'undertakings' offered by the principal producers accused of dumping. These undertakings sought to ensure that sales prices in the EC would not fall below certain reference prices considered adequate to eliminate the injury caused to the complainant parties.

The national affiliation of the parties involved in the EC's DRAM case against Japanese imports reflects the globalization of the semiconductor industry. One of

[102] Ibid.

[103] *Arrangement Between the Government of Japan and the Government of the United States of America Concerning Trade in Semiconductor Products*, Office of the United States Trade Representative, Washington DC, Sept. 1986, and USITC, "Semiconductors: The U.S. Trade Representative Reports Progress in Market Access to Japan," *Monthly Industry Business Review* (Aug. 1990).

[104] For a discussion of additional possible forms of barriers to U.S. exports in the EC, see Flamm, *Europe 1992*, pp. 40-42. During 1993 the application of these rules to U.S. exports was changed through negotiations between the USTR and EC members. For further information, see Ambassador Michael Kantor, U.S. Trade Representative, "1993 Title VII Review of Foreign Country Procurement Discrimination Against U.S. Goods or Services," testimony before the Legislation and National Security Subcommittee of the Committee on Government Operations, Jun. 10, 1993.

[105] For further information see USITC, *The Effects of Greater Economic Integration Within the European Community on the United States* (investigation No. 332-267, USITC publication 2204, July 1989, pp. 4-7 to 4-25, and USITC, *The Effects of Greater Economic Integration Within the European Community on the United States: First Follow-Up Report (investigation No. 332-267), USITC* publication 2268, Mar. 1990, pp. 4-3 to 4-7.

[106] U.S. industry officials, interviews by USITC staff, 1991.

[107] Commission Regulation No. 288/89 *OJ* No. L 33/23 (Feb. 3, 1989).

[108] USITC, *Foreign Industrial Targeting and Its Effects on U.S. Industries, Phase II: The European Community and Member States* (investigation No. 332-162), USITC publication 1517, Apr. 1984, p. 230.

[109] USITC, "Semiconductors: Capital Investments in Europe Continue to Grow," *Monthly Import Business Review* (Dec. 1991).

[110] *Notice of Initiation of an Anti-Dumping Proceeding Concerning Imports into the Community of Certain Types of Electronic Micro-circuits Known as EPROMs Originating in Japan, OJ* No. C 101, (Apr. 14, 1987), p. 10.

[111] *Notice of Initiation of an Anti-dumping Proceeding Concerning Imports of Certain Types of Electronic Micro-circuits Known as DRAMs Originating in Japan, OJ* No. C 181 (Jul. 9, 1987), p. 3.

[112] *Notice of Initiation of an Anti-dumping Proceeding Concerning Imports of Certain Types of Electronic Micro-circuits Known as DRAMs Originating in the Republic of Korea, OJ* No. C 57 (Mar. 6, 1991), p. 9.

[113] *Council Directive 91/131, OJ* No. L 65 (Mar. 12, 1991), p. 42.

[114] *Council Directive 165/90, OJ* No. L 20 (Jan. 25, 1990), p. 5.

[115] *Council Directive 611/93 and Decision 93/157, OJ* No. L 66 (Mar. 18, 1993), p. 1-9 and 37-38.

the parties was a subsidiary of Motorola, and one of the Japanese producers was a subsidiary of TI. Motorola and TI are headquartered in the United States and are among the largest U.S. semiconductor producers.

During the 1986-92 period, foreign government policies in several countries seeking to develop indigenous semiconductor and electronic equipment industries also affected the competitiveness of U.S. producers. In Brazil, for example, domestic producers enjoyed fiscal incentives, R&D subsidies, and relatively favorable anti-trust treatment, while semiconductor imports from the United States were limited and U.S. intellectual property was inadequately protected.[116]

U.S. MARKET[117]

Consumption

From 1986 to 1992 the value of U.S. nominal consumption of semiconductors more than doubled, rising from $15.7 billion to $32.7 billion at an annually compounded average rate of growth of 13 percent (table 2 and figure 9). This growth was driven by a rise in demand for personal computers and, to a lesser extent, for telecommunications, transportation, and military equipment. U.S. imports as a share of U.S. consumption increased from 38 percent in 1986 to 47 percent in 1992, reflecting an increase in the competitiveness of foreign producers in the U.S. market and the use of offshore manufacturing facilities by U.S.-headquartered firms.

ICs accounted for most of the growth in U.S. consumption and were the main type of semiconductor consumed during 1986-92. The apparent value of U.S. consumption of ICs during 1986-92 rose from about $13.5 billion to about $29.1 billion at an annual average rate of growth of 14 percent. During this period the product mix of IC semiconductor consumption changed. Consumption of ICs based on MOS technologies grew significantly faster than consumption of ICs based on bipolar technologies, as producers increasingly turned to MOS technologies for reducing manufacturing costs. Likewise, consumption of digital ICs grew faster than analog ICs because digital applications, such as electronic computing and digital communications, increased faster than analog applications. U.S. imports as a share of U.S. consumption of ICs increased from about 39 percent to about 48 percent.

The value of apparent U.S. consumption of discrete semiconductors rose from about $2.2 billion in 1986 to about $3.6 billion in 1992 at an annually compounded average growth rate of 9 percent. However, as a share of total semiconductor consumption, consumption of discrete devices declined from about 14 percent in 1986 to about 11 percent in 1992.

During 1986-92 the value of annual U.S. consumption of semiconductors grew by over 10 percent except in 1990. After contracting by 15 percent in 1985, U.S. consumption grew steadily from 1986 to the latter part of 1989, when the U.S. economy approached a recession and orders for electronic equipment, particularly orders for personal computers, fell.[118] As a result of this recession, U.S. consumption of semiconductors did not grow in 1990. In 1991 and 1992 though the performance of computer and other electronic equipment producers remained weak, U.S. consumption of semiconductors grew significantly as computer producers incorporated the latest generations of higher value digital MOS semiconductor devices into their work station and high-end personal computer offerings and as demand for computers, particularly personal computers, was spurred by an intense price war.[119]

Production[120]

From 1986 to 1992 the value of U.S. shipments of semiconductors increased by 98 percent from $14.6 billion to $28.9 billion (table 2). Shipments of ICs accounted for most of the increase, with producers of virtually all electronic products increasing their demand for these devices. Value of U.S. shipments of ICs increased by 107 percent, from about $12.3 billion in 1986 to about $25.5 billion in 1992. In contrast, value of shipments of discrete semiconductors increased by only 49 percent, from $2.3 billion in 1986 to about $3.4 billion in 1992.

[116] NACS, *A Strategic Industry at Risk,* p. 16. For additional specific references to trade barriers see Office of the United States Trade Representative, *1992 National Estimate Report on Foreign Trade Barriers* (Washington, DC: GPO, 1992).

[117] Data in this section are compiled from official statistics of the U.S. Department of Commerce and include semiconductor parts unless otherwise noted. A large portion of the semiconductors classified as "U.S. imports for consumption" in these statistics are not consumed in the United States but rather exported as foreign exports. While this is not believed to have a significant bearing on the general trends discussed in this section, it should be noted that U.S. imports, consumption, import penetration, and the U.S. trade deficit discussed the section are somewhat overstated. The staff of the USITC estimates that "U.S. imports for consumption" exported after entering the United States has grown steadily from 1986 to 1992 and could have been as high as 13 percent of total U.S. imports in 1986 and as high as 29 percent in 1992. Alternative approaches to capture U.S. imports consumed in the United States are currently being evaluated by the U.S. Department of Commerce in consultation with the staff of the USITC and other government agencies and are discussed in "Comparative Evaluation of Methodologies for Trade Calculations Reflecting U.S. Competitiveness," a draft report prepared by Ronald M. Powell of the Electronics and Electrical Engineering Laboratory of the National Institute of Standards and Technology, August 5, 1992.

[118] According to the National Bureau of Economic Research, the private organization that officially dates the beginning and end of most recent recessions, this recession began in July 1990 and ended in March 1991.

[119] U.S. industry officials, interviews by USITC staff, 1991-92.

[120] Data in this section are compiled from official statistics of the U.S. Department of Commerce and include semiconductor parts unless otherwise noted.

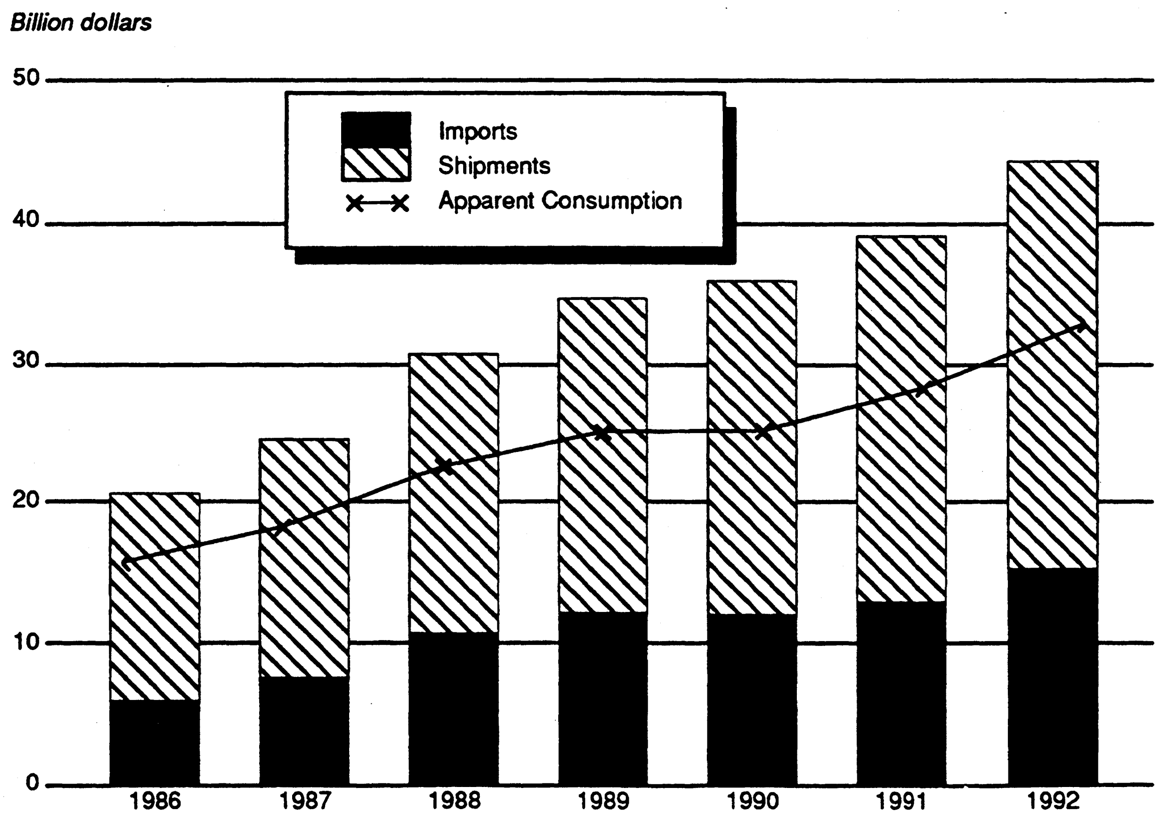
Table 2
Semiconductors: U.S. producers' shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1986-92

Year	U.S. shipments	U.S. exports	U.S. imports	Apparent U.S. consumption	Ratio of imports to consumption
	Million dollars				Percent
1986	14,599	4,878	5,955	15,675	38
1987	16,819	6,241	7,592	18,171	42
1988	19,793	8,056	10,732	22,470	48
1989	22,304	9,531	12,172	24,946	49
1990	23,715	10,710	12,023	25,029	48
1991	25,968	10,831	12,928	28,065	46
1992	[1]28,886	11,465	15,275	[1]32,696	[1]47

[1] Estimated by the staff of the U.S. International Trade Commission.

Source: Compiled from official statistics of the U.S. Department of Commerce, except as noted.

Figure 9
Semiconductors: U.S. imports, producers' shipments, and apparent consumption,[1] 1986-92



[1] Apparent Consumption = Producers' Shipments + Imports - Exports.

Source: Compiled from official statistics of the U.S. Department of Commerce.

During 1986-92, U.S. producers' exports of semiconductors grew faster than their domestic shipments (see section on Consumption above). During this period the proportion of U.S. shipments exported increased from 33 percent to 40 percent as the semiconductor markets in Asia, the EC, and other major electronic equipment-producing areas grew faster than the U.S. market and as U.S.-headquartered semiconductor producers increasingly used offshore semiconductor testing and assembly facilities. From 1986 to 1992 the proportion of shipments accounted for by U.S. exports of semiconductors parts, most of which were sent to these testing and assembly facilities, increased from 18 percent to 23 percent and reached a high of 27 percent in 1990.

Imports[121]

The value of U.S. imports of semiconductors and parts increased by 157 percent, from $6.0 billion in 1986 to $15.3 billion in 1992 (table 3) at an annual average rate of growth of 17 percent. During this period an estimated 50 percent of these imports consisted of chips, wafers, and other semiconductor parts manufactured in the United States, exported for assembly and testing, and then returned to the United States. The remainder were primarily finished semiconductors produced entirely abroad.

From 1987 to 1990 most U.S. imports of semiconductors produced from U.S.-made parts were entered into the United States under HTS subheadings 9802.00.60 and 9802.00.80. U.S. imports entered under these subheadings are limited to those that have U.S.-made parts and are assessed duties only on the value added resulting from foreign processing. Though there are no tariffs on most semiconductors, these devices began to be imported under HTS subheadings 9802.00.60 and 9802.00.80 because such entries were exempt from a custom's user fee that was imposed at the end of 1986. In August 1990, this exemption was eliminated and customs fees limited to a $400 cap per importation.[122] Since then, many importers have ceased entering semiconductors produced from U.S.-made parts using these subheadings (figure 10).

Malaysia, Korea, the Philippines, Singapore, Taiwan, Mexico, Thailand, and Hong Kong, where the most U.S. assembly plants are, were the principal suppliers of semiconductor devices that entered United States under HTS subheadings 9802.00.60 and 9802.00.80. In 1992 U.S. imports of these devices from these countries accounted for 98 percent of total U.S. imports of these devices entered under HTS subheadings 9802.00.60 and 9802.00.80.

In 1992 Japan, Korea, and Canada were the primary suppliers of U.S. imports of semiconductors, excluding those entered under HTS 9802.00.60 and HTS 9802.00.80. During 1986-92 Japan increased its share of these U.S. imports from 25 percent to 39 percent, reflecting, in large part, increased U.S. imports of digital MOS DRAMs, a commodity product line dominated by Japanese producers. Korea also increased its share of these U.S. imports, from 10 percent to 15 percent, as suppliers in that country aggressively pursued the market for these DRAMs.

ICs accounted for 91 percent of U.S. semiconductor imports in 1992, up from 88 percent in 1986. Since ICs accounted for a large share of imported semiconductors, the principal sources of these devices are the same as the principal sources for all imported devices. Discrete semiconductors accounted for about 9 percent of total semiconductor imports in 1992, down from 12 percent in 1986.

Reflecting trends in U.S. production, digital MOS ICs represented the largest and fastest growing segment of U.S. imports of ICs.[123] However, in contrast to U.S. digital IC production, U.S. imports of digital MOS ICs were predominantly memory devices rather than microprocessors. Whereas on average U.S. shipments of digital MOS memory devices accounted for about 23 percent of total U.S. shipments of ICs, U.S. imports of these memory devices accounted for about 37 percent of total U.S. imports of ICs. Likewise, while the average of U.S. shipments of digital MOS microprocessors accounted for about 20 percent of U.S. shipments of ICs, U.S. imports of these devices accounted for only 8 percent of total U.S. imports of ICs (figure 11). These patterns in trade reflect the relatively strong competitive position of foreign firms producing commodity ICs and the relatively strong position of U.S. firms producing noncommodity ICs.

FOREIGN MARKETS

Foreign Market Profile

Japan, Europe, and several developing countries in Asia are the largest foreign consumers of semiconductors in the world. In 1992 Japan accounted for 29 percent of the world's consumption of semiconductors, Europe accounted for 17 percent, and developing countries in Asia as a group for 16 percent. From 1986 to 1991 consumption of semiconductors in these foreign markets generally grew faster than consumption in the United States. This trend was reversed in 1992 as U.S. demand for semiconductors grew significantly and the economies of all other major semiconductor purchasing countries slowed down (figure 12).

During 1986-91, the market for semiconductors in Japan grew by 112 percent, from $11.4 billion to $24.3 billion. This growth resulted primarily from an increase in global demand for video cassette recorders, video movie cameras, and computers, many of which are exported for consumption overseas. In 1992 Japanese semiconductor consumption fell to

[121] The U.S. import data discussed here refer to U.S. imports for consumption and may be overstated as discussed at the beginning of this U.S. Market section.

[122] *Customs and Trade Act of 1990*, Pub. L. 101-382, Aug. 20, 1990, sec. 111, subtitle (b)(2)(B)(ii).

[123] U.S. imports of digital MOS ICs increased from $2.5 billion in 1986 to $7.8 billion in 1991. During this period U.S. imports of digital bipolar ICs decreased from $1.0 billion to $0.9 billion and analog ICs increased from $0.6 billion to $1.2 billion.

Table 3
Semiconductors: U.S. imports for consumption, by principal sources, 1986-92

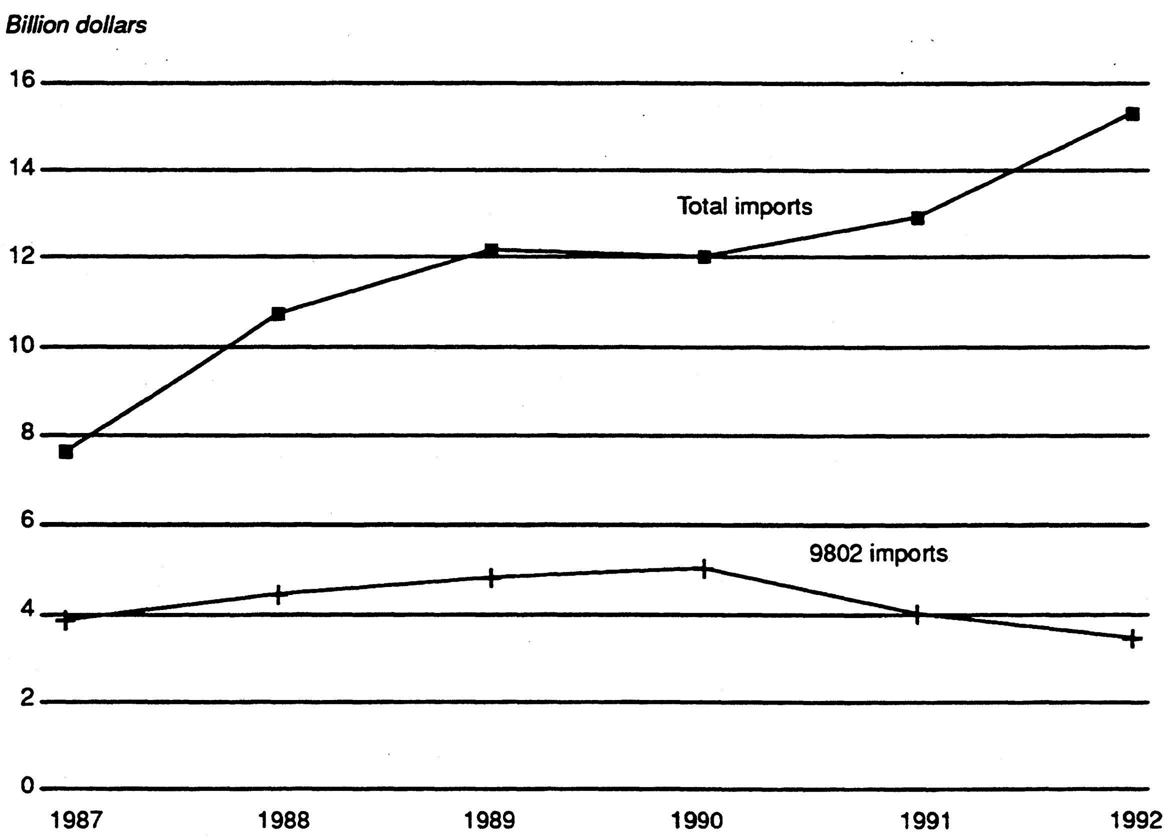
(1,000 dollars)

Source	1986	1987	1988	1989	1990	1991	1992
Japan	1,357	1,831	3,092	3,783	3,216	3,575	4,296
Malaysia	1,114	1,244	1,536	1,655	1,618	1,584	1,986
Republic of Korea	586	782	1,367	1,825	1,767	1,779	1,982
Canada	376	605	724	901	1,006	1,420	1,728
Singapore	628	811	1,018	1,041	1,135	1,173	1,251
Taiwan	306	439	599	593	636	673	931
Philippines	471	538	569	498	566	650	826
Hong Kong	98	123	241	213	263	276	372
Mexico	267	303	306	354	367	334	363
Thailand	243	339	405	355	379	382	315
All other	510	577	874	954	1,070	1,083	1,286
Total	5,955	7,592	10,732	12,172	12,023	12,928	15,336
EC-12	383	482	710	778	865	810	934
ASEAN	2,469	2,938	3,530	3,555	3,711	3,790	4,378

Note.—Because of rounding, figures may not add to totals shown.

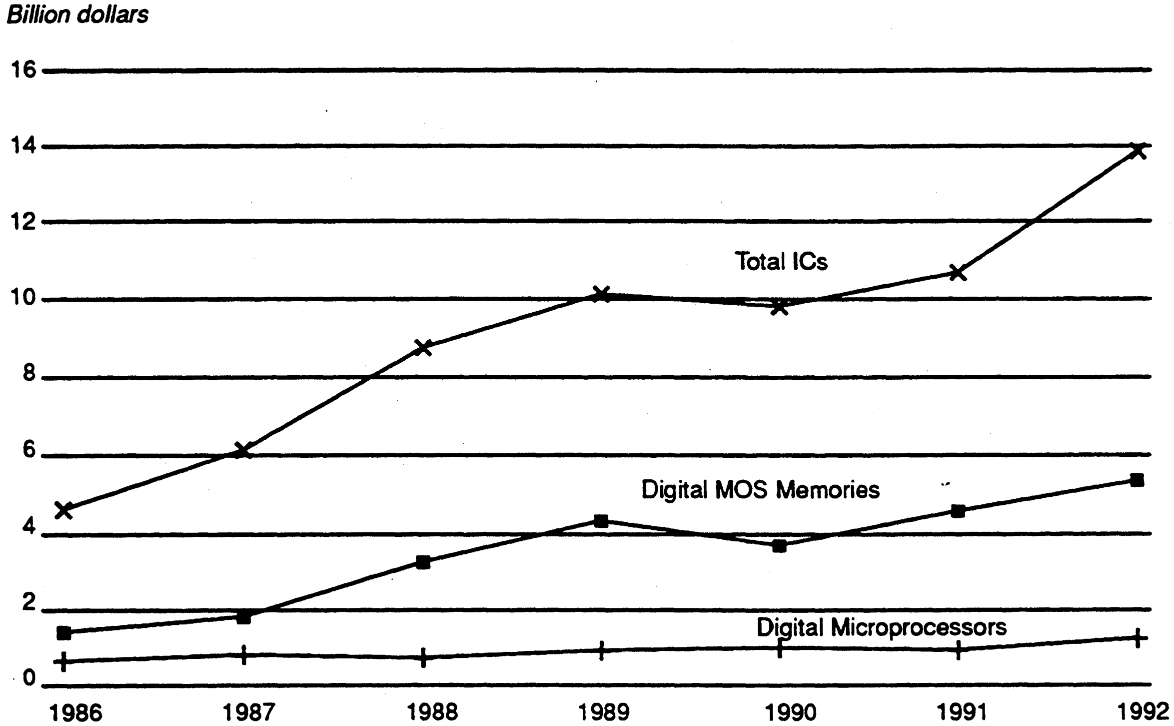
Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 10
U.S. imports of semiconductors, total and under HTS subheadings 9802.00.80 and 9802.00.60, 1987-92



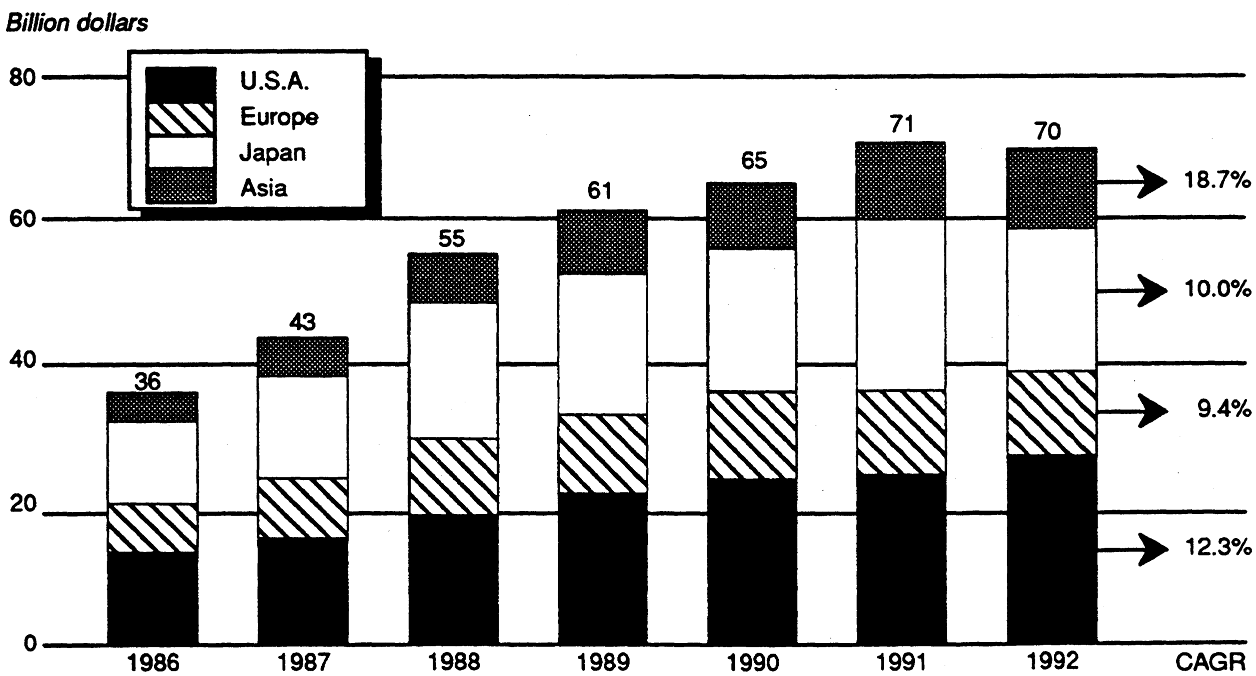
Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 11
Semiconductors: U.S. imports of integrated circuits (ICs), total and digital metal oxide semiconductor (MOS) memories and microprcessors, 1986-92



Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 12
Semiconductors: World market by regions, 1986-92[1]



[1] These data exclude wafers, parts, and modules classified in SIC 3674 and are in current dollars for 1986-91 and projected in constant 1991-dollars for 1992.

Source: Elsevier Advanced Technology, Oxford, United Kingdom.

$20.2 billion as domestic and international demand for consumer electronic goods fell.

Unlike other major semiconductor markets, Japan's semiconductor market is overwhelmingly supplied by domestic production. In 1989, for example, imports accounted for 49 percent of U.S. consumption but only for about 14 percent of Japan's consumption. Import penetration of Japan's semiconductor markets increased during 1986-92. This increase reportedly took place in part as a result of the efforts made to meet the market access provisions of the U.S.-Japanese Semiconductor Arrangement.[124] During 1986-92 U.S.-headquartered firms accounted for most of the foreign market share of Japan's semiconductor market, although their sales in that market grew at a significantly slower rate than those of other foreign producers. In 1986 the share of Japan's market held by U.S.-headquartered firms was about 9.1 percent and the total foreign share of this market was about 9.3 percent.[125] By the end of 1991 the U.S. share of Japan's semiconductor market had increased by nearly a third to slightly above 12 percent, whereas other foreign producers had increased their share tenfold, to about 2 percent.[126]

The demand structure for semiconductors in Japan, and to a lesser extent in Europe and developing countries in Asia, is somewhat different from the demand structure for semiconductors in the United States. In these foreign markets a relatively large proportion of semiconductors are used in the construction of consumer electronic goods. However, in the United States semiconductors are used primarily in the manufacture of computers. In 1991 purchases of semiconductors for use in consumer electronics goods accounted for about 38 percent of total semiconductor consumption in Japan, about 22 percent in Europe, and about 38 percent in developing Asian countries. In contrast, that year such purchases accounted for only 6 percent of total U.S. semiconductor consumption.

During 1986-92, the value of consumption of semiconductors in Europe increased by 71 percent, from $6.8 billion in 1986 to $11.7 billion in 1992, as domestic economic growth spurred demand for consumer electronics goods and computers and other capital equipment. During this period, consumption of semiconductors in Europe was also driven by an increase in U.S. and Japanese investment in electronic production in that region. U.S. computer firms alone increased their asset holdings in Europe by 62 percent, from $36.7 billion in 1986 to $59.6 billion in 1989.[127] U.S. and other foreign firms increased production in Europe to better supply the market there and in reaction to changes in rules of origin and government procurement.[128]

The value of worldwide semiconductor consumption outside the United States, Japan, and Europe increased from $4.0 billion in 1986 to $11.3 billion in 1992. Practically all this consumption took place in Canada and in developing countries in Asia. The electronic equipment industries in those countries are often owned and operated by U.S.- or Japanese-headquartered firms and depend heavily on imports of semiconductors, parts of semiconductors, and other inputs from the United States and Japan.

U.S. Exports[129]

The value of U.S. exports of semiconductors and parts increased by 135 percent, from $4.9 billion in 1986 to $11.5 billion in 1992, representing an average annual growth rate of 15 percent (table 4). U.S. exports grew during this period as the market for semiconductors in Europe, Asia, Canada, Japan, and other major electronic equipment-producing areas increased faster than the market for semiconductors in the United States. Part of this growth also resulted from the depreciation of the dollar during most of this period and from an increased use of offshore semiconductor testing and assembly facilities by U.S.-headquartered semiconductor producers.

More than half of U.S. exports during 1986-92 consisted of chips, wafers, and other semiconductor parts exported to assembly and testing plants in developing countries such as Malaysia, Singapore, Korea, the Philippines, and Taiwan. Most of the production of these assembly plants is sent to the United States (see figures 13 and 14). Outside these assembly locations, the largest foreign markets for U.S. exports were in the EC, Canada, and Taiwan. These three markets accounted for more than half of U.S. exports of semiconductors (excluding parts) in 1992 (figure 15). U.S. exports of semiconductors are principally intracompany transfers from U.S. producers to their foreign sales and manufacturing affiliates and direct sales to large, unaffiliated manufacturers of electronic equipment.

ICs accounted for most of the growth in U.S. exports and were the main type of semiconductor exported during 1986-92. During this period the value of exports of ICs (excluding parts) increased at an annual average rate of about 16 percent, from $1.8 billion to $4.4 billion, increasing their share of the total U.S. semiconductor export market (excluding parts) from about 82 percent to 89 percent. On the other hand, the value of U.S. exports of discrete semiconductors (excluding parts) increased at an average annual growth rate of only about 5 percent during this period, from $0.4 billion to $0.5 billion,

[124] See section on U.S. nontariff measures.

[125] Note that not all of this growth in foreign share of Japan's semiconductor market was accounted for by imports. These share numbers refer to all semiconductor sales made in Japan by foreign-headquartered firms regardless of where the devices were manufactured.

[126] U.S. Department of Commerce and World Semiconductor Trade Statistics data used by the Government of the United States to monitor progress of market access provisions of the Semiconductor Arrangement entered into by the United States and Japan.

[127] U.S. Department of Commerce, U.S. Bureau of the Census, *U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates*, 1986 and 1989 eds., table 5.

[128] See section on Foreign Nontariff Measures earlier in this report.

[129] Export data in this section are compiled from official statistics of the U.S. Department of Commerce, include parts unless otherwise stated, and refer to domestic exports.

Table 4
Semiconductors: U.S. exports of domestic merchandise, by principal markets, 1986-92

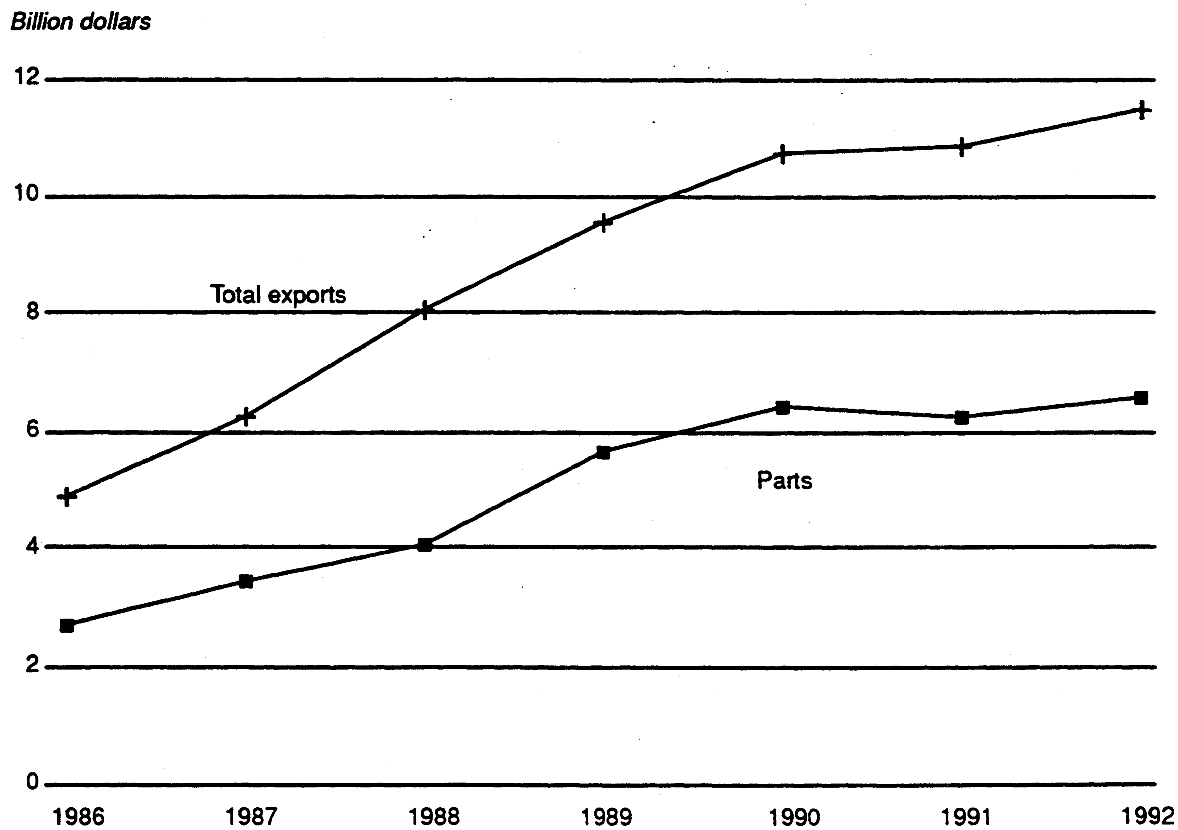
(1,000 dollars)

Market	1986	1987	1988	1989	1990	1991	1992
Japan	294	471	686	906	1,025	1,048	911
Malaysia	960	1,191	1,238	1,362	1,486	1,581	1,494
Republic of Korea	450	551	693	726	862	740	835
Canada	330	455	760	1,284	1,334	1,343	1,569
Singapore	475	524	672	844	1,056	1,091	1,338
Taiwan	265	471	561	640	760	887	1,096
Philippines	432	489	492	511	562	536	631
Hong Kong	157	212	354	445	536	534	689
Mexico	417	478	580	373	411	403	494
Thailand	246	388	458	423	506	477	367
All other	851	1,012	1,562	2,014	2,172	2,189	2,040
Total	4,878	6,241	8,056	9,531	10,710	10,831	11,465
EC-12	624	736	1,191	1,582	1,730	1,759	1,611
ASEAN	2,116	2,592	2,860	3,147	3,623	3,685	3,830

Note.—Because of rounding, figures may not add to totals shown.

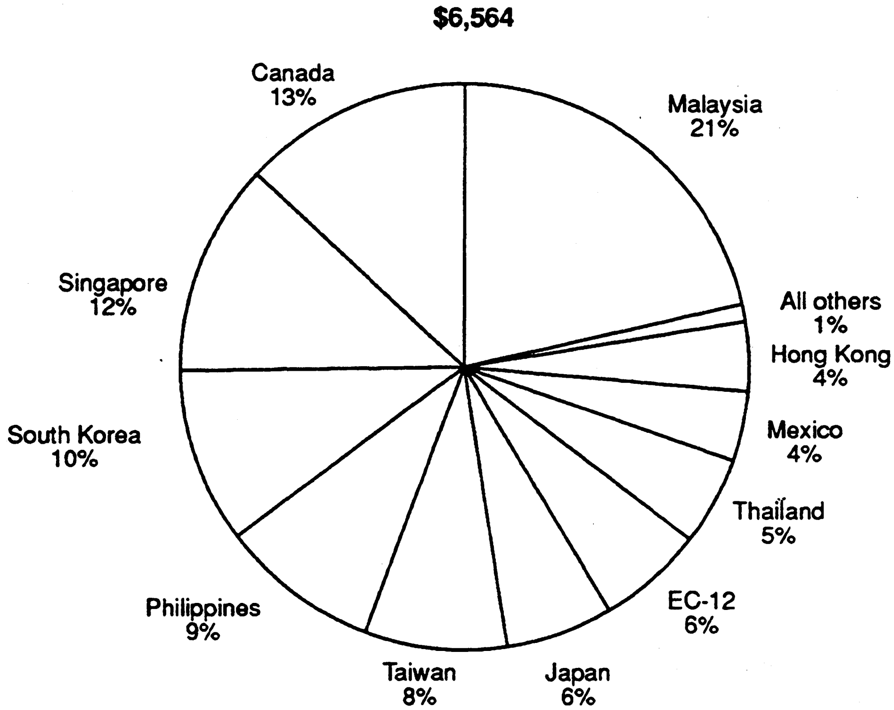
Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 13
Semiconductors and semiconductor parts: U.S. exports, 1986-92



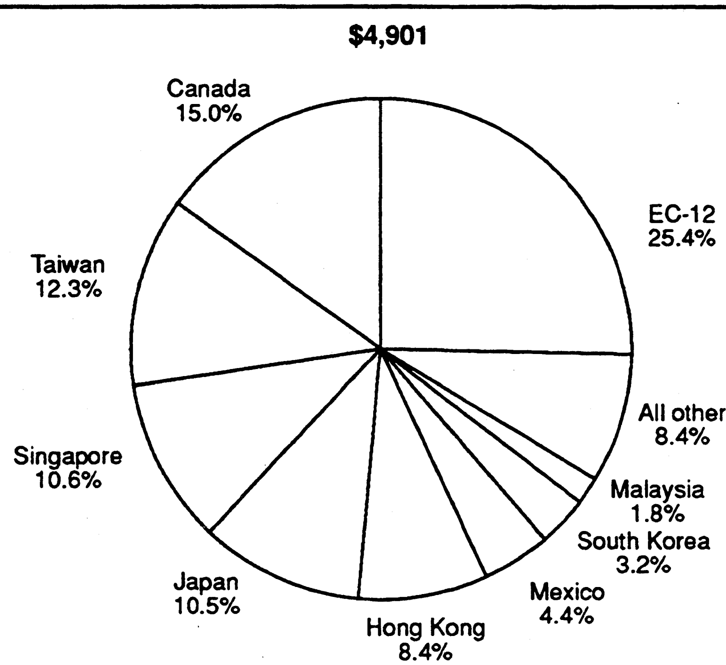
Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 14
Semiconductor parts: U.S. exports by markets of destination, 1992[1]



[1] Because of rounding, percentages may not total 100.
Source: USITC staff estimates based on official statistics of the U.S. Department of Commerce.

Figure 15
Semiconductors, excluding parts: U.S. exports by markets of destination, 1992



Source: USITC staff estimates based on official statistics of the U.S. Department of Commerce.

decreasing their share of the total semiconductor export market from about 18 percent to 11 percent.

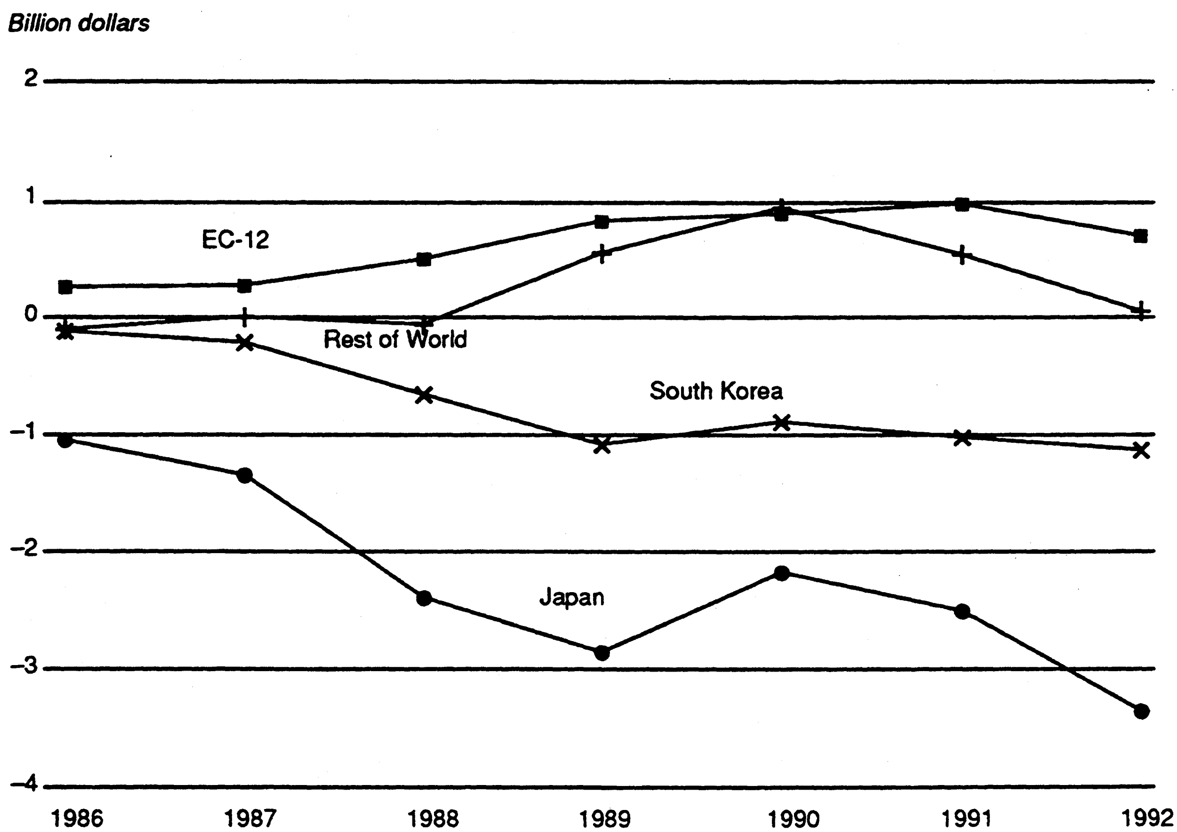
U.S. TRADE BALANCE

From 1986 to 1992 the U.S. balance of trade in semiconductors changed from a deficit of $1.1 billion to a deficit of $3.8 billion. The increase in this deficit was principally caused by a deteriorating trade balance with Japan and Korea. Excluding trade with these two countries, the U.S. balance of trade changed from a surplus of $0.1 billion in 1986 to a surplus of $1.8 billion in 1990 and then fell to a surplus less than $0.1 billion in 1991-92. The improvement was primarily accounted for by U.S. exports to the EC, Taiwan, Hong Kong, and a large number of small trading partners (figure 16 and table 5).

Data in this section are compiled from official statistics of the U.S. Department of Commerce that classify as "U.S. imports for consumption" certain semiconductors that are not consumed in the United States but exported as foreign exports. As a result, deficits are overstated and surpluses understated above. The staff of the USITC estimates the actual U.S. trade deficit in semiconductors in 1986 could have been as low as 280 million and the U.S. trade surplus in these products in 1992 could have been as high as 600 million.[130]

[130] Alternative approaches to capture U.S. imports consumed in the United States are currently being evaluated by the U.S. Department of Commerce in consultation with the staff of the USITC and other government agencies and are discussed in "Comparative Evaluation of Methodologies for Trade Calculations Reflecting U.S. Competitiveness," a draft report prepared by Ronald M. Powell of the Electronics and Electrical Engineering Laboratory of the National Institute of Standards and Technology, August 5, 1992.

Figure 16
U.S. trade balance in semiconductors and parts, 1986-92



Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 5
Semiconductors: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1986-92[1]

(Million dollars)

Item	1986	1987	1988	1989	1990	1991	1992
U.S. exports of domestic merchandise:							
Japan	294	471	686	906	1,025	1,048	911
Malaysia	960	1,191	1,238	1,362	1,486	1,581	1,494
Republic of Korea	450	551	693	726	862	740	835
Canada	330	455	760	1,284	1,334	1,343	1,569
Singapore	475	524	672	844	1,056	1,091	1,338
Taiwan	265	471	561	640	760	887	1,096
Philippines	432	489	492	511	562	536	631
Hong Kong	157	212	354	445	536	534	689
Mexico	417	478	580	373	411	403	494
Thailand	246	388	458	423	506	477	367
All other	851	1,012	1,562	2,014	2,172	2,189	2,040
Total	4,878	6,241	8,056	9,531	10,710	10,831	11,465
EC-12	624	736	1,191	1,582	1,730	1,759	1,611
OPEC	7	10	11	20	22	21	31
ASEAN	2,116	2,592	2,860	3,147	3,623	3,685	3,830
CBERA	18	16	15	9	9	9	10
Eastern Europe	1	2	1	1	1	2	3
U.S. imports for consumption:							
Japan	1,357	1,831	3,092	3,783	3,216	3,575	4,286
Malaysia	1,114	1,244	1,536	1,655	1,618	1,584	1,986
Republic of Korea	586	782	1,367	1,825	1,767	1,779	1,982
Canada	376	605	724	901	1,006	1,420	1,728
Singapore	628	811	1,018	1,041	1,135	1,173	1,251
Taiwan	306	439	599	593	636	673	931
Philippines	471	538	569	498	566	650	826
Hong Kong	98	123	241	213	263	276	372
Mexico	267	303	306	354	367	334	363
Thailan	243	339	405	355	379	382	315
All other	510	577	874	954	1,070	1,083	1,236
Total	5,955	7,592	10,732	12,172	12,023	12,928	15,275
EC-12	383	482	710	778	865	810	934
OPEC	14	5	1	5	14	26	43
ASEAN	2,469	2,938	3,530	3,555	3,711	3,790	4,378
CBERA	67	3	3	2	1	2	4
Eastern Europe	([2])	([2])	([2])	([2])	([2])	1	1
U.S. merchandise trade balance:							
Japan	-1,063	-1,360	-2,406	-2,877	-2,191	-2,526	-3,376
Malaysia	-154	-54	-298	-293	-131	-3	-492
Republic of Korea	-135	-231	-674	-1,099	-905	-1,038	-1,147
Canada	-46	-150	35	384	328	-77	-158
Singapore	-152	-287	-347	-196	-79	-82	87
Taiwan	-41	32	-38	47	124	214	165
Philippines	-38	-49	-77	13	5	-114	-195
Hong Kong	59	89	113	232	272	258	317
Mexico	149	175	274	19	45	70	131
Thailand	3	49	52	68	127	94	52
All other	341	435	688	1,061	1,102	1,107	804
Total	-1,077	-1,352	-2,676	-2,642	-1,303	-2,097	-3,810
EC-12	241	254	482	804	865	949	676
OPEC	-7	5	10	15	8	-6	-13
ASEAN	-353	-346	-670	-407	-89	-105	-548
CBERA	-49	13	13	7	8	6	7
Eastern Europe	([2])	1	1	1	1	2	2

[1] Import values are based on customs value; export values are based on f.a.s. value, U.S. port of export.
[2] Less than 0.5 million.

Note.—Because of rounding, figures may not add to totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce.

APPENDIX A
EXPLANATION OF TARIFF AND TRADE AGREEMENT TERMS

TARIFF AND TRADE AGREEMENT TERMS

The ***Harmonized Tariff Schedule of the United States*** (HTS) replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989. Chapters 1 through 97 are based upon the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description, with additional U.S. product subdivisions at the 8-digit level. Chapters 98 and 99 contain special U.S. classification provisions and temporary rate provisions, respectively.

Rates of duty in the ***general*** subcolumn of HTS column 1 are most-favored-nation (MFN) rates; for the most part, they represent the final concession rate from the Tokyo Round of Multilateral Trade Negotiations. Column 1-general duty rates are applicable to imported goods from all countries except (1) those enumerated in general note 3(b) to the HTS plus Serbia and Montenegro, whose products are dutied at the rates set forth in ***column 2***, and (2) countries whose goods are subject to embargo. Goods from Albania, Armenia, Belarus, Bulgaria, the People's Republic of China, the Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, Turkmenistan, and the Ukraine are currently eligible for MFN treatment, as are the other republics of the former Socialist Federal Republic of Yugoslavia. Among articles dutiable at column 1-general rates, particular products of enumerated countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS column 1. Where eligibility for special tariff treatment is not claimed or established, goods are dutiable at column 1-general rates.

The ***Generalized System of Preferences*** (GSP) affords nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 and renewed in the Trade and Tariff Act of 1984, applies to merchandise imported on or after January 1, 1976 and before September 30, 1994. Indicated by the symbol "A" or "A*" in the special subcolumn of column 1, the GSP provides duty-free entry to eligible articles the product of and imported directly from designated beneficiary developing countries, as set forth in general note 3(c)(ii) to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984; this tariff preference program has no expiration date. Indicated by the symbol "E" or "E*" in the special subcolumn of column 1, the CBERA provides duty-free entry to eligible articles, and reduced-duty treatment to certain other articles, which are the product of and imported directly from designated countries, as set forth in general note 3(c)(v) to the HTS.

Preferential rates of duty in the special subcolumn of column 1 followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free Trade Area Implementation Act*** of 1985 (IFTA), as provided in general note 3(c)(vi) of the HTS. Where no rate of duty is provided for products of Israel in the special subcolumn for a particular provision, the rate of duty in the general subcolumn of column 1 applies.

Preferential rates of duty in the special subcolumn of column 1 followed by the symbol "CA" are applicable to eligible goods originating in the territory of Canada under the ***United States-Canada Free-Trade Agreement*** (CFTA), as provided in general note 3(c)(vii) to the HTS.

Preferential nonreciprocal duty-free or reduced-duty treatment in the special subcolumn of column 1 followed by the symbol "J" or "J*" in parentheses is afforded to eligible articles the product of designated beneficiary countries under the ***Andean Trade Preference Act*** (ATPA), enacted in title II of Public Law 102-182 and implemented by Presidential Proclamation 6455 of July 2, 1992 (effective July 22, 1992), as set forth in general note 3(c)(ix) to the HTS.

Other special tariff treatment applies to particular ***products of insular possessions*** (general note 3(a)(iv)), goods covered by the ***Automotive Products Trade Act*** (APTA) (general note

3(c)(iii)) and the ***Agreement on Trade in Civil Aircraft*** (ATCA) (general note 3(c)(iv)), and ***articles imported from freely associated states*** (general note 3(c)(viii)).

The ***General Agreement on Tariffs and Trade*** (GATT) (61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786) is the multilateral agreement setting forth basic principles governing international trade among its 111 signatories. The GATT's main obligations relate to most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national (nondiscriminatory) treatment for imported products; the GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, and other measures. Results of GATT-sponsored multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as Schedule XX.

Officially known as "The Arrangement Regarding International Trade in Textiles," the ***Multifiber Arrangement*** (MFA) provides a framework for the negotiation of bilateral agreements between importing and producing countries, or for unilateral action by importing countries in the absence of an agreement. These bilateral agreements establish quantitative limits on imports of textiles and apparel, of cotton and other vegetable fibers, wool, man-made fibers and silk blends, in order to prevent market disruption in the importing countries—restrictions that would otherwise be a departure from GATT provisions. The United States has bilateral agreements with many supplying countries, including the four largest suppliers: China, Hong Kong, the Republic of Korea, and Taiwan.

APPENDIX B
REPORTS OF THE U.S. INTERNATIONAL TRADE COMMISSION PERTAINING TO SEMICONDUCTORS

Non-recurring Reports

U.S. Tariff Commission. *Electronic Receiving Tubes and Transistors,* worker petition, (investigation No. TEA-W). TC publication 396, 1971

________. *Capacitors and Semiconductors* (investigation No. TEA-F-22). TC publication 394, 1971

________. *Capacitors and Semiconductors* (investigation No. TEA-W-82/88). TC publication 395, 1971

________. *Transistors* (investigation No. TEA-W-196). TC publication 588, 1973

U.S. International Trade Commission. Transistors and Diodes.(investigation No. TEA-W-255). USITC publication 715, 1975.

________. *Competitive Factors Influencing World Trade in Integrated Circuits.* (investigation No. 332-102). USITC publication 1013, Nov. 1979.

________. *Summary of Trade and Tariff Information, Semiconductors.* Control No. 6-5-22, USITC publication 841, July 1982.

________. *Microprocessors.* Investigation No. 337-TA-153, instituted in July 1983, no report was issued.

________. *Competitive position of U.S. Producers of Semiconductors.* Investigation No. 332-200, instituted in 1984, no completion date at this time.

________. *Probable Economic Effects of Providing Duty Free Treatment for U.S. Imports of Certain High Technology Products.* Investigation No. TA-131(b)-9, USITC publication 1705, June 1985.

________. *Summary of Trade and Tariff Information, Semiconductors.* Control No. 6-5-22 (supplement), USITC publication 841, Aug. 1984.

________. *64K Dynamic Random Access Memory Components From Japan.* investigation No. 731-TA-270 (P), USITC publication 1735, Aug. 1985.

________. *Erasable Programmable Read Only Memories From Japan.* Investigation No. 731-TA-288 (P), USITC publication 1778, Nov. 1985.

________. *Dynamic Random Access Memory Semiconductors of 256 Kilobits and Above From Japan.* Investigation No. 731-TA-300 (P), USITC publication 1803, Jan. 1986.

________. *64K Dynamic Random Access Memory Components From Japan.* Investigation No. 731-TA-270 (F), USITC publication 1862, June 1986.

________. *Erasable Programmable Read Only Memories From Japan.* Investigation No. 731-TA-288 (F), USITC publication 1927, Dec. 1986.

________. *In the Matter of Dynamic Random Access Memory Semiconductors.* Investigation No. 337-TA-242, USITC publication 2034, 1987.

________. *Erasable Programmable Read Only Memories.* Investigation No. 731-TA-276, USITC publication 2196, Dec. 1989.

________. *DRAMs of One Megabit and Above From the Republic of Korea.* Investigation No. 731-TA-556 (P), USITC publication 2519, June 1992.

________. *DRAMs of One Megabit and Above From the Republic of Korea.* Investigation No. 731-TA-556 (F), USITC publication 2629, May 1993.

Recurring Reports

Production Sharing: U.S. Imports Under Harmonized Tariff Schedule Subheadings 9802.00.60 and 9802.00.80, formerly *Imports Under Items 806.00 and 807.00 of the Tariff Schedules of the United States*, published yearly since 1986. This report analyzes statistical data on imports of goods containing U.S. metal or U.S. made components. Last published as USITC publication 2592, 1993.

U.S. Trade Shifts in Selected Commodity Areas, published semiannually to analyze statistical data on U.S. trade performance and significant commodity shifts. Last published in USITC publication 2677, September 1993.

APPENDIX C
GLOSSARY

GLOSSARY

Analog integrated circuit

An integrated circuit that stores or manipulates data with a predictable functional relationship between input and output. For example, in an IC amplifier the output is a magnified version of the input. Analog ICs contrast with digital ICs that manipulate data using the on/off properties of transistors.

Application–specific integrated circuit (ASIC)

An integrated circuit designed for one narrow use. Often custom or semicustom.

Bipolar

One of the two types of transistors and integrated circuits; the other is metal–oxide semiconductor (MOS). They are faster than MOS devices but usually more difficult to make.

Bit

An abbreviation for a digit used in the binary numerical system. A zero (0) or one (1) in the binary language of computers.

Captive producer

A semiconductor manufacturing firm that produces exclusively for in–house consumption. Contrasts with merchant producer.

Component

An individual electronic part, such as a transistor, diode, or capacitor.

Density

The amount of bits, or dice, per unit of area or per wafer.

Deposition

An operation in which film is placed on a wafer without a chemical reaction with the underlying layer.

Die

The small piece of the wafer on which an individual semiconductor device has been formed.

Diffusion

A process in which desired impurities are introduced into a semiconductor wafer by baking the wafer at high temperatures and pressures in chemically altered atmospheres.

Digital integrated circuit

An integrated circuit that uses binary codes (0's or 1's) to store and manipulate data by using the on/off properties of transistors. Contrasts with analog ICs.

Diode

A semiconductor component that allows electricity to flow only in one direction.

Dynamic random access memory (DRAM)

A type of IC based on RAM circuitry that requires some external support circuitry.

Electrically erasable programmable read–only memory (EEPROM)

Refers to user programmable IC memory devices that retain the stored information in the absence of electric power and in which the stored information may be altered electrically.

Gate array

A kind of semicustom circuit.

Integrated circuit (IC)

A complete electronic circuit composed of two or more interconnected active components, such as diodes or transistors, and fabricated on a single semiconductor substrate, usually silicon.

Linear integrated circuits

An analog integrated circuit whose output signal has a "one–to–one" relationship with the input signal. Most analog ICs are linear, and, as a result, the terms "analog" and "linear" are often used interchangeably. However, there are nonlinear analog circuits with input and output relationships that are, for example, logarithmic.

Lithography

A process in which the desired circuit pattern is projected onto a photoresist coating covering a silicon wafer. When developed, portions of the resist can be selectively removed with a solvent, exposing parts of the wafer for etching and diffusion.

Logic circuit

A type of digital integrated circuit that performs certain logical or mathematical functions and often provides connections between other major parts of computers.

Memory device

An integrated circuit that stores data or information. Memory devices are categorized according to accessibility (at random or serially), size, speed, and to whether they can be written to or only read from.

Merchant producer

A manufacturing firm that produces semiconductor primarily for sale on the open market. Contrasts with captive producer.

Metal–oxide semiconductor (MOS)

One of two families of silicon transistors and integrated circuits (the other is bipolar).

Microprocessor

An integrated circuit consisting of memory, logic, and other circuitry that can be programmed to perform many different circuit functions. Microprocessors have permitted the development of powerful personal computers, digital watches, and other electronic equipment.

Mixed signal integrated circuit

An integrated circuit that combines digital and analog circuitry.

Photosensitive semiconductors

Semiconductor devices that process light signals or use light instead of electrical currents as an input or output.

Random access memory (RAM)

A principal type of circuitry used in memory ICs. Compared with other types of memory circuitry, RAM provides the fastest capabilities for storing and retrieving digital information. However, RAM circuits are not suited to certain applications because, unlike circuits based on read only memory (ROM) circuitry, they need to be connected to a source of electrical power to retain stored information.

Semiconductor

A material, typically silicon or germanium, that is a poor conductor of electricity. The term has come to refer to all devices made of semiconducting material, including integrated circuits, discretes, and hybrids (See semiconductor device).

Semiconductor device

An electronic device whose main functioning part is made from materials (usually silicon) whose conductivity ranges between that of a conductor and an insulator. Semiconductor devices achieve amplification and rapid on–off switching by moving electronic charges along controlled paths inside a solid block of semiconductor material (hence the name "solid state").

Single in–line memory module (SIMMs)

A IC packaging arrangement used to expand the memory capacity of certain electronic equipment and consisting of two or more assembled DRAMs soldered to a printed–circuit board.

Solid–state products

Products utilizing the electric, magnetic, or photic properties of solid materials (See semiconductor device).

Substrate

The material upon which a semiconductor device is built.

Transistor

A three–terminal semiconductor device used mainly to amplify or switch.

Wafer

A thin disk of a diameter usually ranging from 10 to 30 centimeters and made of silicon or other semiconductor material. Wafers are the base on which integrated circuits are fabricated.