CHAPTER 4

Structure and Trade in the International Electronics Industry

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Overview

The wide international dispersion of manufacturing and sales in electronics means these activities take place in an environment heavily conditioned by global political currents and the industrial policies of competing nations, Episodes such as the NTT (Nippon Telegraph and Telephone) procurement dispute, which came to symbolize a much broader range of U.S.-Japan trade frictions, are only one example. More striking is the rhetoric common in the Japanese press, in which international competition in electronics is continually described in terms of the "semiconductor war" or the ''computer war. ''1 The context for investment and production, as well as trade, can be highly politicized. In developing countries, investment may be contingent on performance requirements calling for certain percentages of local value-added, export targets, or employment levels. Companies that do business on a worldwide basis try to manipulate these political currents to their own advantage.

American firms have frequently transferred labor-intensive production operations to low-wage countries as a means of cutting costs; prominent examples include assembly of circuit boards and chassis for television receivers, as well as wire bonding and assembly of integrated circuits (ICs). Sometimes overseas production contributes to foreign sales; American firms can market within the European Economic Community more easily if they produce there rather than exporting. Along with foreign investments for manufacturing, U.S. semiconductor companies have established R&D centers in Europe, with ***similar*** efforts in Japan planned or underway; a number of American computer firms also maintain substantial engineering operations in Europe. The patterns are quite different in consumer electronics, where U.S. companies operate offshore assembly plants but market almost exclusively at home.

Just as American electronics firms market and invest overseas, foreign-owned enterprises are extending their activities to the United States. Of the 15 manufacturers of TVs in this country, 11 are now foreign-owned (3 of the 4 largest remain American). All the consumer-model video cassette recorders sold in the United States—including those marketed by GE, RCA, and Zenith—are made in Japan, Japanese semiconductor manufacturers not only distribute their products here but are setting up assembly plants and R&D organizations. Several leading American semiconductor companies have been purchased by European concerns. Japanese computer manufacturers are selling in the United States through joint ventures with American firms like National Semiconductor, while planning independent marketing efforts for the future. As good an example as any of the ties linking electronics industries in various parts of the world can be found in the genesis of the computer language Ada—recently adopted by the U.S. Department of Defense as a standard, Ada was developed in France by an employee of CII-Honeywell Bull, a company at the time owned 47 percent by the American computer manufacturer Honeywell.

Electronics technology now flows both into the United States and out, although transfers overseas by American firms remain much more frequent. Semiconductor patents owned

[1] See, for example, *Japan Report*, Joint Publications Research Service JPRS L/10662, July 16, 1982, in which seven articles from Japanese publications are translated under the heading "U.S.-Japan VLSI War." The media in Japan are not unique in this tendency. An NBC news special aired Aug. 14, 1982, named after the title "Japan vs. USA: The Hi Tech Shootout."

by Bell Laboratories have been licensed worldwide. RCA continues to receive about $50 million per year from Japan consumer electronics firms for its color TV technology, a sum comparable to RCA's annual profits from making and selling television sets. Computer manufacturers in many countries—including the Soviet Union–design systems to run on IBM software. Apple computers have been widely counterfeited in the Far East. Japanese firms are accused of purchasing stolen information concerning IBM computers, Much of the lithographic equipment for fabricating large-scale ICs is produced in the United States by firms that depend on Japan and West Germany for optical components; one major producer is based in Liechtenstein. ICs that sell in large volume—such as microprocessors or computer memory chips—become commodity items produced to essentially the same specifications in the United States, Japan, and Europe, Sometimes the circuits are identical because of formal licensing agreements, occasionally because the designs have been copied. In other cases, chips may differ internally but function interchangeably, Second-sourcing of ICs often entails agreements for the design and development of peripheral or support chips. Licensing and alternate sourcing arrangements of all types link semiconductor firms throughout the industrialized world; these linkages help define the forms of competition without affecting its intensity.

In such an environment—one increasingly common to many sectors of the world economy, automobiles as well as electronics—issues of international competitiveness and national interest are seldom clear-cut. Trade flows, one of the traditional measures of international competitiveness, can become ambiguous when substantial fractions of imports and exports consist simply of intracorporate transfers. What does it mean when Japanese firms export ICs to the United States that were originally designed here, or when competitors like National Semiconductor and Oki Electric announce a joint venture in which National will manufacture Oki-designed 64K RAMs (random-access memory circuits) in the United States? Should it matter to the Federal Government that TV or semiconductor plants formerly controlled by American interests now belong to Japanese or European concerns? If U.S. companies chose to export nonmilitary technologies, is this anyone else's business? Organized labor would answer yes to this last question, out of concern for American jobs. So might some businessmen—but more likely with reference to a rival's exports of technology than their own.

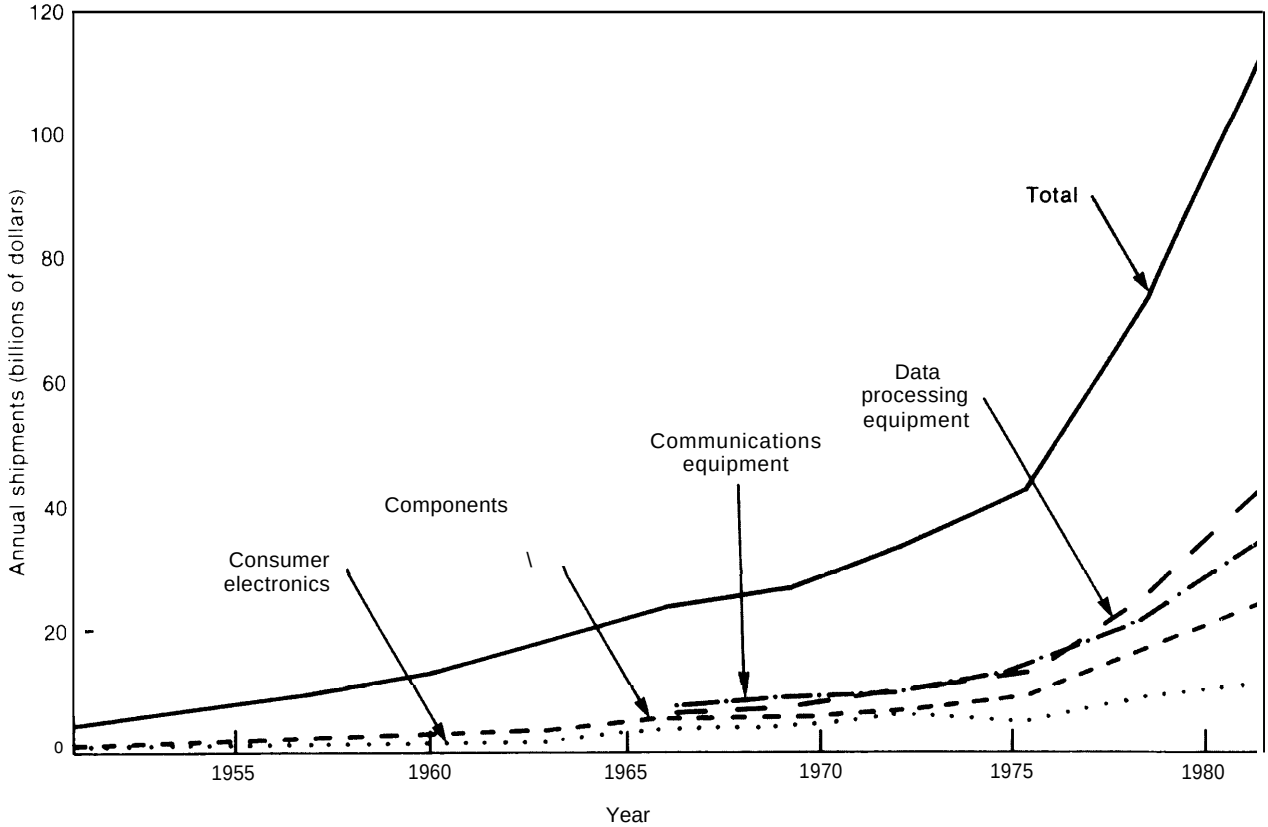
This chapter explores the background for such questions without attempting to answer them (they seldom have definitive answers). As for the preceding chapter, the approach is largely descriptive, aimed at giving a picture of the world electronics industry that will serve to frame issues of policy and competitiveness.

The U.S. Electronics Industry: Introduction

Electronics is, first of all, a large and diverse industry. Sales of the more than 6,000 electronics manufacturers in the United States exceeded $125 billion in 1982 and are growing rapidly; the industry employs more than 1½ million people. Most of these 6,000 plus companies are small. Nearly three-quarters have annual sales of less than $5 million; about half produce components of various types. As figure 17 indicates, domestic shipments—the plot includes the value of both imports and exports—have expanded more than 25 times over the past 30 years, an annual growth rate exceeding 11 Percent, Recent expansion has been even faster: the growth rate over the past decade reached nearly 15 percent. U.S. output of durable goods came to about $500 billion in 1982; thus electronics, broadly defined, accounted for nearly 25 percent of the total.[2]

[2] *Economic Report of the President* (Washington, D. C.: U .S. Government Printing Office, February 1983), p. 170. If nondurable are included, electronics output accounted for about 10 percent of U.S. manufactures. Sales of communications equipment and other classes of electronics products that are not the subject of this report are included in these comparisons and in figure 17 to illustrate the overall size of the industry.

Figure 17.—Sales Trends in the U.S. Electronics Market



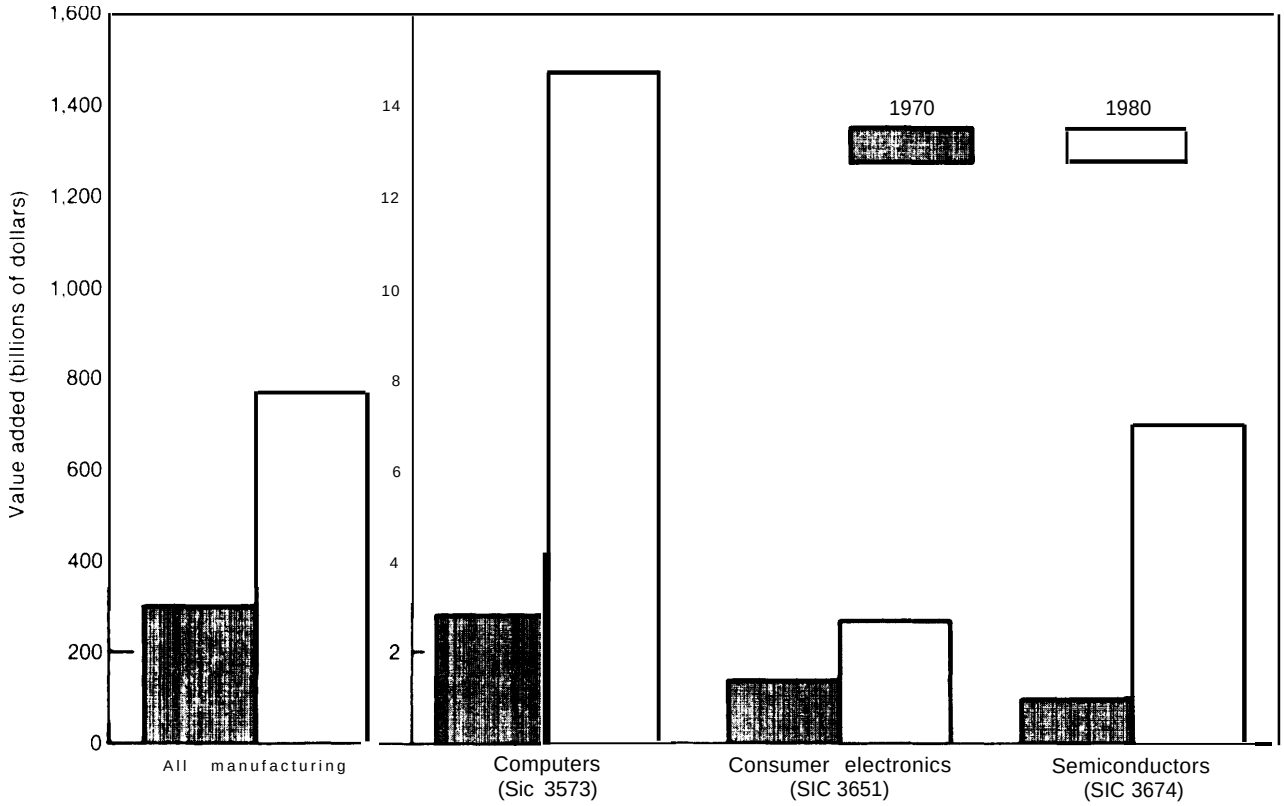
SOURCE" *Electronic Market Data Book* 7982 (Washington, D.C Electronic Industries Association, 1982), p. 4.

In fact, the sales totals in figure 17 involve some double counting because manufacturers of final products purchase components from other electronics firms. Examining value-added data, figure 18, which subtract the value of intermediate goods inputs from final sales figures, shows the industry to be somewhat smaller but the growth trend remains about the same.

Throughout its history the electronics industry has been one of the most technologically dynamic in the U.S. economy. Applications of computing power and smart electronics have become widely diffused both within the industry and outside it—products from supermarket checkout terminals to Boeing 767s now depend on microprocessors.[3] The diversity found among American electronics firms is, in its own **way,** as impressive as the technical virtuosity of the industry's products. These products—which range from CB radios to satellite-based communications systems, carbon resistors to vastly powerful computers—are probably distributed more widely through the rest of the U.S. economy than the output of any other industry. This pervasiveness has the corollary of involving almost all parts of the Nation's distribution system. There are few manufacturing firms, even fewer wholesalers and retailers, virtually no individuals, who do not buy electronic products.

[3]About 180 microprocessors go into each 767, A Cadillac Seville uses 10, along with nearly 100 other ICs, an even larger number of discrete transistors, and about 1,000 other electronic components. See A. R. Karr, "FAA Is Making Stiff Demands on Boeing To Prove the Safety of Its New 767 Jetliner," *Wall Street Journal,* July 23, 1982, p. 36; L. Givens, "Engineering Highlights of the 1983 Automobiles," *Automotive Engineering,* October 1982, p. 31.

Figure 18.—Value Added in U.S. Manufacturing



SOURCE 1977 Census of Manufactures, 1980 Annual Survey of Manufactures

Because of this diversity, the industry cannot be meaningfully discussed as a whole—a difficulty even more acute when the topic is international competitiveness, which implies examining the behavior of individual corporations to at least some extent. This is not the steel industry—where the firms active in a given market are easily defined, their competitive postures well known, the paramount considerations production costs and delivery. Nor is it automobiles, where the domestic industry consists of three or four corporations—again with clear identities, well-understood strengths and weaknesses—and their suppliers. Among the companies that populate electronics, some are as large and well known as U.S. Steel or Ford, while others—including many of the technological and market leaders—are small concerns with relatively specialized product lines, companies little known to outsiders. Three random examples: VisiCorp, which supplies software for small computers; GCA Corp., which designs and builds semiconductor fabrication equipment; John Fluke Manufacturing Co., specializing in instruments. While electronics is certainly better defined than the emerging biotechnology industry, in a sense there is little point in speaking of an electronics "industry" at all. Rather, there is a large group of companies sharing certain characteristics such as the relevance of their products, whether hardware or software, to the processing and transmission of information. Moreover, when subsets of the larger group are examined, boundaries shift and blur as a result of time and technical change—semiconductor firms move into systems, computer firms into data communications. As a result, classifications and subclassifications for reporting production and trade data are not always useful,

sometimes lagging years behind major developments in the industry and its products. *

In part for such reasons, OTA's examination of electronics covers only three portions of the industry: consumer electronics, semiconductors, and computers. In capsule form, these can be described as follows:

- ***Consumer electronic*** products are sold through retail distribution channels; they include radios, TV sets, sound reproduction equipment, video games, digital watches, and calculators, Most of these products fit within the "home entertainment" category. Personal computers—which could be classed as consumer products—also have utilitarian applications, In this report, personal computers are included with other data processing systems because–except at the very bottom of the price range—they are similar to machines sold for business applications.
- ***Semiconductors*** are one species of electronic component, sold to manufacturers of final products or used internally (30 to 40 percent of U.S. output falls in the latter category, produced by "captive" facilities). Included are discrete devices, such as power transistors, as well as an immense variety of ICs, some of which were described in the preceding chapter. Needless to say, marketing and distribution channels for semiconductors differ greatly from those for consumer electronics. Because of their importance for competitiveness, *semiconductor equipment manufacturers–firms* that develop and supply the equipment needed to produce microelectronic devices—are discussed separately below.
- The *computer* industry, for purposes of this report, includes 'manufacturers of mainframe machines, minicomputers, and personal or desktop units, as well as peripheral equipment. While peripherals are not covered in detail—nor are independent software vendors—the many smaller firms in these portions of the industry are an important source of competitive strength for the United States. Except for personal machines, data processing equipment manufacturers sell almost exclusively to other businesses, as well as to institutions such as Federal, State, and local governments. With the dramatic cost reductions of recent years, computers are now found in even the smallest organizations, personal machines, sold both for business and household use-–mostly through retail channels—promise a further enlargement of information processing markets.

Many electronics firms do business in more than one of these sectors of the industry. IBM makes both computers and semiconductors, as do NCR, Digital Equipment Corp., and Texas Instruments, The latter firm also sells consumer products, Zenith builds personal computers as well as TVs; although 80 percent of its business is in TV, the company is trying to diversify. RCA is a major force in satellite communications as well as consumer electronics; in fact, the company is a conglomerate with substantial interests quite divorced from electronics. Hewlett-Packard makes a variety of instrumentation and measuring equipment, as well as computers—and, like many other electronics companies, some of its own semiconductors. Firms like IBM, GE, and Texas Instruments have substantial military sales, while some companies thought of mostly as defense

*Beyond the official 4-digit SIC system (Standard Industrial Classification; see ch. 9 where employment is discussed by SIC category) for reporting production and consumption within the United States, the Department of Commerce has subdivided the category for Semiconductors and Related Devices (SIC 3674) into 27 narrower subgroups. Of these, six apply to bipolar ICs, only three to MOS ICs—despite the fact that the latter have long since reached greater sales levels. For computers, the SIC subdivisions have not kept up at all: of the two categories, virtually all computers-from 8-bit personal machines costing a few thousand dollars to supercomputers—fall in SIC *357311* (general purpose); the second category is reserved for military and other specialized systems, Much the same is true of the somewhat different classifications and categories used by the United States for imports and exports (other countries have their own reporting systems). One result is that data on production can seldom be directly compared with that for trade; although concordances are available, one-to-one correspondence does not always exist, Apparently, none of the systems as yet makes explicit provision for software except as a service item, yet software accounts for a substantial and increasing fraction of the value of computer systems and is frequently sold separately from hardware.

contractors play small but significant roles in the broader world of commercial electronics. Hughes and Lockheed, for instance, are known and respected for their R&D in microelectronics; research performed by aerospace contractors often finds eventual commercial application, although in recent years more electronics technology has flowed from commercial developments into military hardware and software than the other way.

These three portions of the electronics industry are described next in more detail, from the viewpoint of structure and on a world basis.

Consumer Electronics

The United States, With Particular Attention to Color Television

American consumer electronics firms have had great difficulty retaining their competitiveness. U.S. producers of TVs and other home entertainment equipment have shared the plight of firms manufacturing components like capacitors, switches, and circuit boards: these rather simple products can be made overseas with the aid of cheap labor at highly competitive costs. Of a total consumer electronics market exceeding $20 billion, a market that recently has been expanding by nearly 10 percent annually, imports today account for the majority of sales in many product categories (table 8),[4] Virtually all production of some types of consumer goods—portable radios and video cassette recorders (VCRs) are examples—takes place abroad, mostly in the Far East. For other products, such as black-and-white TVs, American manufacturers remain viable competitors in only narrow segments of the market. A parallel decline in color TV production was averted in part through orderly Marketing Agreements (OMAs) which limited imports from three Asian nations. OMAs encouraged investment in the United States by Japanese and Taiwanese manufacturers of color televisions. *

The remaining American consumer electronics manufacturers have been forced by the pressure of import competition—pressure that has led to frequent accusations of unfair trade practices, including charges of dumping that were upheld after lengthy investigations (see

[4]For radios and TVs as defined by SIC 3651, the value of imports exceeded 50 percent of the value of total sales for the first time in 1981—1982 *U.S. Industrial Outlook* (Washington, D. C.: Department of Commerce, January 1982], p. 344. Note that data collected and reported by different organizations may represent different definitions of consumer electronics. For instance, the $21.4 billion figure given by *Electronics* magazine for 1982 sales is about a third greater than that reported by the Electronic Industries Association (EIA) largely because the magazine's survey covers many product categories left out of the EIA total—*Electronics,* Jan. 13, 1983, p. 136.

*The 3-year OMA with Japan was allowed to expire in 1980 after a finding by the U.S. International Trade Commission that the domestic industry had adjusted so that protection was no longer needed. At that time, the OMAs with South Korea and Taiwan were continued, one reason being the much lower labor costs these countries enjoyed compared with Japan, giving them potentially greater competitive advantages; these two OMAs expired in July 1982 and were not renewed. Events leading up to the import quotas are discussed in ch. 11.

Table 8.—U.S. Sales and Imports of Selected Consumer Electronic Products, 1982

	US. sales (millions of dollars)	Imports (millions of dollars)	Import penetration (percent)[a]
Color television	$.4,253	$546	12.80/o
Black-and-white TV	507	344	67.9
Video cassette recorders	1,303	1,032	100.0[a]
Home and auto radios[b]	1,579	1,207	76.4
Stereo systems[c]	1,754	1,342	76.5
	$9,396	$4,471	47.60/o

[a]Because many items Imported in a given year are not sold until the following year, dividing imports during a given calendar year by sales in that same year may give only a rough indication of import penetration, for instance, *all* video cassette recorders sold in the United States are imported even though 1962 sales figures exceed 1982 import figures.
[b]Including auto tape players.
concluding audio tape units and other component equipment

SOURCE" *Electronic Market Data Book 1983* (Washington, D.C.: Electronic Industries Association, 1963), pp 6, 19, 23, 31

chs. 5 and 11)—to switch tactics in order to survive, The two largest American manufacturers of color TVs, Zenith and RCA, now carry out many of their assembly operations abroad, The move to offshore assembly, although resisted for some years by Zenith, ultimately became necessary to lower costs.

Americans buy more color TVs than any other consumer electronic product (table 8); televisions have also been a center of controversies over U.S. trade policy. For many purposes, color TV can stand for the U.S. consumer electronics industry as a whole. Table 9 summarizes data on domestic production and imports of color sets, broken down into three screen-size categories. The figures show that market growth—in terms of both domestic production and imports–has come in the small and intermediate screen sizes, while production of large screen sets has dropped considerably since the late 1960's. In 1967, when imports took only a little over 5 percent of the market, large screen models accounted for more than three-quarters of all sales. By 1981, the market share of large screen color sets had dropped to less than one-quarter; meanwhile, the overall color TV market had more than doubled. From the beginning, ***imports have been concentrated in the smaller screen models where sales have been growing.*** Most large sets are still made in the United States, but as sales swung toward second and third sets where portability and low cost are major selling points the large screen market shrank.

Table 9 also illustrates the effects of OMAs which took effect in 1977 (with Japan) and 1979 (with Taiwan and South Korea). Imports of small- and medium-size sets dropped by more than a million units between 1977 and 1979, a decline of nearly ***50*** percent. Imports have since stayed well below the 1977 level, but assembly in the United States by foreign firms has made up much of the difference:

Table 9.—U.S. Production and Imports of Color TV Receivers (thousands of sets)

Screen size[a]	1967	1969	1971	1973	1975	1977	1979	1981
Small								
U.S. production	373	579	645	1,267	905	1,040	1,710	2,220
Imports	157	480	780	936	637	1,148	818	1,238
Total small	'530	1,059	1,425	2,203	1,542	2,188	2,528	*3,458*
Imports as percent	29.6°/0	45.30/0	54.7%	42.5%	41.3%	52.5%	32.4%	*35.8 %*
Medium:								
U.S. production	624	1,000	1,851	3,182	2,167	3,014	4,559	5,668
Imports	171	399	413	379	562	1,350	49?	503
Total medium	795	1,399	2,264	3,561	2,729	4,364	5,050	6,171
Imports as percent	21.5%	28.5%	18.2%	10.6%	20.6%	30.90/0	9,70/0	8.2 %
Large:								
U.S. production	4,295	3,653	2,902	3,379	2,317	2,951	2,743	2,626
Imports	—	2	[b]	[b]	16	40	60	116
Total large	4,295	3,655			2,333	2,991	'2,803	2,742
Imports as percent	—	0.050/0			0.7%	1 .3 "/0	2.1 %	4.2%
All sizes:								
U.S. production	5,292	5,232	5,398	7,828	5,389	7,005	9,012	10,514
Imports	328	881	1,193	1,315	1,215	2,538	1,369	1,857
Total all sizes	5,620	6,113	6,591	9,143	6,604	9,543	~i3,381	12,371
Imports as percent	5.8%	14.40/0	18.1 %	14.40/0	18.4%	26.6%	13.2 %	1 5.0%

[a]Screen sizes are defined as follows ***Small: 1967, 1959-16*** inch and under 1971$1–17 inch and under *Mad/urn: 1967, 1%9–17* 19 inch*1971-81*—18 and 19 inch ***Large:*** *All years—20* inch and over

[b]Not available but very small

SOURCES. ***1967, 1969***—*Television* Receivers *and Certain Parts Thereof* (Washington, D C U S Tariff Commission Publication 436, November 1971), p A-57
1971 -79- Television Receiving Sets From Japan (Washington, D C U S International Trade Commission Publication 1153, June 1981), pp H-6, H-7, H-1 7, H-18
1971 ***and*** 1973 *Import* data— *Television Receivers,* Color *and Monochrome, Assembled or Not Assembled, Finished or Not Finished, and* Subassemblies *Thereof* (Washington, D C U S International Trade Commission Publication 808, March 1977), p A-91
1975 ***Import data—Color*** *Television Receivers and Subassemblies Thereof* (Washington, D C U S. International Trade Commission Publication 1068, May 1960), p D-7
1981 product/on-Co/or Television Receivers U S Production, Shipments, Inventories, Exports, Employment, Manhours, and Prices, First Calendar Quarter 1982 (Washington, D C U.S international Trade Commission Publication 1245, May 1982), table 1
1981 Imports — *Electronics Foreign Trade Five- Year Summary* 1977- *1981* (Wash ington, D C Electron icIndustries Association, March 1982), p 49

Employment

Even while domestic production and sales of TVs have expanded, employment has, since the mid-1960's, been falling (see ch. 9, especially fig. 57). There are two major reasons: increases in productivity and in foreign value-added. Productivity growth has come from simplifications in chassis design and from automation, both reducing labor content. At the same time, U.S. firms have moved some of their operations offshore, reducing domestic employment. Assembly in the United States by foreign firms compensates only in part; foreign-owned plants import many components and subassemblies. Although import quotas were justified in part on the basis of preserving American jobs, the employment data examined in chapter 9 shows that the OMAs had little apparent effect in arresting job losses.

Structure

Domestic TV production has most recently been accounted for by about 15 companies (the roster is fluid) that undertake some part of their manufacturing in the United States. These firms are listed, with their approximate share of color TV sales and the locations of their principal U.S. production facilities, in table 10. Zenith and RCA have, between them, held around 40 percent of the color TV market for many years. Imports and foreign manufacturers with production facilities here have taken sales primarily from smaller American manufacturers.

These sales have recently been growing a good deal more rapidly than many observers had anticipated, confounding those who predicted that the market was approaching saturation. The Electronic Industries Association forecast for 1980 had been 9.2 million color sets, a figure that was exceeded by nearly 1½ million. Sales in 1981 and 1982 were likewise affected much less by economic conditions than might have been expected. One reason seems to have been new demand stimulated by video games; rather than tying up the family TV, many households purchased second (perhaps third) sets. Derived demand of this type is at work in numerous electronics markets; home computers may also help expand color TV sales.

Table 10.—Firms With Color TV Manufacturing Facilities in the United States

Company	Ownership	Location(s)	Approximate market share, 1982 (percent)[a]
RCA Corp.	Us.	Bloomington, Ind.	20.0%
Zenith Radio Corp.	Us.	Chicago, Ill.	19.4
General Electric Co.	Us.	Portsmouth, Va.	8.0
Curtis Mathes Manufacturing Co.	Us.	Dallas, Tex.	1.2
North American Philips Corp. (Magnavox, Sylvania)	Netherlands	Jefferson City, Term. Smithfield, N.C.	11,5
Matsushita Industrial Co. (Quasar, Panasonic)	Japan	Chicago, Ill.	7.5
Sony Corp. of America	Japan	San Diego, Calif.	7.0
Hitachi Consumer Products of America, Inc.	Japan	Compton, Calif.	2.3
Sharp Electronics Corp.	Japan	Memphis, Term.	2.0
Sanyo Manufacturing Corp.	Japan	Forrest City, Ark.	1.5
Mitsubishi Consumer Electronics America, Inc.	Japan	Santa Ana, Calif.	1.5
Toshiba America, Inc.	Japan	Lebanon, Term.	1.4
Gold Star Electric International, Inc.	South Korea	Huntsville, Ala.	0.8
Sampo Corp. of America	Taiwan	Atlanta, Ga.	0.5
Tatung Co. of America, Inc.	Taiwan	Long Beach, Calif.	0.3
Private brands:			
Sears (mainly Sanyo)			7.3
Montgomery Wards (mainly GE, also N. A. Philips)			2.5
J. C. Penney (RCA and others)			1.5

[a]Company market shares do not include private brand sales. Market share figures do not total to 100 because of uncertainty concerning private brand market shares and suppliers of private brand sets. Nor are Importers without U.S. production facilities listed,

SOURCES *Television Receiving Sets From Japan* (Washington, D.C : U.S. International Trade Commission Publication 1153, June 1981), p. A-13; information from Department of Commerce and individual firms. Market share estimates from *Television Digest* surveys, July 1981 ·June 19S2

Competition has kept margins between prices and costs in color TV small. Absent data on manufacturing costs, this can be gaged in at least two ways. First, profits have been modest compared with other sectors of the economy. Net operating profit as a percentage of sales—not a particularly good measure, but the only one available (return on equity or on total capital would be better)—has been substantially lower than in most other U.S. industries. As table 11 shows, profitability in TV manufacture has, since the early 1970's, been far below that in electrical and electronic equipment, which itself has shown profitability levels quite close to the average for all U.S. manufacturing. An expanding market has not meant high profit margins for American producers.

The second indication of the efficiency of the market comes from data on relative price movements. Figure 19 shows retail prices on an index basis for TVs (both monochrome and color) compared with other consumer durables. The flat price history for TVs demonstrates that productivity improvements have been passed through to consumers as lower prices. This figure—along with the profitability data in table n-indicates the strength of

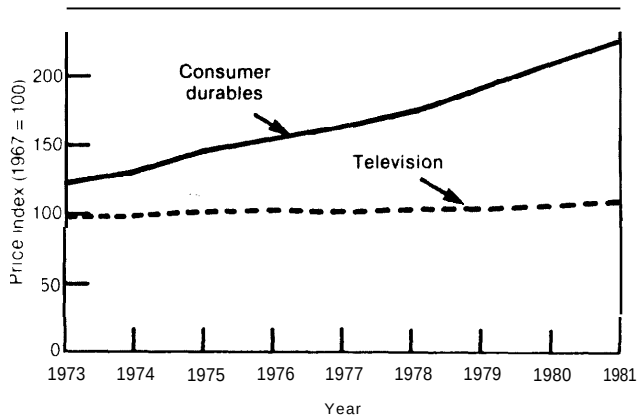
Table 11 .—Profitability in U.S. Color TV Manufacturing

Year	Net operating profit (or loss) as a percentage of net sates	
	All U.S. color TV manufacturers	All U.S. electrical and electronic equipment manufacturers
1971	8.7%	7.0 "/0
1973	5.8	8.4
1975	0.6	6.2
1977 ....., .	2.8	8.7
1978	1.5	8.1
1979	0,8	7.5
1980	1.9	7.5
1981	(0.1)	7.3

[a]Includes monochrome IV manufacturing for 1971 to 1975. Covers firms manufacturing In the United States regardless of country of ownership.

SOURCES *1971-75—Television Receivers, Color and Monochrome, Assembled* or *Not Assembled,* F/n/shed or *Not F/n/shed, and Subassemblies Thereof* ('Washington, D. C." U.S. International Trade Commission Publication 808, March 1977), p. A-59
1977-80—Television Receiving Sets From Japan (Washington, D.C: U S. International Trade Commission Publication 1153, June 1981), pp A-53, A-56,
1981 and revised 1979—Color Television Receivers: Quarterly Profits and Capacity and Certain Annual Expenditures of U S Producers (Washington, D.C.: U S. International Trade Commission Publication 1235, March 1982), table 1

Figure 19.— Price Index for TVs Compared to All Consumer Durables



SOURCES *Consumer Durables—Economic Report of the President 1982* (Washington, D C U S Government Printing Office February 1982), p 294
Televisions —Electronic Market Data Book 1982 (Wash ington, D C Electronic Industries Association 1982), p 29

the competitive forces at work. Fierce price competition has been a characteristic of the TV industry in the United States for many years.

This competition has led rather directly to major structural change in the U.S. industry: replacement of American-owned by Asian- and European-owned production facilities. Japanese and Taiwanese companies that previously exported to the United States have established assembly operations here; foreign interests have also purchased existing plants. The OMAs encouraged both types of investments, but at least some would have been made in any case. Sony's factory in San Diego antedates the OMA with Japan by 7 years. Matsushita's purchase of Motorola's Quasar operations came in 1974, and Sanyo's rescue of Warwick Electronics, a primary supplier to Sears, in 1976,

The American TV plants purchased have generally been in competitive difficulty and seeking some sort of financial reprieve. When Motorola decided to leave the consumer electronics business, the company approached both RCA and Zenith before finding a buyer for its Quasar division in Matsushita. North American Philips purchased Magnavox in 1974, while taking over GTE-Sylvania's consumer operations, consisting of the Philco and Sylvania brands, in 1981, Thus, the color TV business has been one in which large foreign

multinationals have absorbed smaller and financially weaker U.S. companies. This is not to say that the U.S. operations of foreign firms have fared much better; they do not seem to have been any more profitable than American-owned TV manufacturers, perhaps less so (table 11 averages profit data for companies with plants in the United States whether American- or foreign-owned).

What are the implications of these changes? On the one hand, foreign takeovers point to the fact that some U.S. companies, for whatever reasons, have simply been unable to maintain their competitiveness. It seems likely that even purely domestic competition would, sooner or later, have led to a series of failures among the smaller American color TV manufacturers, From the point of view of the consumer, that foreign enterprises purchased and modernized these plants has probably yielded a more competitive industry; certainly the concentration has not changed appreciably (the 15 TV manufacturers at present compare with 16 a decade ago), On the other hand, many of the higher skilled jobs remain overseas, along with management control.

The distribution network for TVs has mirrored broader trends in the structure of American retailing rather than changing in any fundamental way as a consequence of foreign competition. Furniture and department stores have become less important as outlets, while sales have increased through appliance and discount retailers, along with chains like Sears and J. C. Penney. These shifts have multiple causes: heightened price competition; changing consumer preferences leading to much greater sales of small, easily portable sets (table 9); improvements in reliability, a consequence of solid-state chassis designs (chs. 3 and 6) lessening the need for after-sales service and repair. The opening of the distribution structure has added to price competition in the TV market.

Imports and Offshore Assembly in Color Television

International trade flows in color TV show two more or less concurrent trends: imports of complete sets into the United States by foreign firms, with subassemblies coming later, accompanied by re-imports from U.S.-owned subsidiaries following offshore assembly.

As table 12 demonstrates, by 1976 one-third of the U.S. color TV market was being supplied by shipments from the Far East. American producers had seen—some had experienced—ear-

Table 12.—Color TV Imports Into the United States

Year	Number of color TVs imported by origin (thousands)				Imports from all sources as a percentage of U.S. consumption
	Japan	Taiwan	Korea	Total[a]	
1967	315	–	—	318	6.7%
1969	879	22	—	912	15.7
1971	1,191	85	–	1,281	18.9
1973	1,059	325	2	1,399	15,8
1975	1,044	143	22	1,215	17.9
1976	2,530	235	47	2,834	33.0
1977	1,975	318	92	2,476	27.0
1978	1,434	624	437	2,775	26.4
1979	513	368	314	1,369	13.6
1980	435	303	293	1,288	11.7
1981	727	514	393	1,946	15.6

[a]Includes imports from countries not listed individually

SOURCES *1967, 1969 — Television Receivers and Certain Parts Thereof* (Washington, D C : U S Tariff Commission Publication 438, November 1971), p A-82.
1971, 1973— *Television Receivers, Color and Monochrome, Assembled or Not Assembled, Finished or Not Finished, and Subassemblies* Thereof (Washington, D C U S International Trade Commission Publication 808, March 1977), pp. A-W, A-99.
1975.79-Co/or Television Receivers and Subassemblies Thereof (Washington, D C U S International Trade Corn. mission Publication 1088, May 1980), p D-6.
1980—Television Receiving Sets From Japan (Washington, D C U S. International Trade Commission Publication 1153, June 1981), p H-21
198f-information from Department of Commerce

lier incursions in portable radios and monochrome TVs; as early as 1970, half the black-and-white sets sold in the United States were imports. The sentiment in the U.S. industry was that if import trends in color TV continued this far more lucrative market would also be taken over.

It makes little difference now whether or not such perceptions were accurate: increasing import penetration was the proximate cause for negotiation of the 1977 OMA with Japan. But what table 12 also shows is that no sooner did imports from Japan drop—in 1978—than imports from South Korea and Taiwan jumped, Although taking a slightly smaller fraction of the market, the number of imported color TVs actually grew in 1978. Only in 1979, when quotas with Taiwan and Korea took effect, did the import share come down.

This period, the late 1970's, coincided with the beginning of large-scale Japanese production here; color TV output in the United States by Japanese-owned firms went from 1.2 million sets in 1977 to 3,2 million in 1980—mostly final assembly operations which substituted imports of components for imports of complete sets. As table 13 shows, not only have subassemblies gone from half of all color TV-related imports by value to more than three-quarters, but *the total value of color TV imports including sub assemblies increased, despite the OMAs,* (Imports of incomplete TVs—as well as certain types of subassemblies —were restricted by the quotas, and remained small, but other subassemblies were uncontrolled.)

Table 13.—U.S. Imports of Complete Color TVs Compared to Incomplete TVs and Subassemblies

	Value of imports (millions of dollars)		
	1976-"	1978	1980
Complete color TV receivers	$ 520	$ 577	$ 311
Incomplete receivers and subassemblies[a]	527	748	1,112
	$1,049	$1,335	$1,427

[a]More than 98 percent subassemblies mostly circuit boards and picture tubes Incomplete sets are valued at only a few million dollars annually

SOURCE *Television Receiving Sets From Japan* (Washington, D C U S International Trade Commission Publication 1153 June 1981) pp H 20 H 22 H-23

The second major effect on the import side of the ledger has been the rising quantity of what are known as 807 imports. There are certain conditions to be satisfied—described in chapter n-but in essence item 807.00 of the U.S. Tariff Schedules allows an American company to export components for further processing abroad, then re-import them while paying duties only on the value added in the offshore facility, Absent this provision, tariffs would be assessed on the total value of re-imported goods. Labor cost savings have been the primary reason for moves offshore, with item 807 making the choice more attractive. In most cases, final assembly has remained here. All the major U.S. color television manufacturers have taken advantage of item 807 in their efforts to keep labor costs down, with Zenith being the last to moves

Table 14—which includes black-and-white TVs, although these are small compared to 807 imports of color sets—shows that offshore assembly and re-importation account for a substantial fraction of imports. In 1980, 44 percent by value of all U.S. imports of TVs and subassemblies entered under the provisions of item 807,00. (This does not mean that 44 percent of the value was added overseas, but that 44 percent of imports had *some* value added in other countries after originating here, In 1980, foreign value added came to about 11 percent of the total value of all imports,) As table 14 indicates, Mexico accounts for the majority of 807 imports, with Taiwan in second place. Mexico is unique in being almost exclusively an offshore assembly site for U.S. firms, which operate factories close to the border. The concurrent trends of foreign investment in U.S. plants and American investment in offshore produc-

[5]Zenith's decision to transfer much of its production to Mexico and Taiwan, entailing layoffs to more than 5,000 U.S, workers, came at the end of 1977—"Sltuation Report: color Television, " Department of Commerce, May 1978, p.4. The company evidently judged both the risks and costs of moving offshore to be less than for automation of its domestic production facilities. App. B discusses the costs and benefits of offshore manufacturing from an economic perspective.

Item 806.30 of the U.S. Tariff Schedules permits re-importing with duties charged only on foreign value added under a

Table 14.—Imports of Color and Monochrome TVs, Plus Subassemblies, Under Item 807.00 of the U.S. Tariff Schedules[a]

Source	Value of imports (millions of dollars) 1976	1978	1980
Japan:			
Total imports from Japan[b]	$ 666	$ 627	$ 435
807 imports[b]	0.6	3.6	5.7
Taiwan:			
Total imports from Taiwan	287	416	*354*
807 imports	150	184	*169*
South Korea:			
Total imports from Korea	36	137	164
807 imports	0.5	—	1.5
Mexico:			
Total imports from Mexico	261	348	536
807 imports	257	347	513
Singapore:			
Total imports from Singapore	25	77	185
807 imports	5	17	64
Other countries:			
Total imports	29	81	94
807 imports	15	60	26
All sources of imports:			
Total imports	1,304	1,687	1,770
807 imports	428	611	780
807 as percent of total	32.80/o	36.20/o	44.1 %

[a] Breakdowns for color and black.and.white sets covering subassemblies (and incomplete sets) are not available; however, the vast majority of 807 imports are color subassemblies—mostly circuit boards.
[b] Total import figures consist of the value of all imports entering from the source country; *807* imports consist of the total value of imports entering under item 807.00 from the source country, not the duty-free value, which is only a fraction of this Greater detail is available in the report cited below.

SOURCE" Television Receiving *Sets From Japan* (Washington, D.C.U.S International Trade Commission Publication 1153, June 1981), p. H-30

somewhat different set of conditions than for item 807.00. For practical purposes, 806.30 imports of televisions are negligible.

The table below lists several offshore plants operated by American firms, indicating the kinds of products that are shipped to the United States—mostly components and subassemblies for color sets; some black-and-white TVs are made overseas, but few complete color sets. North American Philips has also established overseas facilities.

Offshore Manufacturing Plants of Major U.S. TV Manufacturers[a]

Company	Location	Year established	Products
General Electric	Singapore	1988	TV parts and subassemblies
RCA	Taiwan	1969	TVs, subassemblies, parts
	Mexico	1969	Subassemblies
Zenith	Taiwan	1971	Complete monochrome TVs; circuit boards, parts, subassemblies for color TVs
	Mexico	1978	Circuit boards, parts, subassemblies, chassis

[a] Because of the fluidity of offshore manufacturing activities, the information in this table is not necessarily complete or current.

SOURCES Annual reports, R. W Moxon, "Offshore Production in the Less-Developed Countries by American Electronics Companies, " DBA thesis, Harvard University, 1973

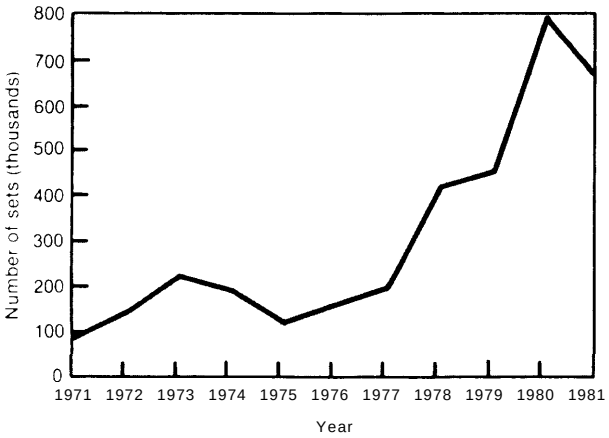
tion have caused the rapid shift in composition of U.S. color TV imports toward components and subassemblies illustrated in table 13.

U.S. consumer electronics manufacturers have been able to reduce production costs through offshore assembly. To the extent that their ability to remain competitive has depended on transferring some operations abroad, American workers have lost job opportunities. On the other hand, a total collapse of color TV production in the United States would have cost more jobs—a point explored in greater depth in chapter 9 as well as appendix B.

Exports

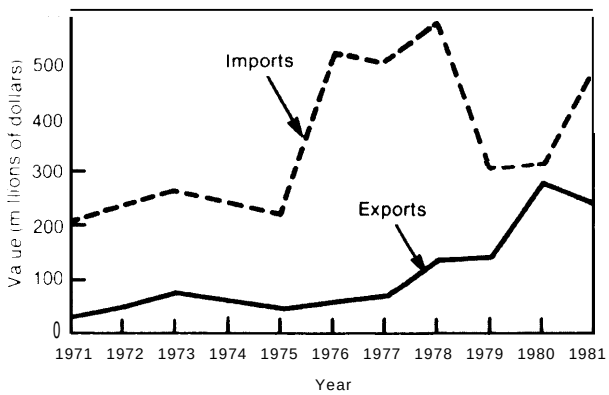
Despite the large negative U.S. trade balance in consumer electronics—which, depending on year and the definitional bounds employed, has been in the range of $3% billion to $6 billion annually—and the continuing pressure generated by imports, the U.S. industry has managed to export growing numbers of color TVS. Figure 20 shows the export trend in numbers of color sets, while figure 21 compares imports

Figure 20.— U.S. Exports of Color TV Receivers



SOURCES *1971*- 79— *Color Television Receivers and Subassemblies Thereof* (Washington D C U S International Trade Commission Publication 1068 May 1980), p A 25
1980, 1981 — *Electronics Foreign Trade Five Year Summary 19771981* (Washington, D C Electronic Industries Association, March 1982), pp. 38, 50

Figure 21 .—U.S. Exports and Imports of Color TV Receivers (complete sets only)



SOURCE *Consumer Electronics Annual Review* (Washington D C Electronic Industries Association, 1982), p 37

and exports of complete TVs in terms of value. Two-thirds of U.S. color TV exports have recently gone to Latin American countries, in **a** number of which color broadcasting has only recently begun.[6]

[6] 1981 U.S. industrial *Outlook* (Washington, D. C.: Department of Commerce, January 1981), p. 441. The remainder are sold mostly in Canada. No information is available on the fraction of exports originating with the U.S. operations of foreign-owned firms.

The Japanese Consumer Electronics Industry

The market for consumer electronics in Japan is now second only to that in the United States, with 1982 sales of $10.9 billion, about half the level here.[7] This was certainly not always the case; in 1965, when U.S. output was approaching 3 million color TVs, Japan produced less than 100,000. How did the Japanese consumer electronics industry grow in size and competitiveness so that it could ship more than a million color sets to the United States by 1971 (table 12)–at which time Matsushita was already the largest consumer electronics producer in the world?

Early Development

In fact, the United States had a good deal to do with the development and expansion of Japan's consumer electronics industry.[8] After World War II, the Japanese economy was in shambles. The government could not stimulate developments in electronics through defense spending, but had clearly decided by the end of 1953—when television broadcasting began in Japan—to promote consumer electronics as a road to overall strengthening of the industry. In November of that year, the Ministry of International Trade and Industry (MITI) announced a policy aimed at increasing production capacity for TVs. One step was to restrict imports. The government also encouraged acquisitions of foreign technology, most of which came from American firms.

[7] *Electronics*, Jan, 13, 1983, pp. 136, 154. While other sources—defining consumer electronics more or less inclusively–give different magnitudes, the relative sizes of the U.S. and Japanese markets remain about the same. The figures cited later in this paragraph come from *The U.S. Consumer Electronics Industry* (Washington, D. C.: Department of Commerce, September 1975), pp. 20 and 24, and "International Technological Competitiveness: Television Receivers and Semiconductors, draft report CRA 425 prepared by Charles River Associates, Inc. for the National Science Foundation under NSF grant No. PRA 78-20301, July 1979, p. 2-19.

[8] Much of the material that follows is drawn from "Sources of Japan's International Competitiveness in the Consumer Electronics Industry: An Examination of Selected Issues, " prepared for OTA by Developing World Industry and Technology, Inc. under contract No. 033-1010. o.

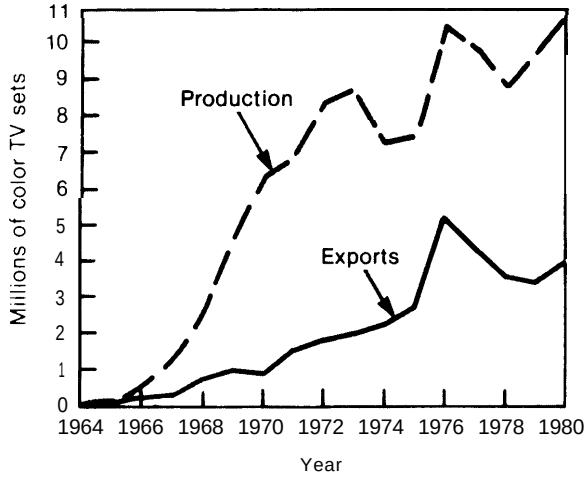
U.S. servicemen stationed in Japan after World War II and during the Korean War proved an attractive market for Japanese consumer electronics manufacturers. Both fledgling companies like Sony and larger firms with prewar roots like Matsushita swiftly expanded their outputs of radios and audio tape recorders. Sometimes U.S. products brought to Japan by servicemen were reverse-engineered. By the mid-1950's, production was growing at very high rates; Japan's output of TVs doubled from 613,000 sets in 1957 to 1.2 million the next year, reaching 2.8 million in 1959.[9]

High-volume production of color sets began in 1964, spurred by the televising of the Tokyo Olympics. Exports followed, as shown in figure 22, with a large though variable fraction—in some years as much as half—of Japan's color TV production shipped abroad. During the 1960's, almost all these exports were destined for the United States, many to be sold by private brand retailers such as Sears; by the turn of the decade, Japan was producing as many color TVs as were made here. More recently, Japanese firms have also shipped large numbers of TVs to Western Europe and other parts of the world; in 1977, 95 percent of Japan's color TV exports reached the United States but 3 years later half were shipped to other Asian nations, Canada, and Western Europe—another consequence, at least in part, of the OMA limiting Japan's access to the U.S. market.

Within Japan, consumer electronics firms have competed strongly among themselves. Although the larger, more diversified enterprises—well-known companies like Matsushita (which markets in the United States under Panasonic, Quasar, and National brand names), Hitachi, and Sony—have had secure positions for many years, smaller firms have come—and mostly gone—depending on economic conditions and technological or market opportunities. The number of companies making radios in Japan dropped from 80 in 1948 to 18 in 1950. The more than 30 entrants in the

[9]"Fifty Years of Japanese Broadcasting, " Japan Broadcasting Corp., Radio and TV Culture Research Institute, 1977, p. 227.

Figure 22.—Japanese Production and Exports of Color TV Receivers



SOURCES *Exports-1964.67-Japan Economic Yearbook, 1968,* p 171
1968.70–Japan Economic Yearbook, 1971, p 208
7971.75–Japan Economic Yearbook, 1976/77, p 133
1976—Japan Economic Journal, February 15, 1977, p 8
Production—7962.70-Japan Economic Yearbook, 1971, p 289
1971.75–Japan Economic Yearbook, 1976/77, p 215
7976–Japan Economic Journal, February 15, 1977, p 8
***Exports and production—1977.79–Japan** Economic Yearbook 1980/81, p* 125
*Exports **and product/on—1980—Japan** Electronics Almanac **1982*** (Tokyo Dempa Publications. Inc , 1982) p 129

TV market in the early 1950's were likewise quickly winnowed down by competitive forces; after a decade, virtually all of Japan's output of TVs was accounted for by the top 10 manufacturers.[10] At present, the Japanese TV industry is dominated by a few large vertically integrated firms which make many of their own components. Some of these firms also manufacture broad ranges of other electrical and electronic products—e.g., semiconductors, computers. Matsushita, the largest in terms of consumer electronics sales, has held around 30 percent of the Japanese color TV market in recent years.

Japan's consumer electronics firms based many of their product developments on technologies developed first in the United States. From 1960 through 1967 alone, Japanese com-

[10]*Gijutsu Donyo no Genjo to Kongo no Mondai (Technological* Imports and Future Problems] (Tokyo: Ministry of International Trade and Industry, 1963), pp. 723-725. The number of color TV manufacturers in Japan has continued to decrease, from 22 in 1963, to 15 in 1972, to 11 in 1978—"Sources of Competitiveness in the Japanese Color Television and Video Tape Recorder Industry, " Developing World Industry and Technology, Inc., for the Department of Labor, Oct. 16, 1978, p. 100.

panies negotiated nearly 200 licensing agreements with RCA.[11] Until the 1970's, most of the flow of TV technology into Japan contributed to incremental improvements in existing products and processes. At the same time, Japanese companies actively sought more advanced technologies, realizing that imitation and refinement could only take them so far. Sony, for example, took out a license from Western Electric covering transistor technology in 1954; 10 years later, Toshiba was negotiating to purchase video tape recorder technology from Ampex.

Government Supports

While the aid given consumer electronics by Japan's Government–through policies encouraging exporting as well as protection from outside competition—has helped the industry, Japanese industrial policy, here as elsewhere, has been more notable for careful targeting of critical areas than for the overall magnitude of assistance. The success stories of individual firms reveal a host of factors contributing to growth, only one of which is government support. Continuing attention to manufacturing technologies, reduced costs through economies of scale and rapidly increasing productivity, innovative product designs and marketing strategies, home-grown R&D—all have made contributions.

MITI's role—discussed more extensively in chapter 10—is not restricted to supporting the industry. Faced with the 1977 OMA, it was MITI that allocated export quotas among Japanese TV manufacturers. Earlier the agency not only set price levels for exports to Western Europe, aiming to alleviate protectionist pressures, but in 1974 negotiated a quota on shipments.[12] In the wake of the increasing difficulty Japanese TV manufacturers faced in exporting, the ministry established a Plant Export Policy Committee intended to guide and encourage overseas investment. It is no surprise that when Japanese consumer electronics firms have been accused of price-fixing and other unfair trade practices, the allegations have often focused on MITI as coordinator.[13]

Industrial Structure

The three-tiered structure that characterizes many Japanese industries—large end-product manufacturers supplied by an array of small firms, many of them affiliates, the third tier consisting of even smaller suppliers and subcontractors—is found in consumer electronics as in the Japanese electronics industry at large. The structure differs from that of other countries mostly in that second- and third-tier firms tend to be more closely linked to end-product manufacturers, the links ranging from longstanding buyer-seller relationships to partial ownership. According to many Western observers, relationships between vendor and vendee—which tend to be arms-length in the United States, typified by hard bargaining over price—are more cooperative and supportive in Japan. Moreover, the second- and third-tier firms act as "shock absorbers" over the course of the business cycle, being the first to hire or fire and thus adding to the flexibility of the system. * Japanese firms are said to gain a variety of advantages compared to American companies, even where the latter, on the usual quantitative measures of vertical integration, exhibit a greater degree of internal production and value added. Of course, just as in the United States—where Zenith's component production is smaller than RCA's—Japan's consumer electronics producers differ significant-

[11] See "Sources of Japan's International Competitiveness in the Consumer Electronics Industry: An Examination of Selected Issues," op. cit., app. D, for a list. RCA established a small engineering laboratory in Tokyo as early as 1954, primarily to assist its licensees.

[12] *Television Digest*, June 27, 1977, p. 7.

[13] See, for example, J. Nevin, "American-Built Consumer Electronics: Can the Species Be Saved?" Appliance *Manufacturer*, February 1977, p. 74. At the time, Nevin was president of Zenith.

* Discussion of ties among purchasers, suppliers, and affiliates in Japan suffers from an unfortunate lack of empirical analysis; as a result, it is difficult to evaluate these arrangements, particularly from the viewpoint of the economy as a whole rather than the corporations which have developed them. On employment stability and layoffs in Japanese companies, see ch. 8.

ly in effective levels of integration. Matsushita makes perhaps 90 percent of its own TV components; worldwide, only Philips, the Dutch multinational, comes close to this figure. *A

Names like Sony, Pioneer, and Toshiba have now become well known in the United States, indeed throughout the world. Many of these corporations are not only integrated in consumer electronics but highly diversified. Mitsubishi makes cars, steel, and ships as well as a wide range of consumer products. Yamaha builds pianos and motorcycles along with stereo equipment, Companies like Matsushita and Hitachi are leaders in home appliances; the latter, frequently compared to GE, gets about 20 percent of its sales in consumer goods ranging from TVs and stereos to washing machines. Hitachi is also a major producer of computers and semiconductors, as well as heavy machinery, both electrical and nonelectrical.[15] Even at Sony, revenues from TVs account for only about a third of sales, with another third from other consumer electronics products.[16] In part because of their diversified businesses, Japanese consumer electronics manufacturers—more so than most of their American counterparts—had begun to design and manufacture their own semiconductors by the 1960's; even today, half of Japan's output of microelectronics devices goes into consumer products, versus only 15 to 20 percent in the United States.

As early as 1971, 5 of the 10 largest consumer electronics producers in the world were Japanese, led by Matsushita and including Hitachi, Toshiba, Sony, and Mitsubishi. The Japanese consumer electronics industry was already considerably larger than the American, with more than twice as many employees and—although productivity had not yet reached the U.S. level—a much higher rate of growth in output per man-hour.[17] The larger Japanese consumer electronics firms have by now become true multinationals; not only do 7 of Japan's 11 color TV manufacturers operate plants in the United States, Japanese companies manufacture TVs in countries such as West Germany, Spain, and the United Kingdom, along with developing nations in Asia and South America. Matsushita has approximately 40 manufacturing plants outside Japan, mostly in developing countries. Sanyo and Matsushita are the leaders in foreign investment, with each accounting for about $1.5 billion in overseas production during 1980, much of this in other Asian nations.[18]

Japan's dominance of consumer electronics—now global though facing increased challenges from other Asian countries—extends well beyond TVs; Japanese corporations account for about 60 percent of world production of audio equipment, as well as virtually all VCRs. Philips is the only non-Asian company with its own technology for consumer VCRs—a product which, after a very long gestation period in the R&D laboratories of several Japanese companies, notably Sony and Matsushita (see ch. 5), was initially slow to find a a market. Now that sales are booming, Japanese firms are reaping the dividends, building virtually all their VCRs at home and exporting about 80 percent of them.[19] In this new generation of consumer products, Japan has taken a leadership position—although their designs were originally based on American technology, they have been through several generations of

[14] "Sources of Competitiveness in the Japanese Color Television and Video Tape Recorder Industry, " op. cit., p. 148.

[15] N. Pear] stine, "That Old Nobushi Spirit, " *Forbes*, July 23, 1979, p. 42.

[16] "Sources of Competitiveness in the Japanese Color Television and Video Tape Recorder Industry, op. cit., p. 143; "Sony Heads Back to Broadcast Market, " *Electronics*, Mar. 27, 1980, p. 98.

[17] *The U.S. Consumer Electronics Industry,* op. cit., Pp. 24, 26. From 1972 to 1976, employment in TV manufacturing in Japan declined by almost half although output grew substantially—"Colour Television: Japan's Global Strategy Adapts to New Realities, Part II, " *Multinational Business, No.* 4, 1978, p. 18,

[18] J. Marcom, Jr., "Japanese Consumer Electronics Firms See Room To Expand Plants in Southeast Asia, " *Asian Wall Street Journal Weekly*, Mar. 1, 1982. Total production outside Japan in 1980 for the five largest Japanese consumer electronics firms came to about $4,3 billion.

"'Stagnant Export Industries Outlined, " *Japan Report,* Joint publications Research Service JPRS 1./10639, July 7, 1982, p. 56. Japan's estimated 1982 production of VCRs was 12.2 million units, with 9.7 million scheduled to be shipped abroad. Two Korean firms also build VCRs.

independent development already—rather than following behind American or European firms as had been the case with TV receivers.

Consumer Electronics in Western Europe

Table 15 compares relative sizes, as of 1978, of color TV manufacturers with headquarters in various parts of the world, While production levels will have changed, it is unlikely that positions have altered greatly except in the case of Philips—which, with the acquisition of GTE-Sylvania's TV operations by Magnavox in 1980, has probably moved into first place. Note that among the lower volume producers of TVs lumped under the "other" category are a number of large, diversified concerns with relatively small consumer electronics operations—e.g., General Electric.

The 13 color TV producers listed in table 15 include 5 Japanese companies, 3 American (of which only 2 now remain), and 5 European (counting ITT in this category)-–the latter all rather small except for Philips. The Dutch-based multinational has been a dominant force in European consumer electronics markets for years, but in color TV as in electronics as a whole the European industry includes many small-scale producers; more than 30 in the case of TVs. This dispersion of production capacity mirrors the relatively isolated markets that continue to characterize Western Europe a quarter-century after the establishment of the European Economic Community (EEC).

Table 15.—Worldwide Production of Color TV Receivers by Firm, 1978

Company	Headquarters	Annual production (millions of color TVs)
Matsushita, ...	Japan	3.60 (12.50/o)
Philips [a]	Netherlands	3.50 (12.1 %)
RCA	United States	2.00 (6.90/o)
Zenith	United States	1.97 (6.8%)
Sanyo	Japan	1.95 (6.8°/0)
Sony	Japan	1.70 (5.9%)
Toshiba	Japan	1.50 (5.20/o)
Grundig	West Germany	1.40 (4.80/o)
Hitachi	Japan	1,25 (4.3°/0)
GTE-Sylvania [a] . . .	United States .	1.20 (4.2%)
AEG-Telefunken . .	West Germany	0.98 (3.4%)
Thomson-Brandt .	France	0.94 (3.3%)
ITT [b]	United States	0.78 (2.7%)
Other		7.10 (24.60/o)
		28.9 million

[a] Figures for Philips Include Magnavox but not GTE Sylvan la, whose U S TV facilities were purchased by Magnavox in 1981 Saba, a German TV producer was sold by GTE to Thomson Brandt the same year

[b] ITT is an American based conglomerate that produces televisions in Europe but not the United States

SOURCE *Financial Times* Nov 18 1980

As a whole, the European consumer electronics market is nonetheless large. Table 16 gives approximate 1982 sales by major product category for the United States, Japan, and Europe. European consumers buy more TVs and VCRs than Americans, and almost as much audio equipment (radios, stereos, etc.).[20] Only in the "other" category of table 16 is the U.S. market much larger—a reflection of affluence and appetite for products like electronic toys and games; Americans bought more than 10 times as many toys and games as Europeans last year,

In contrast to the color TV markets of the United States and Japan, where most sales are replacements or additional sets, only about 60 percent of Western European households have color sets. In some countries—even France—the penetration is far less. While these large and still-expanding markets have attracted non-European firms, importers have faced an uphill battle; local producers are shielded by an array of trade barriers, with broadcasting standards the strongest,

Technologies for receiving European broadcast signals—particularly the PAL (Phased Alternating Line) system used everywhere except in France—are covered by a wide array of patents. Initially, the owner of the PAL patents, the West German firm AEG-Telefunken, refused licenses to all Japanese companies, Eventually licenses were granted allowing imports of smaller screen models only, or local production by Japanese manufacturers.[21] In ad-

[20] West Germany is the la rgest country market, absorbing 2.6 million color TVs in 1979. Sales in Italy during 1 979—where color broadcasting beg. a nonly 3 years earlier—totaled 1.9million sets, while consumers in the United Kingdom bought 1.8million and i n France 1.5 million The 1979 figure for the U n ited States was about 10 m i l l I o n, slightly below total l European sales of 10.5 m i l 11(I n, See *Financial Times*, Nov 1 8, 1980, *p.* 18.

[21] In the [J n i t e d K i n g d o m, for exa m p l e, sets with scree 11 s i z e s over 20 inches ca n not be i mported from Japa n. " Sectoral Study

Table 16.—Consumer Electronics Markets in the United States, Europe, and Japan

	1982 sales (billions of dollars)					
	Color TV	Monochrome TV	Video cassette recorders	Audio equipment	Other	Total
United States	$4.4	$0.5	$1.3	$5.7	$9.5	$21.4
Europe	5.0	0.4	2.4	5.2	1.5	*14.5*
Japan	2.6	0.02	1.8	*3.6*	*2.9*	10.9

SOURCES: *Electronics,* Jan. 13, 1963, pp 136, 146, 154; Mar. 10, 1963, p. 8.

dition to the protective effect of broadcast standards and patent licenses, tariffs into the EEC are relatively high—14 percent for color TVs—while value-added taxes can be as much or more. Some European countries have, from time to time, also adopted import quotas.

Just as they did in the United States, Japanese color TV manufacturers have established European production facilities to circumvent market restrictions, Five Japanese firms assemble color sets in Britain either through joint ventures or wholly owned subsidiaries, with much of this output being exported to other EEC countries. [22] Sony was the first to build TVs in the United Kingdom, just as it led the way into the United States; its British plant opened in 1968. While most of the foreign investment in the EEC has flowed to Britain, Japanese firms **have** holdings in countries like Italy and Spain as well—the latter particularly attractive because wage levels are comparatively low.

The first of more than 75 PAL patents lapsed in 1981; all will expire during the current decade. With considerable anxiety, Europe's color TV manufacturers are awaiting stiffer Japanese competition in the lucrative large screen market. For some—i.e., Telefunken, which entered bankruptcy in August 1982 after a period of poor financial performance extending over nearly 10 years—even the protection available in the past has not been enough. [23]

The fragmented character of the industry and market in Europe has created competitive problems for consumer electronics firms that cannot generate the revenues to support ongoing R&D and investments in up-to-date manufacturing facilities. Besides Philips, the principal exception has been the French company Thomson-Brandt, the consumer arm of the Thomson group, Both Philips and Thomson have recently moved to increase the scale of their European operations, aiming to position themselves for competition with the Japanese. Philips has solidified its ties with the West German firm Grundig—of which it purchased a 25-percent share in 1979—in part through joint efforts to improve the Philips VCR system.[24] Thomson-Brandt—although losing money in recent years—invested more than $150 million between 1978 and 1980 in acquisitions of West German consumer electronics firms.[25] The company's aim—which the French Government actively supported even before Thomson was nationalized under Mitterrand—has been

No. 2: Transfer of Technology in the Consumer Electronics Industry-The Television Sector," Organization for Economic Cooperation and Development, Paris, Sept. 14, 1979, p. 16. Korean firms have been denied PAL licenses of any type.

Color broadcasting in the United States, Japan, and South America is based on the NTSC (National Television System Committee) system, developed here and approved in 1953 by the Federal Communications Commission after several years of controversy—" In the Wake of the Transistor," *Electronics,* Apr. 17, 1980, pp. 281, 284. France has its own SECAM (Sequential and Memory) system, also used in Eastern Europe.

[22] The companies are Sony, Matsushita, Toshiba, Mitsubishi, and Hitachi—''Sources of Japan's International Competitiveness in the Consumer Electronics Industry: An Examination of Selected Issues, " op. cit., pp. 124-125.

[23] See, for example, "Germany's Telefunken Insolvent: Huge Concern Discloses Debt of $1.84 Billion, " *New York Times,* Aug. 10, 1982, p. D1. The company had not paid dividends since 1974.

"''Philips: An Electronics Giant Rearms To Fight Japan, " *Business Week* Mar. 30, 1981, p. 86. A major difference between Philips' strategy and that of Japanese color TV manufacturers like Toshiba or Matsushita has been the siting of foreign manufacturing facilities. Almost all of Philips' operations are in industrialized countries, mostly in Europe (North American Philips is legally independent although closely tied to the Dutch firm]. In contrast, Japanese companies have moved aggressively into developing country markets.

[25] J. Tagliabue, "Europeans Battle Japanese TV Tubes, " New *York Times,* Feb. 10, 1982, p. D4.

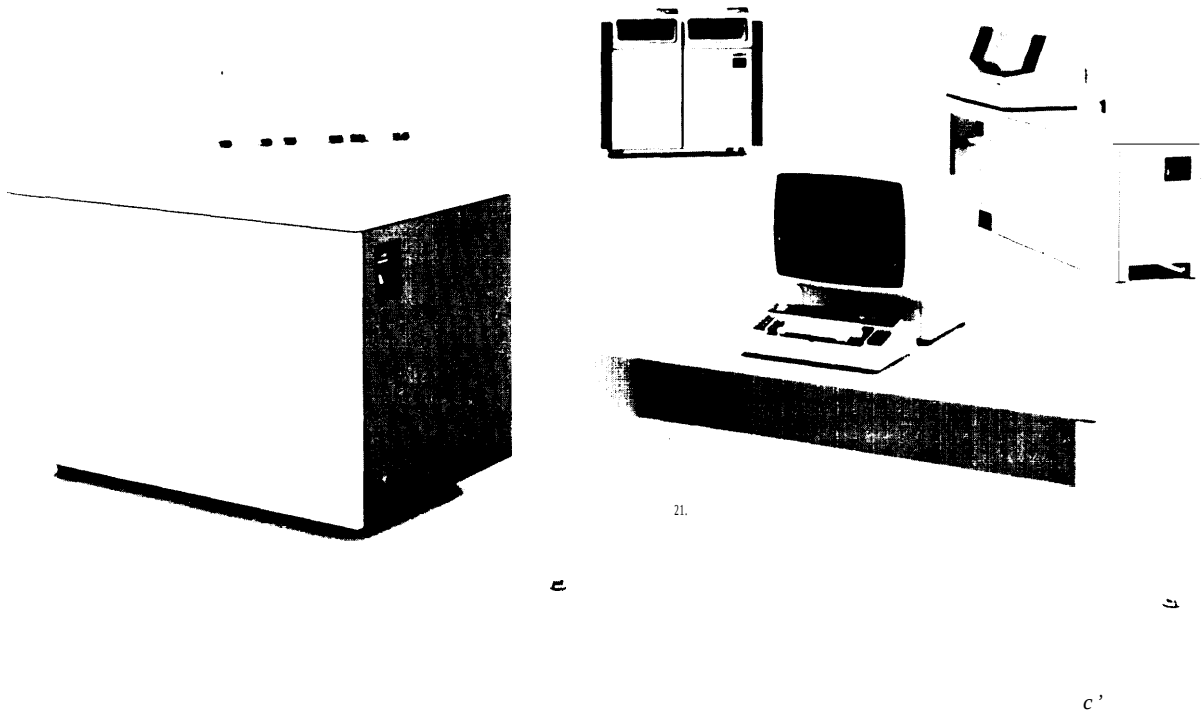


Photo credit: IBM

Small general-purpose computer system

to expand from its base in France to other parts of Europe.

In common with major Japanese producers, the larger European electronics manufacturers tend to be diversified. Philips makes computers and semiconductors, as does the largest of the West German entrants, Siemens—although Siemens has only a small consumer electronics business. Table 17 illustrates something of this diversification. The table ranks firms by sales in electronics—worldwide sales for European companies, sales only in Europe for American producers. Note first that U.S. firms have about 30 percent of the total European electronics market—mostly in computers, semiconductors, and other nonconsumer products. No European country can claim a share of total European electronics sales approaching that of the United States.[26] Second, although Japan's electronics manufacturers are perceived as rapidly increasing threats, as yet no Japanese firm has European sales in the top 20. Finally, the the low profit levels of the European companies in the table offer a striking contrast to American corporations like IBM or Xerox. The predominance of computer firms in table 17 demonstrates the size and importance of the information processing market in industrial-

[26] %. de Jonquieres, "U.S. Dominates Europe's Electronics Markets," *Financial Times*, July 9, 1982, p. 7. Twenty-eight of the hundred largest firms ranked by electronics sales (defined as in table 17) are American. Sales for the 28 American companies came to $31.5 billion, with West German companies following at $19.2 billion; the top 100 firms had sales totaling $100 billion. Figures for the United Kingdom and France came to $12.3 billion and $11.3 billion, respectively. Japanese companies did $3.7 billion of business in Europe. (The totals are annualized for slightly different periods within the calendar years 1980 and 1981.)

Table 17.—Electronics Firms Ranked by European Sales[a]

Company	Headquarters	Electronics sales (billions of dollars)	Electronics as a percent of total company sales	Pre-tax profits as a percent of sales
Philips .,	Netherlands	$11.1	600/0	1.9 "/0
IBM	United States	9.4	99	22.5
Siemens	West Germany	8.7	49	5.0
ITT	United States	8.6	50	6.7
Thomson	France	6.5	75	3.1
GEC[b]	United Kingdom	3.8	47	13.7
AEG-Telefunken	West Germany	2.9	36	(1.9)[c]
Ericsson	Sweden	2.0	70	7.7
CGE	France	1.9	18	6.3
Xerox	United States	1.9	80	16.5
Olivetti	Italy	1.7	68	6.8
Plessey	United Kingdom	1.7	85	10.0
ICE	United Kingdom	1.7	100	3.5
Grundig	West Germany .	1.5	100	(5.4)[c]
CII-Honeywell Bull	France	1.5	100	3.4
Thorn-EMI	United Kingdom	1.5	27	4.2
Bosch	West Germany	1.4	21	6.0
Hewlett-Packard.	United States	1.1	100	16.9
Racal	United Kingdom	1.1	90	13.6
Honeywell	United States	1.1	100	8.2

[a]The figures and rankings are for electronics sales only, but include electronic products of all types. For European firms, worldwide sales are listed; for American companies, only sales within Europe—whether through local production or imports. Sales figures are on an annualized basis but cover slightly different time periods between January 1980 and June 1981.
[b]The British General Electric Co. (GEC) is not related to the American firm of the same name.
[c]Loss.

SOURCE: G. de Jonquieres, "U S. Dominates Europe's Electronics Markets," *Financial Times*, July 9, 1982, p 7 Based on "Mackintosh European Electronic Companies File, 1981-82 "

ized economies. Not only do IBM, Hewlett-Packard, and Honeywell get much of their European revenues from computer sales, but several European companies in the table—ICL, CII-Honeywell Bull—are primarily computer manufacturers. Siemens and Olivetti are more diversified, but also among the larger European suppliers of data processing equipment.

Consumer Electronics in Other Parts of the World

A number of developing Asian economies have already established themselves as significant competitors in the global market for electronic products: Taiwan, South Korea, Hong Kong, and Singapore all have rapidly growing industries. The capabilities of each differ, as do the roles their governments have played. Generally, manufacturers in these countries are still concentrating on consumer electronics (see ch. 10, table 79), although clearly intending to move toward more advanced products, including semiconductors and computers; in essence, they are following the Japanese model. Only Taiwan and Korea have locally owned TV industries of any size. Hong Kong and Singapore have been effective competitors in calculators, electronic watches, and toys and games; Hong Kong's $2.6 billion in electronics exports during 1980 were split approximately 70:30 between consumer products and components.[27]

Japanese firms have invested extensively in TV production facilities in other Far Eastern nations, as have American manufacturers and a few European companies (Thomson-Brandt has a color TV plant in Singapore). RCA transferred some of its color production to Taiwan as early as 1969. By the time Rockwell's Admiral division left the business at the end of 1978, all of its TV production had been moved to Taiwan; the facilities were sold to a Hong Kong-based conglomerate.[28] Although U.S. companies have not invested in Korean consumer electronics plants, Matsushita began

[27]R. Neff, "Hong Kong Prepares To Change, " *Electronics*, July 14, 1982, p. 124.
[28]*Television Receiving Sets From Japan* (Washington, D. C.: U.S. International Trade Commission Publication 1153, June 1981), p. A-21.

to ship color TVs from Korea to the United States in the mid-1970's.[29] By the end of the decade, Japanese electronics firms relied on subsidiaries or subcontractors in other Asian nations for two-thirds of their production of radios, 40 percent of their black-and-white TVs, and more than a quarter of their audio tape recorders. so In turn, Japan supplied electronics manufacturers in the rest of Asia with about 70 percent of their ICs and other high-technology components.

Wage Rates and Investment

Chief among the attractions of Asian nations as locales for foreign investment have been low wages, Savings in labor costs have drawn both Japanese and American firms making consumer electronics and semiconductor devices, As the economies of these countries develop, wage rates go up; table 18 illustrates the narrowing gap between Japan and other Asian nations over the period 1975-80, Labor costs in all the countries listed except the Philippines have increased with respect to Japan, but the rise in several of the more advanced economies—Korea, Hong Kong, Singapore—has been particularly steep. All three have been preferred investment sites for Japanese electronics firms, several of whom have responded to wage increases by returning some production to Japan, making extensive use of automated equipment.[31] In comparison to the higher wage countries listed in table 18, the electronics industries in Indonesia and Sri Lanka remain in an early stage of development.

As the patterns outlined above might suggest, foreign investments have made substantial contributions to the development of host country electronics industries.[32] Foreign-owned plants train people who can then staff indigenous companies, as well as nurturing the infrastructure—suppliers, transport facilities, financial institutions, government agencies—needed to support a local industry. Moreover, as the economies of these countries expand, their own electronics markets grow. At present, consumers in Taiwan probably buy more consumer electronic products than those in any Asian country except Japan, with South Korea close behind. Demand should continue to grow rapidly in both Taiwan and Korea; color TV broadcasting–which began at the end of 1980 in South Korea—will be a major spur.

During the 1960's, most of the developing Asian economies pursued policies aimed at attracting outside capital. Several countries later restricted direct investment, but in response to slow economic growth during the latter part of the 1970's often moved back toward selective encouragement. Foreign-owned electronics plants in Asia have typically been built for export rather than local sales; table 19 illustrates the heavy dependence of these countries on exports as well as foreign capital.

Table 18.—Wage Rates for "Skilled" Labor in Asian Countries Compared to Japan

	1975	1980
Japan	100	100
Hong Kong	29	38
South Korea	22	51
Malaysia	20	29
Taiwan	15	21
Singapore	15	32
Philippines	14	12
Thailand	13	17
Indonesia	9	12
Sri Lanka	2	3

SOURCE *Denshi Sangyo no Kokusaika no Hoko to sono Eikyo ni Kansuru Chosa Hokoku* (Survey Report on Trends in the Internationalization of the Electronics Industry and Their Influence, Part II on East and Southeast Asia) (Tokyo Nihon Denshi Kikai Kogyokai (Electronic Industries Association of Japan), March 1981), p. 5

[29] "'International Technological Competitiveness: Television Receivers and Semiconductors, op. cit., p. 2-23.

[30] *Denshi Sangyo* no *Kokusaika no Hoko to sono Eikyo ni Kansuru Chosa Hokoku* (Survey Report on Trends in the Internationalization of the Electronics Industry and Their Influence, Part II on East and Southeast Asia) (Tokyo: Nihon Denshi Kikai Kogyokai (Electronic Industries Association of Japan), March 1981].

[31] J. Marcom, Jr., "Japanese Electronic Firms Cut Reliance On Offshore Plants," *Asian Wall Street Journal Weekly,* Aug. 17, 1981, p.1.

[32] For a case study that describes how technology transfers associated with offshore assembly in Korea helped build the foundation for a domestic industry, see J. N. Behrman and H. W. Wallender (eds.), *Transfers of Manufacturing Technology Within Multinational Enterprises* (Cambridge, Mass.: Ballinger, *1976],* ch.10 on "Motorola -Korea.'

Table 19.—Foreign Capital, Production, and Exports in Asian Electronic Industries, 1979

	Foreign investment as a percentage of total investment in electronics	Total electronics production (millions of dollars)	Exports as a percentage of total electronics production
South Korea	250/o	$3,300	70%
Taiwan	45	3,200	80
Hong Kong	-10	2,000	90
Singapore	80+	1,850	90
Malaysia	90+	990	75
Indonesia	high	540	Not available
Philippines	very high	320	90
Thailand	very high	110	10

SOURCE *Denshi Sangyo no Kokusaika no Hoko to sono Eikyo ni Kansuru Chosa Hokoku* (Survey Report on Trends in the Internationallzation of the Electronics Industry and Their Influence, Part II on East and Southeast Asia) (Tokyo: Nihon Denshi Kikai Kogyokai (Electronic Industries Association of Japan), March 1981), p. 7.

By *1978,* before the OMA, Korea's shipments of color TVs to the United States exceeded 400,000 sets (table 12)—a graphic illustration of expanding scale and rising competitiveness in the country's consumer electronics industry, which, in contrast to that in Taiwan, owed little to U.S. capital (although Japanese investment had been substantial). Following in the footsteps of Japanese and Taiwanese color TV manufacturers, the Korean Gold Star firm has now established U.S. production facilities. Gold Star—a member of the Lucky Group, a large conglomerate—began operations in Alabama during 1982 (table 10), Taiwan's exports of color sets to the United States had, before the OMAs, been even greater than those of Korea. Many of these shipments came from plants operated by RCA and Zenith, who own a considerable fraction of Taiwan's production capacity and who were also restricted by the 1979-82 OMA. Tatung, the country's largest electronics manufacturer, opened the first Taiwanese-owned assembly plant in the United States in 1980, with Sampo beginning production in Atlanta the following year.[33] Such investments are a clear indication that consumer electronics firms in the rapidly industrializing nations will continue their efforts to penetrate U.S. markets.

China has been a major exception to otherwise common trends in the developing Asian economies (also see ch. 10, which compares industrial policies in these countries). The People's Republic has negotiated a number of joint ventures with foreign concerns, most of whom have viewed it as potential market more than potential competitor. Sony, for instance, has announced an agreement with China's National Electric Technology Import Corp. to provide technology and manufacturing equipment for producing VCRs in Beijing.[34] The People's Republic has already become a significant market for consumer electronics products originating elsewhere in Asia; Japanese firms have dominated shipments of black-and-white TVs, with South Korea and Taiwan leading in exports of tape recorders and radios, respectively.[35] American and European firms are also competing for electronics sales in China, though seldom in consumer products.

The Example of South Korea[36]

As the paragraphs above indicate, and as table 19 also shows, South Korea—along with Taiwan—is a leader among developing Asian electronics industries. Government has given

[33] T. Furukawa, "See Taiwan Elect. Growth," *Electronic News,* Dec. 7, 1981, p. W. About half Taiwan's total exports of electronics have been coming to the United States. On Gold Star, see E. Lachica, "Korea's Gold Star Seeks To Make a Name for Itself in the U.S. Television Market," *Asian Wall Street Journal Weekly,* July 5, 1982, p. 8.

[34] N. Hashimoto, "Sony, China To Try A New Approach to Joint Ventures," *Asian Wall Street Journal Weekly,* Jan. 19, 1981, p. 6.

[35] "Chugoku ni Dairyo Yushutsu," (Large-Volume Exports to China) *Nihon Keizai Shimbun,* Jan. 12, 1981.

[36] The information that follows is drawn largely from *Denshi Sangyo no Kokusaika no Hoko to sono Eikyo ni Kansuru Chosa Hokoku* (Survey Report on Trends in the Internationalization of the Electronics Industry and Their Influence, Part II on East and Southeast Asia), op. cit.

local manufacturers considerable assistance since Korea made its first transistor radios in 1950, with the commitment to expansion in electronics strengthening in recent years. During the 1970's, Korea's production of consumer electronics grew at nearly 50 percent per year—table 20. The fraction of total manufacturing output accounted for by electronics swelled, with exports of consumer electronics increasing at nearly 65 percent annually, During the 1980's, production and exports of data processing and telecommunications equipment are expected to grow faster than consumer goods output, components other than microelectronics to decrease (see table 78, ch. 10).

Table 20.—South Korea's Electronics Production

	Output (millions of dollars)			Average annual growth rate
	1971	1976	1980	(1971-80)
Consume; . . ., ...	$ 33	$ 551	$1,148	48.30/,
Industrial [a] ., . . .	19	126	364	38.8
Components	86	745	1,341	35.7
	$138	$1,422	$2,853	40.0
Electronics as a percentage of all manufacturing .	1.40/0	5.60/o	8.5%	

[a]Includes computers and telecommunications equipment

SOURCE *Denshi Sangyo no Kokusaika no Hoko to sono Eikyo ni Kansuru Chosa Hokoku* (Survey Report on Trends in the Internationalization of the Electronics Industry and Their Influence, Part II on East and Southeast Asia) (Tokyo Nihon Denshi Kikai Kogyokai (Electronic industries Association of Japan), March 1981), p 103.

As table 20 indicates, components—many of them produced by the small firms that predominate in Korean industry—are a staple of the nation's output; of roughly 750 Korean electronics firms in 1978, well over half were capitalized at less than $500,000, and about 500 were parts suppliers. [37] As a result, the country is largely self-sufficient in the components needed for production of both color and monochrome TVs, as well as many other consumer products. The chief weakness of the components sector—a weakness shared with other developing economies—has been ICs. Nevertheless, Korean firms have managed to outstrip their rivals elsewhere in Asia, always excepting Japan, in technology and production capacity for microelectronic devices. [38] While most of the semiconductors now made in Korea are discrete devices and small-scale integrated circuits, the Hyundai Group—a large conglomerate—has announced plans for substantial investments in advanced devices, aiming at production of 64K RAMs and other advanced products within a few years.

[37] Ibid., p. 107.

[38] A. Spaeth, "Korea's Electronics Industry Making Rapid Gains in Shift to High-Technology Products," *Asian Wall Street Journal Weekly*, Dec. 20, 1982, p. 1; R. Neff, "Bold Koreans Push Into Leading-Edge ICs," *Electronics*, June 16, 1983, p. 98.

Semiconductors

Technical advances in electronics, as in many other industries, flow in good measure from synergistic relationships among end-product manufacturers and suppliers—here, suppliers of the primary building blocks for electronic systems, semiconductors. IC designs represent direct responses by companies in the merchant industry to perceived needs at the user level. In their turn, semiconductor firms depend on suppliers who design and build the specialized equipment needed for producing ICs—equipment ranging from electron-beam mask-makers and optical wafer-steppers to annealing furnaces (ch. 3). A separate section below is devoted to the equipment industry because of its role in providing the tools that semiconductor manufacturers need to maintain their own technological competitiveness.

American dominance of world semiconductor markets continued through the 1970's without significant challenge, least of all in ICs. Virtually all the major innovations in microelectronics have come from the United States; most foreign producers depended to considerable extent on licensing agreements with American firms. U.S. companies have also supplied world markets directly, through exports or local pro-

duction by subsidiaries, Including captive production and overseas operations, U.S.-owned firms accounted for nearly two-thirds of total world semiconductor output in 1981.[39] Only near the end of the last decade did the situation begin to change, as Japanese enterprises made rapid strides in IC design and production.

If the 1970's represented the zenith, American dominance seems bound to wane during the present decade. There are many signs. First and perhaps foremost is the determination by other governments to contest the U.S. lead in technology (ch. 10). While the results of government-sponsored R&D efforts have been mixed—and no doubt will remain so—such programs, many of which are of substantial if not overwhelming magnitude, demonstrate the importance other nations attach to an independent capability in microelectronics. The many efforts by foreign enterprises to tap the U.S. technology reservoir through investments in American firms are another sign. Still more tangible evidence that the current decade will not duplicate the 1970's comes, not surprisingly, from Japan. Partly as a consequence of government-subsidized research efforts, as many as six Japanese companies have demonstrated their ability to compete successfully in the design and production of sophisticated ICs—most notably, memory chips such as dynamic RAMs. Although the range of products in which the Japanese are strong is fairly narrow, they are quickly broadening their product lines. For U.S. manufacturers, the competitive situation in the 1980's differs substantially from that to which they had grown accustomed.

The Semiconductor Industry in the United States

Growth continues to be a major descriptor of the U.S. semiconductor industry. Output in the United States, including exports and production consumed internally, has gone from about $600 million in 1960 to $9.5 billion in *1982;* the average annual increase, nearly 14 percent, has been well above the 9 percent (in current dollars) average for the gross national product.[40] Output in 1983 is projected to reach $11.3 billion.

Demand in the rest of the world has also expanded at high rates. Table 21 compares sales in the major markets—the United States, Western Europe, and Japan—for 1974 and 1982. Sales more than tripled in the United States and Japan, with increases for ICs compared to discrete semiconductors especially striking, Over the same period, European semiconductor sales increased by only 75 percent. The Japanese market is now half the size of that in the United States.

Structure

Something over a hundred American firms make semiconductors, with about 60 percent of the industry's output coming from the four largest manufacturers: IBM and Western Elec-

[39] *Status 1982; A Report on the Integrated Circuit Industry* (Scottsdale, Ariz.: Integrated Circuit Engineering Corp., 1982), p. 5.

[40] Domestic shipments were $571 million in 1960—A *Report on the U.S. Semiconductor Industry* (Washington, D. C,: Department of Commerce, September 1979), p. 39. The 1982 and 1983 figures are from 1983 U.S. *Industrial Outlook* (Washington, D. C.: Department of Commerce, January 1983), p. 29-7. Other definitions of the industry's products and boundaries will, as for consumer electronics, result in different figures. The gross national product (GNP) growth rate is based on table B-1, p. 233 of the *Economic Report of the President* (Washington, D. C.: Government Printing Office, February 1982). GNP in real terms has, of course, grown much more slowly,

Table 21 .—Semiconductor Sales in the United States, Western Europe, and Japan

	Sales (billions of dollars)	
	1974	1982
United States		
Discrete semiconductors . . .	$0.88	$1.3
Integrated circuits	1.2	6.3
	$2.1	$7.6
Western Europe		
Discrete semiconductors . . .	$0.77	$0.77
Integrated circuits	0.52	1.5
	$1.3	$2.3
Japan		
Discrete semiconductors . . .	$0.55	$1.2
Integrated circuits.	0.59	2.4
	$1.1	$3.6

SOURCES: *1974—Electronics,* Jan. 8, 1976, pp. 92, 93, 105
1982- Electronics, Jan 13, 1983, pp. 126, 142, 150; Mar, 10, 1983, p 8

tric, which produce only for internal consumption, plus Texas Instruments (TI) and Motorola, which sell most of their production on the open market. Some 80 percent of U.S. output comes from the 20 largest manufacturers, a percentage that would be higher if ICs alone were considered.[41]

Major U.S. merchant companies—those that sell on the open market—are listed by sales level in table 22. Note that 3 of the 10 have been purchased—in 2 cases by foreign interests—since 1977; thus, strictly speaking, the table no longer represents U.S. companies only, The ups and downs of sales figures for various companies over the period *1978-82* show that positions are likely to continue to change; indeed, Motorola nearly caught TI in *1981/1982,* managing small increases despite the recession while the latter company's sales dropped nearly *20* percent.

[41] *Summary of Trade and Tariff Information: Semiconductors* (U.S. International Trade Commission Publication 841, Control No. 6-5-22, July 1982), p. 8.

Market Trends

Table **23** shows sales and projections by device type in the domestic market (exports are not included), while figure **23** illustrates end uses for ICs. Sales growth between *1982* and *1986* is projected at 20 percent per year. While such estimates often miss the mark—1982 sales

Table 22.—Merchant Semiconductor Sales of Ten Largest U.S. Suppliers

	Worldwide semiconductor sales (millions of dollars)				Approximate 1982 market share
	1974	1978	1980	1982	
Texas Instruments	$634	$921	$1,580	$1,300	8.8 "/0
Motorola	481	680	1,120	1,219	8.3
National Semiconductor	210	376	800	673	*4.6*
Intel	115	300	575	578	*3.9*
Fairchild Camera and Instrument acquired by Schlumberger in 1979)	323	358	566	412	2.8
Signetics (acquired by Philips in 1977)	121	214	384	340	2.3
Advanced Micro Devices	26	132	282	329	2.2
General Instrument	63	129	244	313	2.2
RCA	NA	NA	NA	291	2.0
Mostek (acquired by United Technologies in *1980)*	*60*	*134*	*360*	*220*	*1.5*

NA = Not available

SOURCE Dataquest

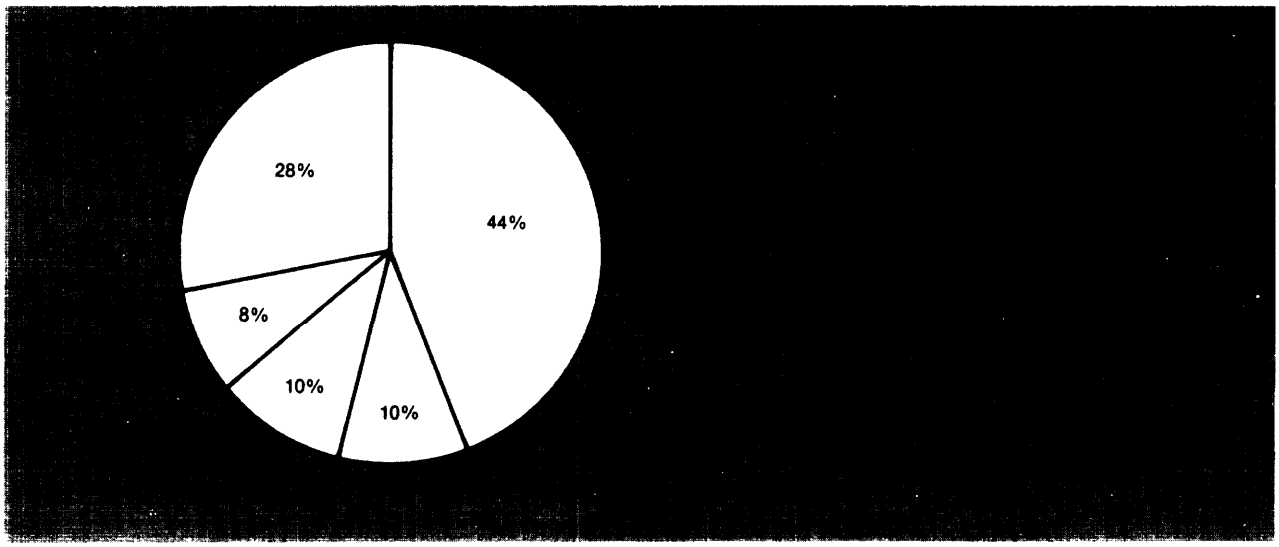
Table 23.—U.S. Semiconductor Sales by Type

	Sales volume (millions of dollars)			
	1975	1980	1982	1986a
Discrete semiconductors	$ 665	$1,255	$1,322	$ 1,720
Integrated circuits:				
Standard logic families	364	1,313	1,183	*1,920*
Microprocessors/microcomputers	68	641	1,053	*2,820*
Memory	257	1,862	2,113	*5,450*
Linear circuits	192	676	868	1,700
Consumer products ICs	—[b]	393	497	820
Custom ICs	—[b]	—[b]	426	1,410
Other ICs	57	304	137	310
	938	5,190	***6.277***	14.430
Total semiconductors	$1,603	$6,445	$7,599	$16,150

[a] Projected.
[b] Included under "Other ICs."

SOURCES *1975*—*Electronics*, Jan. 8, 1976, pp 92, 93.
1980—*Electronics*, Jan 13, 1962, pp 124, 125
1982, 1986—*Electronics*, Jan 13, 1963, pp 128, 129, Mar 10, 1983, p 8

Figure 23.— End Uses of Integrated Circuits Sold Worldwide in the Merchant Market, 1980



SOURCE *Status '80 A Report on the Integrated Circuit Industry* (Scottsdale, Ariz : Integrated Circuit Engineering Corp , 1980), p. 34

proved disappointing when the economy failed to recover as expected—the longer term demand trend is bound to be steeply upward. Growth will be fastest for ICs, with discrete semiconductors—e.g., transistors—declining in relative importance as ICs continue to replace them. Within the IC category, microprocessors and microcomputers are in turn taking over some of the applications formerly performed by standard logic circuitry (ch. 3). Note the rapid increases in demand for microprocessors and single-chip microcomputers and the steep rise anticipated for custom circuits. Because table 23 is based on value rather than units, it may understate demand for memory circuits in comparative terms. Memory chips were the opening wedge for Japanese marketing efforts in the United States; price competition—expected to continue—means that dollar sales gain may be be depressed even as unit sales skyrocket.

Where in 1960 about half of U.S. semiconductor production was sold to the military, 1982 military sales were at a level of $900 million to $1 billion — a bit more than 10 percent of the total; if only ICs are considered, defense production accounts for around 7 percent of demand.[42]

Merchant and Captive Producers

U.S. semiconductor manufacture is marked by two types of companies: 1) the so-called *captive producers* who make semiconductors to be incorporated in their own end products, which may range from consumer items to computers and defense systems, and 2) *merchant manufacturers* who sell a major part of their output to other firms. Some captives—IBM, Western Electric—consume all their production internally, while other integrated producers—RCA, NCR—sell a fraction of their output on the open market and use the rest themselves. Most companies that depend on micro-

[42] L. Wailer, "Cadence Slow for Military Sales," *Electronics,* Aug. 25, 1982, p. 75; *An Assessment of the Impact of the Department of Defense Very-High-Speed Integrated Circuit Program* (Washington, D. C.: National Materials Advisory Board Report NMAB-382, National Research Council, January 1982), p. 6. The two largest defense suppliers, Texas Instruments and Motorola, had 1980 military sales of about $110 million and $90 million, respectively—6.8 percent and 7.4 percent of their total semiconductor output. These figures are for direct sales; semiconductor products embodied in standard systems such as computers would add to the totals.

electronic devices buy a portion of their needs from merchant firms even if they operate captive facilities. While a number of the larger merchant producers also make end products, and consume some of their semiconductor output internally, the fraction tends to be small compared with outside sales—typically in the 10-percent range (table 24; note that this table lists production rather than sales, thus the figures differ somewhat from those in table 22).

The only recent and authoritative data on production by U.S. captives covers ICs only. Collected by the U.S. International Trade Commission (ITC), the data shows the percentage of domestic IC output accounted for by captives to have ranged between 40 and 50 percent during the period 1974-78.[43] Table 25 contains another set of estimates, these based on *worldwide* production of firms with headquarters in the United States (and elsewhere); the captive percentages here are lower than those found by the ITC's surveys in part because U.S. merchant firms have extensive overseas operations while captive production remains more heavily concentrated in the United States.

Table 25 also illustrates the extent to which American companies have captured world markets for ICs (in this table, production by foreign subsidiaries of U.S. firms is attributed to the United States). Although the U.S. position has been challenged by Japanese manufacturers in some segments of the market, American companies still produce more than two-thirds of the world's ICs.

All estimates indicate that captive production accounts for a substantial fraction of U.S. semiconductor output; not only is captive production large, according to table 25 it is increasing. For a variety of reasons, this trend is expected to continue; one projection shows captive IC production rising from about one-third of the worldwide output of U.S.-based firms in 1982 to 40 percent by 1985 and 50 percent at the close of the decade.[44] While such estimates are always problematical, they are based on forces that have been at work in the industry for a number of years—in many cases the same forces that have led enterprises like GE and United Technologies to purchase merchant semiconductor firms. Manufacturers of

[43] *Competitive Factors influencing World Trade in* Integrated *Circuits* (Washington, D.C.: U.S. International Trade Commission Publication 1013, November 1979), pp. 82, 84. The captive percentages were:

1974	1975	1976	1977	1978
44.0%	47.9%	*49.80/o*	*44.10/o*	*40.*.0%

Table 24.—internal Consumption of Several U.S. Semiconductor Producers, 1978

	Semiconductor production (millions of dollars)	
	Total	Internal consumption
Texas Instruments	$1,192	$112 (9.4%)
IBM	750a	750 (100%)
Motorola	582	31 (5.3°/0)
Fairchild Camera and Instrument	389	37 (9.5°/0)
National Semiconductor.	364	37 (105)
Intel	298	30°(10%)
Western Electric	200[a]	200 (loo%)

[a] Estimated
SOURCE Dataquest.

[44] *Status* 1982: *A Report on the Integrated CircuitIndustry,* op. cit., p. 48.

Table 25.—World Integrated Circuit Output by Headquarters Location of Producing Firms

	1978		1982a	
	Production (millions of dollars)	Share of world output	Product ion (millions of dollars)	Share of world output
United States	$4,582	*68.3%*	*$9,700*	*69.5%*
Merchant	3,238		*6,450*	
Captive	1,344		*3,250*	
Captive percentage	29.30/o		*33.50/0*	
Western Europe	453	*6.7*	*620*	*4.4*
Japan	1,195	17.8	3,440	24.7
Rest of the world[b]	482	7.2	190	1.4
	$6.712		$13.950	

[a] Estimated
[b] Includes the Soviet Union and Eastern Europe for 1978 but not 1982

SOURCES ***1978***—*Status* '130 *A Report on the Integrated Circuit Industry* (Scottsdale, Ariz. " Integrated Circuit Engineering Corp , 1980), p 4
1982—*Status 1982: A Report on the Integrated Circuit Industry* (Scottsdale, Ariz Integrated Circuit Engineering Corp , 1982), p 5

products incorporating semiconductors—computers, automobiles, industrial machinery—see benefits in an internal capability for design and production. Large consumers of ICs, such as computer manufacturers (table 26), look for cost savings. But even if the firm supplies only a small fraction of its own needs—as in fact most captives do—experience with state-of-the-art devices is an advantage in the development of end products. Many companies want to be able to produce their own custom ICs; among the secondary benefits is protection of proprietary circuit designs—easier if production is in-house. In their pursuit of such goals, a number of captive facilities have earned places among the technological leaders of the U.S. industry.

The figures in table 26—restricted to firms that build exclusively for internal consumption except for NCR, which ventured into the merchant market in a small way in 1981—should be regarded as no more than rough indications; other estimates differ. The general trends are not in question, however; most captive operations—the exception is IBM—remain modest in size, manufacturing specialized devices. Computer firms predominate in table 26. A good deal of their production consists of small lots—i.e., 1,000 to 10,000—of custom chips for which outside sources are scarce or unavailable.[45] Honeywell's Solid State Electronics Division, for instance—which produces largely for the firm's line of industrial control systems, rather than its general-purpose computers—expects to be making 1,500 different chip designs by 1985. NCR and Burroughs use much of their output in peripherals such as terminals, where the cost advantages are greater than in processors. IBM, unlike other computer firms, makes most of its own memory circuits; the company is the largest producer of semiconductors in the world. At the same time, IBM has probably become the biggest single customer for merchant devices, purchasing substantial quantities of memory chips from Japanese as well as American vendors. One motive for the company's recent acquisition of a substantial interest in Intel was to help protect a major supplier from possible takeovers.

International Operations of U.S. Firms

Most American semiconductor producers are multinationals. Foreign investments began in the late 1950's; a little over a decade later, the overseas production facilities of U.S. semiconductor manufacturers numbered more than a hundred.[46] Overseas plants typically serve one of two purposes. First, many U.S. firms

[45] See L. Marion, "Mainframe Builders Making More ICs," *Electronics,* May 22, 1980, p. 106; W. I. Iversen, "Captive Semiconductor Facilities Are Gearing Up To Compete Against Established Merchant Suppliers," *Electronics,* May 19, 1982, p. 133. All of the mainframe manufacturers profiled in the first of these articles already had, or were planning to install, the capacity for producing at least 20 percent of their own semiconductor needs.

[46] *A Report on the U.S. Semiconductor Industry,* op. cit., p. 38.

Table 26.—Estimated Production Levels for Captive Manufacturers of Integrated Circuits

	1982 IC production (millions of dollars)	Captive production as percentage of all ICs consumed	Circuit types emphasized in captive operations
IBM (worldwide)	$2,080	80 "/0	Bipolar and MOS logic and memory
Western Electric	385	NA	Microprocessors, memory
General Motors (Delco)	185	NA	Bipolar
Hewlett-Packard	160	NA	Wide range of MOS and bipolar
Honeywell [a]	90	10-20	Mostly bipolar logic
NCR	70	40	MOS microprocessors, memory
Digital Equipment Corp. (DEC)	60	NA	Bipolar
Burroughs	40	NA	MOS logic and memory
Data General	30	High	MOS and bipolar; many standard parts
Tektronix	25	NA	Bipolar linear

NA - Not available

[a] Honeywell also owns the merchant firm Synertek, the production of which has been excluded,

SOURCES *Output figures, products*—*Status 1982: A Report on the Integrated Circuit Industry* (Scottsdale, Ariz. Integrated Circuit Engineering Corp , 1982), pp 52-56
Percentage consumption, products—L Marlon, "Mainframe Builders Making More ICs," *Electronics,* May 22, 1980, p 106.

own *offshore* facilities to which labor-intensive production operations—particularly wire bonding and assembly—have been transferred. Second, many companies manufacture semiconductors in industrialized countries to better serve the market or in response to foreign government pressures for local production. Subsidiaries of the second type are often called point-of-sale plants. The larger U.S. merchant firms have made foreign investments of both sorts. Most offshore plants are in newly industrializing countries: Malaysia, Singapore, Taiwan, Mexico, the Philippines, Like color TVs, semiconductors are major U.S. import items under items 806.30 and 807.00 of the Tariff Schedules. The great majority of point-of-sale plants, in contrast, are in Europe—where U.S. merchant companies hold about half the market, These plants are concentrated in the United Kingdom and West Germany. Point-of-sale manufacturing also takes place in Australia, Japan, and Brazil. TI, for instance, builds such products as 64K RAMs in Japan, shipping some back to the United States; the company owns as many as 40 overseas plants in 19 countries,

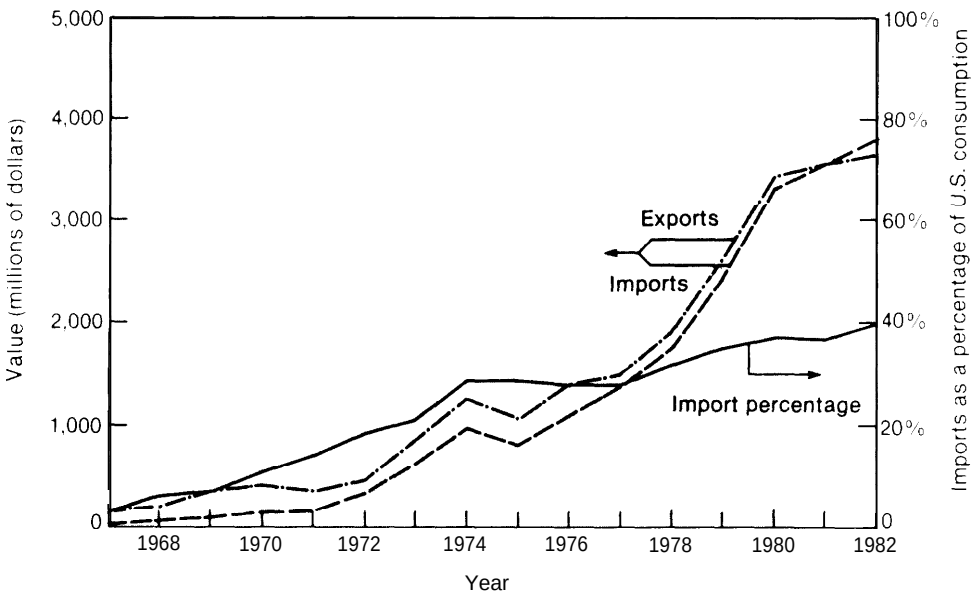
Captives also produce overseas. While IBM has not invested in offshore plants that send semiconductors back to the United States, the company makes ICs in West Germany and France to supply its European subsidiaries. NCR produces semiconductors in Mexico, Hong Kong, the United Kingdom, and West Germany; Rockwell—which splits its production between merchant sales and captive consumption —has plants in Mexico, Taiwan, the Philippines, and Malaysia.[47] Wide dispersion in both production and sales has been a hallmark of the semiconductor industry for many years.

Exports and Imports

As figure 24 shows, U.S. imports and exports of semiconductors have risen steeply over the years. Much of this trade consists of intracorporate transfers—American companies shipping wafers offshore to be returned later in semifinished or finished form. If ICs only are

[47]See *Japan Fact Book '79* (Tokyo: Dempa Publications, Inc., 1979), p. 96, for one of the more complete surveys of semiconductor plants owned by U.S. as well as Japanese firms.

Figure 24.—U.S. Imports and Exports of Semiconductor Products



SOURCES 1967-76—A *Report On the U S Semiconductor Industry* (Washington D C Department of Commerce September 1979), p 59
19774 81—Summary of Trade and Tariff Information Semiconductors (U S International Trade Commission Publication 841, Control No 6.5-22, July 1982), p 26
1982– *1983* U S *Industrial Outlook* (Washington, D C Department of Commerce January 1983), p 29-6

considered, U.S. imports have exceeded exports since 1978, and by slowly increasing margins.[48] For all semiconductor products, as figure 24 indicates, the trade balance has now begun to follow that for ICs onto the negative side of the ledger; still, shipments by American-owned firms continue to predominate among *both* imports and exports. According to table **27,** about **80** percent of all U.S. imports of semiconductor products in recent years have been re-imports after offshore assembly by U.S. producers—which enter under items **806.30** and **807.00** of the Tariff Schedules (virtually all **807).** At the same time, imports from Japan have grown swiftly as a share of total imports. The increase in percentage of domestic value added between 1977 and 1981 stems mostly from the increasing capital intensity—hence increasing share of costs—for the front-end wafer fabrication carried out in the United States.

Table 28 classifies imports for the years 1977 and 1981 by source, showing more clearly the increase in shipments from Japan as compared with other Asian nations. A small fraction of the imports from Japan originate with American-owned companies such as TI, but most come from Japanese manufacturers. Virtually all imports from the other countries listed are 806/807 shipments of U.S.-based multinationals. This table emphasizes the continuing importance of offshore assembly.

[48] *Summary of Trade and Tariff Information: Semiconductors,* op. cit., p. 27.

Table 28.—Origin by Country of U.S. Imports of Semiconductor Products[a]

Country of origin	Import shipments by value and percentage of total imports (millions of dollars) 1977	1981
Japan	$ 87 (6%)	$ 398 (11 °/0)
Malaysia	286 (21 %)	880 (250/o)
Singapore	257 (19°/0)	593 (17%)
Philippines	72 (5°/0)	471 (13%)
South Korea	224 (17°/0)	238 (7°/0)
Mexico	78 (6°/0)	149 (4%)
Taiwan	93 (7%)	131 (4%)
All other	260 (19°/0)	723 (20°/0)
	$1,357	$3,584

[a] Includes discrete semiconductors and integrated circuits, partially completed as well as finished products,

SOURCE" Summary of *Trade arrd Tariff /n formation: Semiconductors* (U.S. International Trade Commission Publication 841, Control No. 6-5-22, July 1982), p. 28.

A similar picture emerges on the export side: nearly three-quarters of U.S. semiconductor exports consist of semifinished products—mostly wafers—shipped to offshore plants.[49] Among industrialized countries, major destinations for U.S. shipments—semifinished as well as completed devices—include Canada and West Germany, the latter serving as a convenient entry point into the European Community; U.S. ship-

[49] In 1981, 73 percent of U.S. exports of semiconductor products went to offshore assembly sites in developing countries—*Summary of Trade and Tariff Information: Semiconductors,* op. cit., pp. 16, 29, The destinations and relative magnitudes of these exports correlate closely with the import figures in table 28. Data on exports to the European Community, mentioned later in the paragraph, come from Bureau of Industrial Economics printouts, Department of Commerce.

Table 27.—Sources of U.S. Imports of Semiconductor Products[a]

Year	Total value of imports (millions of dollars)	Distribution of imports by source: 806/807 imports[b]	Distribution of value added for 806/807 imports[c]: Foreign	Domestic	Imports from Japan	Imports from all other countries
1970	$ 157	88.30/o	43.60/o	56.40/o	NA	—
1975	803	76.9	52.7	47.3	NA[d]	—
1977	1,360	81.5	44.9	55.1	6.40/o	12.1 %
1981	3,584	78.3	32.7	67.3	11.1	10.6

NA - Not available.
[a] Includes discrete semiconductors and integrated circuits, partially completed as well as finished products
[b] Based on total value of all Imports entering under items 806.30 and 807.00 of the Tariff Schedules of the United States
[c] Foreign value added percentages are based on the dutiable value of the 806/807 imports, domestic value added the duty-free value.
[d] In 1975, 4.4 percent of integrated circuits (only) originated in Japan.

SOURCES" *1970,* 1975–A *Report on the U.S. Semiconductor Industry* (Washington, D.C.: Department of Commerce, September 1979), p 62
1977,1981—Summary of Trade and Tariff Information: Semiconductors (U S. International Trade Commission Publication 841, Control No 6.5-22, July 1982), p 15.

ments of semiconductor products to West Germany in 1980 come to about $264 million, 42 percent of total U.S. semiconductor exports to the EC. Point-of-sale production in Europe by American-owned firms is probably somewhat greater than exports from the United States, although precise figures are not available.

Pricing and Profits

American semiconductor firms have invested in offshore production facilities in part because of price battles waged among themselves. Learning curve pricing has been common, with manufacturers anticipating future cost savings when setting prices for new products. Such practices quickly pass production efficiencies along to purchasers; as pointed out in the previous chapter, costs per bit for random access memories—a convenient measure—have fallen steadily over the years.

If price competition in semiconductors has been good for purchasers, it has sometimes cut into the industry's profitability. Merchant sales tend to be quite cyclical; when customers adjust their inventories in response to the business cycle, fluctuations at the supplier level are magnified. In some years, semiconductor industry profits have been higher than for U.S. manufacturing as whole, in other years lower; over the longer term, the semiconductor industry has done about as well as other manufacturing sectors. This variability also shows up when profitability is compared to costs for acquiring investment capital. In 1979, profitability was well above costs of capital, in 1975 —a recession year—substantially below.[50] Larger companies such as TI and Motorola have often managed better than average profits, reflecting at least in part their diversification; when the semiconductor market slumped in 1981, TIs' Geophysical Services subsidiary provided excellent returns, helping the company's net profits.

[50]"U.S. and Japanese Semiconductor Industries: A Financial Comparison, " Chase Financial Policy for the Semiconductor Industry Association, June 9, 1980, p. 5.8.

Employment

Given the extensive offshore assembly activities of U.S. merchant firms—which concentrate on the labor-intensive steps in the production process—it is no surprise that domestic employment in semiconductor manufacturing has not expanded *as* rapidly as unit sales. From 1972 to 1982, the average annual rate of growth in employment was 7.2 percent (ch. 9, especially figs, 56(B) and 60), Over this same period, the rate of growth of output was twice as high (15 percent). Domestic semiconductor manufacturing has shown a steady increase in the proportion of white-collar workers, many of them technical professionals, with commensurate increases in overhead costs as a proportion of direct labor costs.

Semiconductor Manufacturing in Japan

Structure

The independent merchant suppliers that have been such a vital force in the U.S. semiconductor industry have few analogs in other parts of the world; while Japan's Government has made sporadic attempts to stimulate entrepreneurial risk-taking, in the world semiconductor industry only the British-owned Inmos represents a serious attempt at emulation of the American model. Thus it is no surprise to find the major Japanese producers—table 29—to be relatively large, diversified firms that make microelectronics devices for both internal consumption and outside sales—more like RCA than Intel.

The top five semiconductor manufacturers in Japan account for almost three-quarters of the country's production, the next five virtually all the rest. The industry is somewhat more concentrated than that in the United States, with a near absence of small, specialized suppliers. As table ***29*** indicates, many though not all of the principal Japanese competitors in microelectronics are the same companies that U.S. manufacturers face in consumer markets or in computers—Hitachi, Fujitsu, Toshiba. Nippon Electric Co. (NEC), the largest pro-

Table 29.—Total Sales and Semiconductor Share for Major Japanese Producers

	Sales (millions of dollars)				Semiconductor as percentage of total (1981)	Percentage of semiconductors used internally (1982)[b]
	Total	Semiconductor[a]				
	1981	1978	1981	1982		
Nippon Electric Co. (N EC)	$4,850	$520	$960	$990	19.80/o	240/o
Hitachi	15,500	465	825	800	5.3	19
Toshiba	9,540	400	770	740	8.1	8
Fujitsu	3,210	125	415	480	12.9	24[c]
Matsushita	15,700	225	475	410	3.0	13C
Mitsubishi	6,060	145	320	320	5.3	11
Sanyo	4,470	120	215	185	4.8	32
Sharp	2,810	NA	125	140	4.3	27
Oki	986	NA	95	125	9.8	44

N A = Not available.
[a]Merchant sales only.
[b]Estimated from value of merchant sales and value of fiscal year (beginning in April) semiconductor production.
[c]1981

SOURCES: *Merchant semiconductor sales*—Dataquest.
Total semiconductor production—"One Trillion Yen Semiconductor Industry Forecast for FY 1981," *Japan Economic Journal,* June 16,1981, p. 9; "Semiconductor Manufacturers' Strategy In FY-82 Discussed, " *Japan* Report, Joint Publications Research Service JPRS U11012, Dec. 16, 1902, p 93 Yen conversions at 220 per dollar for 19S1, 249 for 1982.
Total sales—"The 500 Largest Industrial Corporations Outside the U.S., " *Fortune,* Aug. 23, 1982, p. 207

ducer of semiconductors in Japan, stands out because of the high fraction of its business accounted for by microelectronics, yet this fraction is only one-fifth; most Japanese producers get substantially smaller proportions of their revenues from semiconductors.

None of the nine firms listed in table 29 consumes as much as half its output internally. Sony, the biggest Japanese manufacturer producing solely for internal consumption, has recently been operating at a level of about $100 million annually—placing them roughly tenth in total semiconductor output. Thus, the distinction between merchant and captive producers is less relevant for Japan; major Japanese computer and/or systems firms both make and sell semiconductors. (Nippon Telegraph and Telephone—which, like AT&T, has a large and widely respected R&D effort in microelectronics—does no manufacturing itself.)

Figure 25 compares semiconductor production in Japan to that in the United States. While it was only in 1981 that Japan's output reached a level half that here, over the 1980-81 period Fujitsu's production increased by one-third, Matsushita's by one-half, Oki's even more.[51] As figure 25 indicates, total production in Japan was up by one-third during a period when U.S. output declined slightly, although remaining flat over the 1981-82 period (comparisons of production level reflect differing demand levels related to economic conditions in the two countries, along with exchange rate fluctuations). While Texas Instruments and Motorola remain the two largest merchant manufacturers in the world, NEC was the third largest by 1980, Hitachi sixth. Given the growth rates of the recent past, other Japanese firms seem likely to follow NEC into the top ranks of the world's producers, No wonder American semiconductor firms are worried.

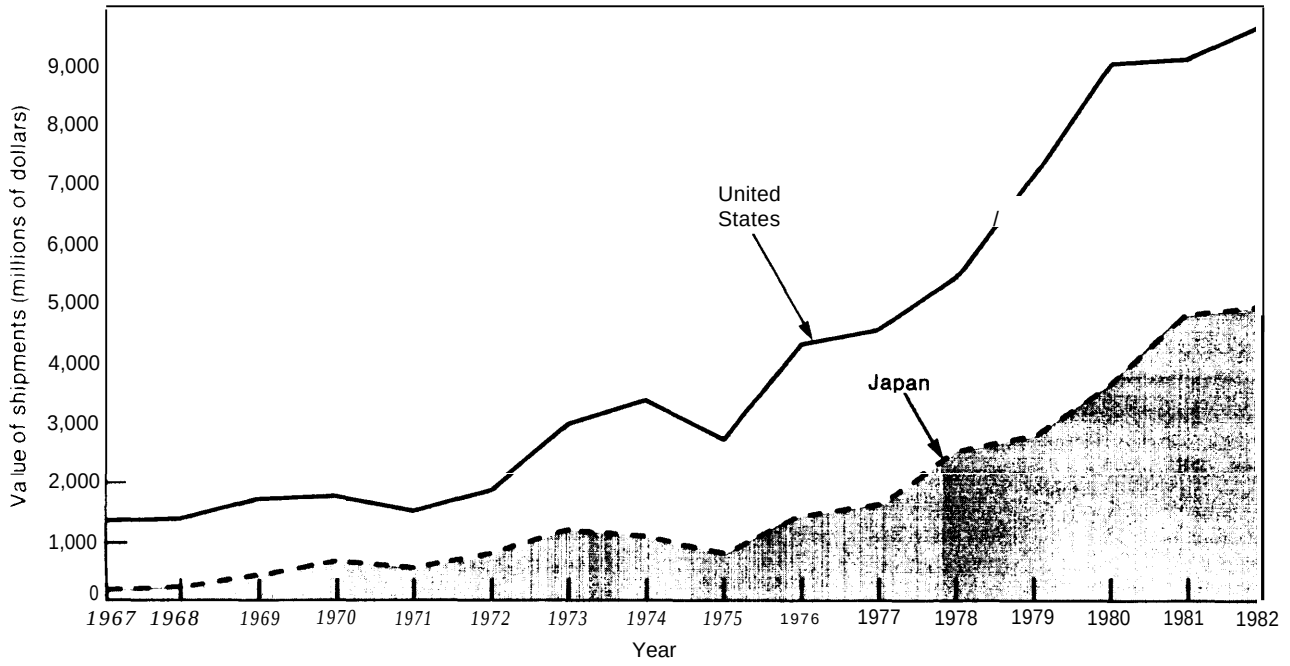
To support the production increases of recent years, Japanese manufacturers have made heavy capital investments. Japan's microelectronics industry reportedly invested nearly $900 million on plant and equipment in 1981, after spending $750 million the previous year.[52] Meanwhile, U.S. producers—remembering the consequences of their spending cuts in 1974 and 1975—have maintained their own capital expenditures at somewhat over $1 billion annually.[53] Because the Japanese industry remains

[51]"One Trillion Yen Semiconductor Industry Forecast for FY 1981, " *Japan Economic Journal,* June 16, 1981, p. 9. Here and at several other places in the chapter, financial or production data for Japanese firms is given on a fiscal year basis, beginning in April of the year noted.

[52]Ibid.

[53]*1982 U.S. Industrial Outlook,* op. cit., p. 238. Japan's exports of semiconductors to the United States benefited from continued investments in new production capacity during the 1974-75 sales slump. When the market recovered, Japanese suppliers of 16K RAMs were able to take advantage of capacity shortages in the United States to enter the American market in a major way.

Figure 25.—Semiconductor Production in Japan and the United States



SOURCES *United States— 1967.76–A Report on the U S Semiconductor Industry* (Washington, D C Department of Commerce, September 1979), p 39
7977-80— Summary of Trade and Tariff /n formation Semiconductors (Washington, D C U S International Trade Commission Publication 641 Control No 6-5-22, July 1982), p 26
1981,1982—1983 U S Industrial Outlook (Washington, D C Department of Commerce, January 1983), p 29-7
Japan— 1967.80-Japan Fact Book '80 (Tokyo Dempa Publications, Inc , 1980), p 188; *Japan Electronics Almanac 1982* (Tokyo Dempa Publications, Inc 1982), pp 149, 178
1981, 1982- *In·Stat Electronics Report,* Feb. 21, 1983, p 5.
Yen conversions from *Economic Report of the President* (Washington, D C U S. Government Printing Office, February 1983), p 275

a good bit smaller than that in the United States, capital spending as a percentage of sales has been considerably higher (see fig. 51, ch. 7),

Early Development

For many years, Japanese expansion in microelectronics was fueled by demand from consumer products manufacturers. In the late 1950's, as much as two-thirds of Japan's total output of transistors went into radios. [54] Even for the period 1974-78, nearly 40 percent of all ICs produced in Japan were purchased by the consumer sector.[55]

Given this dependence on consumer products, it is no surprise that, as in the United States, the early manufacturers of semiconductors in Japan included many firms that also made vacuum tubes. But while few of the American vacuum tube producers were able to carve out a major place in the semiconductor market, the large Japanese firms all negotiated this transition successfully, They were joined by only a few newer companies, although one of these—Sony—was the first Japanese firm to mass-produce semiconductors, The structure of the Japanese industry thus evolved quite differently from that here, as table 30 makes evident.

Most of the technology embodied in Japan's output of semiconductors, as for consumer electronics, was at first based on developments originating in the United States, As of 1974, Bell Laboratories had licensed a greater number of semiconductor patents in Japan than in

[54] J.E. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D, C.: The Brookings Institution, 1971), p. 157.

[55] *Competitive* Factors *influencin, World Trade in Integrated Circuits,* op. cit., p. 117. The percentage would no doubt be higher if all semiconductors were included. Furthermore, an additional 30 percent of Japan's IC output was sold through distributors, much of this presumably ending up in consumer goods,

Table 30.-Major Producers of Semiconductor In the United States and Japan at the End of the 1950's

	Share of domestic semiconductor market
United States (1960)	
Vacuum tube manufacturers	35%
GE	8
RCA	7
Raytheon	4
Philco	4
Westinghouse	4
Others	4
Semiconductor Entrants[a]	60%
Texas Instruments	20
Transition	9
Hughes	5
Motorola	5
Fairchild Camera and instrument	5
Others	16
Western Electric (captive)	5%
	100%
Japan (1959)	
Vacuum tube manufacturers	79%
Toshiba	26
Matsushita	16
Hitachi	15
Nippon Electric Co. (NEC)	15
Mitsubishi	2
Others	5
New entrants[a]	19%
Sony	11
Sanyo	2
Others	6
imports	2%
	100%

[a]Defined as all firms that had not manufactured vacuum tubes. Fujitsu was formed in 1968 from a merger of apair of firms, one falling in each category; the sharesof each have been included under "Others."

SOURCE: J. E. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D.C.: The Brookings institution, 1971), pp 66, 144.

all of Europe.[56] Much the same is true for patents owned by other American companies; nearly half of Fairchild's semiconductor patent licenses have gone to Japanese firms. Over the latter part of the 1960's, royalty payments by Japanese manufacturers to U.S. holders of semiconductor patents averaged $10 million annually.

The Government Role

If the industrial policy of Japan's Government was a secondary influence on consumer electronics, this has certainly not been the case for semiconductors. Here, MITI and the rest of the Japanese bureaucracy took a direct hand—particularly when it came time to move into ICs. Although the repertory of measures was much the same as for the consumer sector—restrictions on imports and foreign investment, promotion of exports, R&D assistance—the relatively comprehensive MITI "vision" developed for the 1970's placed IC technology at the center of an ambitious plan aimed at strengthening the entire electronics industry and building competitiveness in computers and communications (see chs. 5 and 10).

MITI's efforts to keep out foreign semiconductor firms were largely successful; although a number of American companies were allowed to join in minority partnerships or create sales arms, only TI managed to establish a wholly owned manufacturing subsidiary, Liberalization did not come until the 1970's; Motorola has built its presence through a joint manufacturing venture, while several other U.S. semiconductor firms have recently moved to start production in Japan—more than two decades after such investments in Europe,

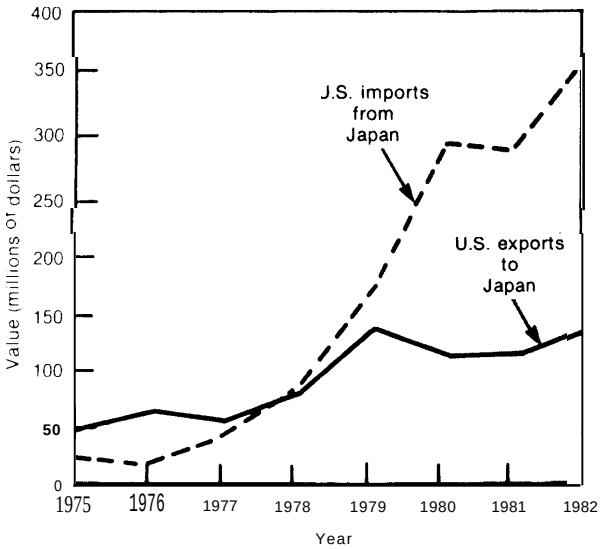
In concert with restrictions on investment, a variety of protectionist measures limited export shipments by American firms. The shares of the Japanese semiconductor market held by U.S. manufacturers thus remain far below those in other industrialized countries, In 1982, U.S. exports of ICs to Japan totaled no more than $135 million (fig. 26), only 4 percent of Japan's own output. In 1981, TI—the chief American supplier within Japan—had sales through local production and export shipments which came to about $120 million; if included in table 29, TI-Japan would barely place in the top 10 among those selling in the Japanese market.[57]

[56]W. F. Finan, "The Exchange of Semiconductor Technology Between Japan and the United States," First *U.S.-Japan Technological Exchange Symposium*, Washington, D.C., Oct. 21,1981. Also see, in general, Tilton, op. cit.

[57]The statistics collected by the United States and Japan for semiconductor trade between the two countries differ in some years by more than 50 percent; Japan typically reports shipments *from* the United States to be higher than U.S. sources show, shipments *to* the United States lower. Some of the reasons are discussed in *A Report on the U.S. Semiconductor Industry*, op. cit., p. 96.

TI's sales in Japan are the largest of any American supplier, though reportedly limited by the original agreement with MITI to a market share no greater than 10 percent. Approximate 1981 sales in Japan by U.S. firms were: TI, $120 million; Motorola, $35 million; Fairchild, $31 million; Intel, $3o million–S. Lohr, "A Piece of Japan's Chip Market," New *York Times*, Feb. 1, 1982, p. D1 (the estimates are those of the Bank of America's Asia Division),

Figure 26.— U.S.-Japan Trade in Integrated Circuits



SOURCE 1983 U .S *Industrial Outlook* (Washington D C Department of Commerce, January 1983) p 29-5 1982 figures estimated

Table 31 .—Japan's Semiconductor Trade

Year	Shipments (millions of dollars) Imports	Exports
1960	$ 1.6	$ 8.0
1965	7.9	21,0
1970	92.1	27.9
1975	172	128
1977	293	310
1978	382	486
1979	559	757
1980	611	1,090
1981[a]	670	1,100

[a]Annualized from first 6 months

SOURCES: ***1960, 1965***—J E Tilton, *International Diffusion of Technology" The Case of Semiconductors* (Washington, D C The Brookings Institution, 1971), p 45
1970, 1975—R H Silin, *The Japanese Semiconductor Industry* (Hong Kong: Bank of American Asia Ltd , May 1960), p 115
1977—Japan Fact Book '80 (Tokyo Dempa Publications, Inc 1960), pp. 212, 216.
197841—Japan Electronics Almanac 1982 (Tokyo Dempa Publications, Inc , 1962), p. 28.
Yen conversions—*Economic Report of the President* (Washington, D C Government Printing Office, February 1982, p 345.

International Trade

As Japanese production grew, exports and imports rose roughly in parallel—table 31—until the latter part of the 1970's, when the balance swung decisively toward exports. Most of Japan's imports are ICs. In recent years, the majority have originated in the United States and Europe; shipments from IBM's European plants to IBM-Japan account for a sizable percentage.[58] As figure 26 shows, U.S. exports of ICs to Japan have not changed much since 1979. Japanese manufacturers export roughly comparable volumes of ICs and discrete devices; these have gone largely to the United States and the developing Asian economies, with shipments to Western Europe rising quickly over the past few years.[59]

Although Japanese semiconductor manufacturers have established production facilities in Asia and Europe, their investments total much less than those of American firms–nor do they compare with Japan's overseas investments in consumer electronics. In value terms, less than 5 percent of semiconductor production by Japanese-owned firms took place outside Japan as of the end of the 1970's; this percentage will no doubt rise as Japanese manufacturers continue to invest in point-of-sale operations in the United States and Europe.[60]

The Semiconductor Industry in Europe

While Western Europe has been largely self-sufficient in consumer electronics, this was never true in semiconductors (or computers); consistently, at least 5 of the top 10 firms in European semiconductor sales have been American-owned.[61] Plants sited in Europe account for about a quarter of world semiconductor production, but well over half of European output flows from subsidiaries of American corporations. Moreover, European-owned

[58] *Japan Fact Book* '80, op. cit., p. 193. Where as late as 1970, 90 percent of Japan's IC imports came from the United States, more recently the figure has been about 60 percent—*Japan Fact Book* '79 (Tokyo: Dempa Publications, Inc., 1979), p. 99.

[59] During 1980, Japan's exports of integrated circuits by value were distributed as follows:

United States	39.5°/0
Hong Kong, Taiwan, Korea, Singapore, and the Philippines	33,5°/0
Western Europe (mostly West Germany)	19,10/.
Rest of the world	7.9%

See *Japan Electronics Almanac 1982*, op. cit., pp. 181, 184.

[60] R. H. Silin, *The Japanese Semiconductor Industry: An Overview* (Hong Kong: Bank of American Asia Ltd., January 1979), p. 137.

[61] On the earlier years of the European industry, see Tilton, op. cit., especially ch. 5.

firms are especially weak in ICs. In 1981, they accounted for about 7½ percent of world output of all types of semiconductors but only 4½ percent of IC production; 8 years earlier, in 1973, European companies supplied 18 percent of the world's semiconductors, about the same as the Japanese at that time.[62] As this demonstrates (see also table 25), Europe's semiconductor manufacturers have declined in importance compared to firms in the United States and Japan, despite efforts by European governments to shore up domestic industries. Indeed, *on a global basis, most of the gains by Japan can be viewed as coming at the expense of European producers.*

Table 32 shows that the primary European entrants are diversified companies; like those in Japan, they get relatively small fractions of revenue from microelectronics. (The sales declines between 1980 and 1982 reflect depressed business conditions.) Most of the firms listed in the table consume some of their production internally, selling the rest on the open market; only SGS-Ates and the three new ventures at the bottom of the list are primarily suppliers of microelectronics. As might be expected, each company's semiconductor line has been shaped to considerable extent by its end products. Philips is strong in linear circuits for consumer electronics, Ferranti in devices for military systems and communications, Siemens in digital ICs for computers and industrial products.

The dilemma of the European manufacturers is exemplified by companies like Siemens and Philips. Both have excellent fundamental technology in microelectronics, but—as table 33 illustrates—have not managed to convert their technical skills into positions of market leadership outside Europe. Sales in other parts of the world by European firms generally come in specialized devices rather than mass-market products; before Inmos began production in 1982, Siemens was the only European-owned company making 64K RAMs.

Table 33 also demonstrates the importance of the European market for several of the larger American producers. While the data are for 1978, the picture has not changed that much over the years: American merchant manufacturers do greater volumes of business in Europe

[62] The 1981 figures are from Status 1982: *A Report on the Integrated Circuit Industry,* op. cit., p. 5; those for 1973 from G. Dosi, *Technical Change and Survival: Europe Semiconductor Industry* (Sussex, United Kingdom: Sussex European Research Centre, 1981), p. 62.

Table 32.—Total Sales and Semiconductor Share for European Manufacturers

		Sales (millions of dollars)			
		Total	Semiconductor		Semiconductor
Company	Headquarters	1980	1980	1982	fraction, 1980
Philips	Netherlands	$18,403	$558	$494	3.0 "/0
Siemens	West Germany	17,950	420	328	2.30/o
Thomson-CSF	France	3,901	190	184	4.80/o
SGS-Ates	Italy	119	100	158	High[b]
AEG-Telefunken	West Germany	6,756	196	150	2.90/o
Plessey	United Kingdom	1,638	49	NA	3.0 "/0
Ferranti	United Kingdom	498	48	82	9.60/o
Inmos	United Kingdom	—	—	26	High
Matra-Harris	France	—	—	14	
Eurotechnique	France	—	—	12	
Other			79		
			$1,690		

NA = Not available
[a] Merchant sales only.
[b] 1980 semiconductor sales estimated, SGS-Ates does almost ail its business in Component%

SOURCES: *1980 semiconductor sales*—E. Williams, "Electronic Components," *Financial Times,* Apr 5, 1962, sec. III, p. I Original source, Dataquest. The SGS-Ates estimate Is from '(Management, American-Style, at Italy's Microchip Manufacturer," *World* Business *Weekly,* Aug. 31, 1961, p. 22.
1982 semiconductor sales—Dataquest; SGS-Ates—"SGS-Ates Expects Move Into Black," Electronics, Apr 21, 1983, p 76
Total sales—"The 500 Largest Corporations Outside the US.," *Fortune,* Aug. 10, 1981, p. 207; "The 100 Largest Foreign Companies," Forbes, July 6, 1981, p. 96; R. Whiteside (cd.), Major *Companies of Europe 1982* (London' Graham & Totman Ltd , 1982), "International Corporate Scoreboard," *Business Week,* July 19, 1982, p 85.

Table 33.—Merchant Semiconductor Sales by Region for Selected Manufacturers, 1978

	Approximate world market share	Proportion of company sales by geographic region			
		United States	Europe	Japan	Rest of world
Texas Instruments . .	11 "/0	55 "/0	31 "/0	10%0	4 %
Motorola	8	62	25	5	8
Nippon Electric Co. (NEC).	7	24	4	77	11
Philips[a].	7	24	63	4	9
National	5	65	19	5	11
Fairchild	5	63	18	3	15
Hitachi	5	6	2	80	12
Toshiba.	5	6	4	70	20
Intel ., ...	4	59	27	3	11
Siemens	3	12	78	0	10

[a]Includes Signetics

SOURCE G Dosi, *Technical Change and Survival Europe's Semiconductor Industry* (Sussex, United Kingdom Sussex European Research Centre, 1981), p 65 Original source, Nomura Research Institute.

than the Europeans do elsewhere; U.S. firms also have much higher sales in Europe than in Japan, a reflection of the effectiveness of Japanese barriers to trade and investment.

As one remedy to the gradual decline painted above, several European manufacturers have actively pursued American technology. One of the companies listed in table 33—Fairchild—was purchased by the French concern Schlumberger in 1979. Philips had acquired Signetics several years earlier. Siemens owns 20 percent of Advanced Micro Devices. Two of the small firms included in table 32–Matra-Harris and Eurotechnique, both French—originated as joint ventures with American partners holding minority interests. For the French, a major goal was technology acquisition; from the standpoint of the U.S. participants, joint ventures may give better entry into European markets—particularly that of France itself, where the telecommunications sector has been especially well protected.

European firms are also negotiating joint ventures with Japanese concerns. Despite persistent efforts to strengthen Europe's technological capability in microelectronics on an EC-wide basis (ch. 10), European companies seem to find it easier to cooperate with American or Japanese firms than with each other. One reason may be that the Americans and Japanese are viewed as having more to offer.

Semiconductor Manufacture Elsewhere

While semiconductors are made in many parts of the world by U, S- and Japanese-owned firms, only a few developing economies have much indigenous production—and then usually in discrete devices rather than ICs. Firms outside the advanced industrial countries (excluding the Soviet Union and Eastern Europe) accounted for only 0.3 percent of world production in 1981, with most of this in the developing Asian nations, Of these, Korea probably has the strongest technical capability in ICs, but Taiwan, Malaysia, Hong Kong, and Singapore are all attempting to improve their positions, Chip production under local ownership began in Taiwan in 1982, with the first products intended for consumer applications.[63] A pair of locally owned companies in Hong Kong have begun producing ICs; while some of the output will go into watches and other consumer products, one of these manufacturers is already making LSI memory chips.[64] The developing Asian nations clearly hope to follow Japan in moving from consumer products into ICs and systems.

[63]R. Neff, "Buzzword in Taiwan is 'Information, '' *Electronics,* Apr. 21, 1982, p. 96. The 0.3 percent figure given above is from Dataquest.

64A. Spaeth, "Two Firms Begin Making Hong Kong's First Chips, " *Asian Wall Street Journal Weekly,* April 5, 1982, p. 20.

Semiconductor Manufacturing Equipment

Advances in IC design move in parallel with advances in processing equipment; indeed, IC designs depend heavily on the capability of the available manufacturing equipment. A number of large-volume semiconductor manufacturers, both here and in Japan, develop some of their own production equipment—including such companies as TI, Western Electric, IBM, and Matsushita. While the Japanese evidently expect to build more of their own equipment in the future, semiconductor manufacturers in all parts of the world, Japan included, have relied heavily on independent equipment suppliers—most of them relatively small American companies. These firms design and fabricate wire bonders, annealing furnaces, ion bombardment apparatus, lithographic equipment, plasma etchers, automated test equipment, and other specialized capital goods. The U.S. semiconductor industry, particularly the smaller independent firms, has drawn strength from the concentration of equipment firms here—about 275 companies, most with annual sales in the range of $5 million and below.[65]

Table 34 lists the 10 leading suppliers of semiconductor manufacturing equipment on the basis of world sales. The industry includes only a few large enterprises, with sales levels dropping rapidly past the top five; nonetheless, the total approaches $2 billion yearly, to which expendable such as chemicals and silicon add perhaps $3 billion more. The larger companies in table 34 tend to concentrate on lithographic equipment and automated circuit testers, relatively expensive items. Something over half the total sales of the industry consists of front-end wafer fabrication equipment, with about half of this for lithography.[66] A number of the equipment firms in table 34—e.g., Varian, Kulicke & Sofa—have entrepreneurial roots similar to the merchant semiconductor manufacturers they do business with. Others, such as Fairchild Test Systems or Canon, are divisions of much larger corporations.

While the lithographic equipment made by Censor—a firm based in Liechtenstein—is well known, and companies like Philips and Siemens can and do build a good deal of their own production machinery, on the whole Europe's

[65] *An Assessment of the Impact of the Department of Defense Very-High-Speed Integrated Circuit Program,* op. cit., p. 133.

[66] L. Wailer, "Advanced Gear Leads Production Sales, *Electronics,* Mar. 10, 1982, p. 46. Back-end testing and assembly equipment accounts for most of the remainder. Other definitions of the equipment industry yield sales estimates spanning a considerable range.

Table 34.—Semiconductor Equipment Manufacturers Ranked by Worldwide Sales

	Headquarters	Sales[a] (millions of dollars) 1979	1981	Major products
Perkin-Elmer	**United States**	**$106.0**	$186.0	Lithographic equipment
GCA	United States	55.7	142.0	Lithographic equipment
Applied Materials	United States	74.6	104.0	Epitaxial reactors, sputterers, plasma etchers
Fairchild Test Systems	United States[b]	111.0	83.1	IC testers
Teradyne	United States	53.5	79.2	IC testers
Varian	United States	60.9	75.0	Ion implanters, sputterers
Eaton	United States	64.1	64.1	Lithographic and test equipment
Takeda Riken	Japan	26.3	55.3	IC testers
Canon	Japan	16,7	47.6	Lithographic equipment
Kulicke & Sofa	United States	36.3	37.5	Wire bonders
Others		NA	∿ 1,000	
			$1,800-$1,900	

NA - Not available.
[a] Open-market sales of semiconductor manufacturing equipment only.
[b] Part of Fairchild camera and instrument, which is now owned by the French concern Schlumberger.

SOURCE: "Gear Makers Sea Essentially Flat Year," *Electronic* News, Mar. 8, 1982, Supplement p. 4. Original source, VLSI Research, Inc. Other sources give considerably different estimates for several of these firms, a number of which are privately held and do not report sales.

equipment industry is weak. The situation is quite different in Japan, Aided over the latter part of the 1970's by the MITI-sponsored VLSI joint R&D project, discussed in more detail elsewhere, Japan is becoming increasingly self-sufficient in processing equipment. The VLSI project concentrated most of its resources on fabrication technology; because the participants were large, integrated manufacturers, the result was to strengthen the internal capabilities of these companies rather than build an independent equipment industry as exists in the United States, While Japan's semiconductor producers continue to buy about half their equipment from American suppliers, the U.S. share of Japan's equipment market has been declining.[67] To counteract this erosion, many American suppliers have been investing within Japan, following the lead of U.S. semiconductor firms. The equipment market in Japan reached about $600 million in 1981; sales have been growing considerably faster than in the United States because of the high capital spending rates of Japanese semiconductor manufacturers.[68] Companies like Canon are also beginning to make inroads into the U.S. equipment market.

[67] R. Neff, "U.S. IC Gear Makers Build in Japan, *Electronics*, July 14, 1981, p. 89.
[68] "Semiconductor Equipment Makers Cutting Into American Share," *Japan Economic Journal*, Dec. 1, 1981, p. 10.

The Computer Industry

For many years the world's producers of data processing equipment seemed to consist of IBM plus a dozen or so much smaller competitors. This picture has changed for several reasons: continued expansion by independent manufacturers of peripherals; rapid growth in sales of smaller systems; the emergence of software as a separate industry. No longer is the typical computer a general-purpose mainframe; now there is no such thing as a typical computer. Processors are becoming more specialized, computing power dispersed to the locations where needed. This evolution does not imply that mainframes have diminished in importance, simply that they no longer account for the vast majority of the output of computer manufacturers. The following description of the data processing equipment industry focuses on processors themselves, with limited attention to peripherals; no attempt is made to cover the software industry, the dimensions of which are largely unmapped.

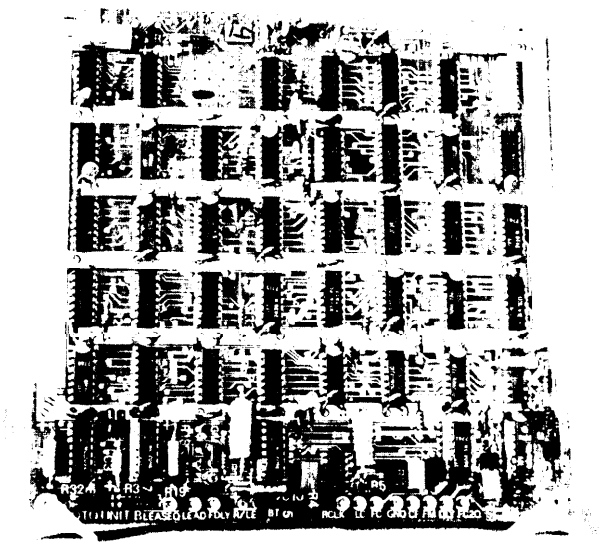


Photo credit *Compugraphic Corp*

Printed circuit board for computerized typesetter

The Computer Industry in the United States

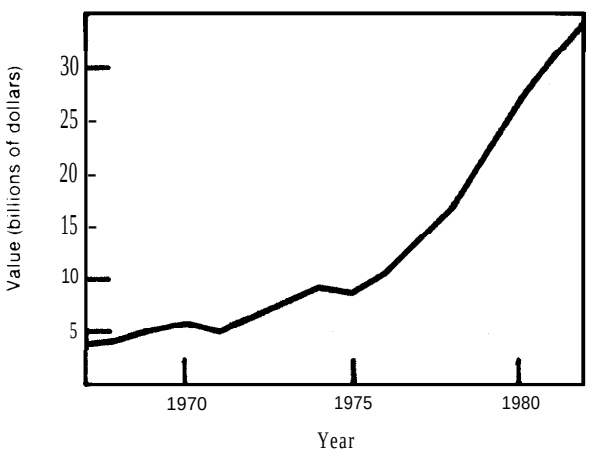
No matter how its boundaries are defined, the value of U.S. production of computers far outstrips that of consumer electronics or semiconductors. Growing predominately from and far surpassing the manufacture of business machines, computer production in the United States–including peripherals–approached $35

billion in 1982 (fig. 27).[69] As for microelectronics, the expansion of the computer industry has been phenomenal; the annual growth rate over the past 10 years has averaged 18 percent. Some parts of the market have grown for periods of several years at 30 to 50 percent annually; while mainframe sales were up by nearly 7 percent in 1982, minicomputer sales increased twice as fast; microcomputer sales grew more than 60 percent.[70] Table 35 gives more detail on U.S. sales for 1975 and 1982; the projections for 1986 indicate that the total market may increase by nearly 10 times over the 1975 figure. Small computers and separately purchased software will lead the expansion.

[69] As defined by Standard Industrial Classification 3573, 1982 estimated shipments (including exports) came to $34. I billion—1983 *U.S. Industrial Outlook,* op. cit., p. 27-5. Other definitions of the industry's boundaries—e.g., that adopted by *Electronics* magazine and referred to in several places below—result in much larger sales figures. *Electronics'* total for 1982 —including imports but not exports by American manufacturers–is $52.1 billion (Jan. 13, 1983, p. 132). Neither of these two figures includes data processing services, itself a major industry; in 1981, the worldwide revenues of U.S. computer services firms exceeded $20 billion—1983 *U.S. Industrial Outlook,* p. 27-4. When the full range of data processing activities are aggregated, figures in the range of $7o billion thus result.

[70] P. Archbold, "The Datamation 100: Welcome to the Club," *Datamation,* June 1983, p. 87.

Figure 27.—U.S. Production of Computer Equipment (SIC 3573)



SOURCE 1972, 1975, 1977, 1960, 1963 editions, *U.S. Industrial Outlook,* Department of Commerce. 1981 and 1982 shipments estimated.

Table 35.—Sales of Computers and Equipment in the United States

	Sales (billions of dollars)		
	1975	1982	1986[a]
Hardware			
Processors			
Desktop, small business, personal	$0.08	$6.05	$25.4
Minicomputers, other small systems	0.78	7.76	16.0
Mainframes	5.40	13.0	18.7
	$6.26	$26.8	$60.1
Memory, mass storage	2.95	4.14	8.9
Other peripherals	3.62	13.2	26.9
Total hardware	$12.8	$44.1	$95.9
Software	***NA***	***3.11***	16.8
Total	$12.8	$47.2	$113

NA = Not available.
[a] Projected.

SOURCES: ***1975—Electronics,*** Jan. 8, 1976, p. 94.
1982,1986—Electronics, Jan. 13, 1963, pp. 132, 133.

Structure

In large measure because IBM is so much bigger than its competitors—with sales nearly eight times those of its nearest rival, the minicomputer specialist Digital Equipment Corp. (DEC)—the U.S. computer industry is highly concentrated by the usual measures; the four largest domestic firms account for three-quarters of sales.[71] Once past the leader, the industry is populated by a relatively large number of firms that do not differ so greatly in size—table 36. The table ranks U.S. computer manufacturers by worldwide sales—an appropriate basis given the global outlook shared by firms in this industry.

Table 36 makes the long-term preeminence of IBM quite evident, but it is the shifts in position beneath that are truly striking. DEC, which more than any other company started the minicomputer industry-largely by virtue of the pioneering PDP-8 of the mid-1960's (ch. 3)—was a tiny company 15 years ago. By 1979, its sales

[71] *Summary of Trade and Tariff Information: Computers, Calculators, and Data Processing Machines* (Washington, D. C.: U.S. International Trade Commission Publication 841, Control No. 6-4-13, September 1981), p. 6. IBM's place in the industry can be judged by noting that its 1982 U.S. sales of computers and related products—a little over half the company's worldwide sales—came to $18.9 billion, 40 percent of the total U.S. computer market in that year (the IBM sales figure is from "The Datamation 100: Welcome to the Club," op. cit., the total U.S. market figure from table 35. Most of IBM's sales are in computers, but it does have other business activities.

Table 36.—U.S. Computer Manufacturers Ranked by 1982 Worldwide Sales

	Computer-related sales (millions of dollars)		Return on equity (1982)[a]	Major products
	1975	1982		
IBM	$11,116	$31,500	23.40/o	Mainframes and minicomputers; peripherals; office automation
Digital Equipment Corp. (DEC)	534	4,019	14.3	Minicomputers and peripherals
Burroughs	1,447	3,848	5.7	Mainframes and minicomputers
Control Data Corp. (CDC)	1,218	3,301	11.1	Mainframes and peripherals
NCR	960	3,173	12.4	Mainframes and peripherals
Sperry (Univac)	1,295	2,800	9.2	Mainframes and peripherals
Hewlett-Packard	250	2,165	16.3	Mini and microcomputers; peripherals
Honeywell	1,324	1,685	13.2	Mainframes and minicomputers
Wang	50	1,322	20.6	Minicomputers; office automation
Xerox	80	1,300	18.0[b]	Peripherals; office automation

[a]Al Ilines of business
[b]1981

SOURCES 1975—0 Rothenbuecher, "The Top 50 Companies in the Data Processing Industry," *Datamation*, June 1976, p 48
1982—P Archibold, "The Datamation 100 Welcome to the Club, " *Datamation*, June 1983, p. 87.

ranked sixth, and in 1981 DEC surpassed the mainframe companies between it and IBM to become the second largest computer manufacturer in the world. Wang Laboratories—known for its small business systems and word processors—entered the top 10 in 1981. The computer industry no longer consists of IBM plus the five smaller mainframe-oriented companies –CDC, NCR, Burroughs, Sperry-Univac, Honeywell. Yet it is not so many years since American firms could be contrasted to the rest of the world as the "big eight''—the six mentioned plus GE and RCA. The latter two have dropped out of the computer business; even so, while producing computers their sales volumes were greater than virtually any foreign manufacturer.

Aggregated data on the profitability of the U.S. computer industry tends to be dominated by IBM's figures, which–as table 36 indicates—have usually been well above the average, The computer industry has been less affected by the business cycle than most; nearly all the firms listed in table 36 did reasonably well in 1982 despite a depressed economy. In general, the industry has been more profitable than U.S. manufacturing as a whole. *

Evolution and Structural Change

Many of the early entrants in the computer industry began as business machine manufacturers. While IBM trailed such firms as Remington Rand and Underwood into data processing, its share of the market rose steadily; dating computer manufacturing from 1951, by the end of the industry's first decade more than 70 percent by value of all systems installed in the United States had been built by IBM.[72] This percentage held roughly constant through the 1960's, only beginning to fall as minicomputer sales surged; while IBM has retained its posi-

* Comparing the industry composite figures for "Office Equipment, Computers" With the "All-Industry Composite" as tabulated by *Business Week* in their yearly corporate scoreboard issues (each March) gives the following picture:

Return on Equity (Profits as a Percentage of Value of Common Stock)

	Computer composite	*A1l-industry composite*
1974	*16.90/o*	14.00/o
1976	17.9	14.0
1978	20.4	15.1
1980	19.2	15.3
1981	15,2	14.0
1982	15.9	11.0

Again note that the computer figures are heavily weighted by IBM's profits, and that the firms Business Week includes in this category do not necessarily coincide with the "computer industry" as defined elsewhere.

[72] *Gaps in Technology: Electronic Computers (Paris:* organization for Economic Cooperation and Development, 1969), p. 39. The percentage by number of machines was somewhat less, IBM's position benefited greatly from success in marketing to the Department of Defense; in the mid-1960's, nearly half the company's U.S. sales were to the Federal Government, a much larger fraction than any of its rivals managed. At the end of the 1960's, perhaps three-quarters by value of all computers in the world were IBM machines (pp. 8, 139).

tion in mainframes, still holding around 70 percent of the domestic market for large systems, its share of minicomputer sales in the United States is only about 20 percent.[73]

Virtually any business or other organization is now a potential computer purchaser; with the appearance of machines in the $1,000 and under price range, so are households. As costs come down, sales rise; the mid-1960's, which brought the minicomputer, proved a watershed for the industry. Many of the older mainframe companies had trouble competing successfully in markets for small systems—indeed still do. New entrants emerged building small, inexpensive systems suitable for dedicated applications as well as general-purpose data processing. While most of the companies that had been competing in the mainframe market introduced smaller machines—later if not sooner—newcomers such as DEC and Data General, the latter spun off from DEC in 1968, emerged as the leaders.

Table 37 lists major producers of minicomputers. (The distinctions between mainframes and minis are arbitrary; this listing simply follows one definition, as noted in the table.) Although IBM sells more small systems than any other company, its advantage does not compare with the margin it holds in mainframes, and indeed might disappear under a more restrictive definition of "minicomputer." Only a few other entrants from the early days of mainframes are major factors in this part of the market. The table is restricted to American firms, but would differ little if foreign manufacturers were included. U.S. companies dominate world minicomputer markets more completely than for either mainframes or desktop machines; only the West German firm Nixdorf is among the world's 10 largest minicomputer manufacturers (although its U.S. sales were but $150 million in 1981, the company has a substantial presence in Europe).

Just as the minicomputer opened vast new markets through lower costs—made possible largely by ICs–so the microcomputer has followed, again extending sales to new groups of customers. And just as the growth of minicomputer sales saw new firms challenging the established leaders, so microcomputer systems have been pioneered by companies like Commodore, Apple, and Tandy (makers of Radio Shack computers); now it is DEC and Hewlett-Packard that find themselves in a reactive position. Table 38 shows how fast microcomputer sales have been expanding—although they are still small in value compared even to minicomputers—and the extent to which new entrants have taken leading positions; even so, IBM is already in second place.

Change is taking place at the other end of the market as well, with plug-compatible manufacturers (PCMs) continuing to enlarge their positions. Building mainframe processors and peripherals that are compatible with IBM systems, these companies strive to offer superior price/performance combinations; perhaps one-third of the disk drives used with IBM processors, for instance, are now supplied by other firms.[74] CDC, one of the first to make plug-compatible peripherals, sells processors that run on IBM software as well, while Amdahl continues

[73] G. Anders, "Lawsuit's End May Spur IBM To Acquire Firms, Expand in Satellite, Office Markets," *Wall Street Journal,* Jan. 11, 1982, p. 29.

Table 37.–Major U.S. Manufacturers Ranked by 1982 Worldwide Minicomputer Sales[a]

	Minicomputer sales (millions of dollars) 1975[b]	1982	Return on equity, 1982[c]
IBM	$450	$3,000	23.40/o
Digital Equipment Corp. (DEC)	160	1,680	14.2
Burroughs	290	800	5.7
Data General	35	604	5.8
Hewlett-Packard	70	588	16.3
Wang	15	585	20.6
prime	NA	351	31.1
Honeywell	80	330	13.2
Gould	NA	325	10.60/0
Texas Instruments	25	320	8.9

NA = Not available.
[a] This table uses *Datamation's* definition of the minicomputer market; all such definitions are arbitrary and others might give a different ranking.
[b] Approximate.
[c] All lines of business

SOURCES: 1975—O. Rothenbuecher, "The Top 50 Companies in the Data Processing Industry," *Datamation,* June 1976, p 48.
1982-P. Archbold, "The Datamation 100: Welcome to the Club," *Datamation,* June 1963, p 67.

[74] "IBM's Coming Disk-Drive Surge," *Business Week* June 11, 1979, p. 116.

Table 38.—Major U.S. Manufacturers Ranked by 1982 Worldwide Microcomputer Sales

	Microcomputer sales (millions of dollars)		Return on equity, 1982[a]
	1979	1982	
Apple	$ 75	$664	28.0°/0
IBM	—	500	23.4
Tandy (Radio Shack)	150	466	32.3
Commodore	55	368	52.9
Hewlett-Packard	NA	235	16,3
Texas Instruments	—	233	8.9
Digital Equipment Corp. (DEC)	–	200	14.3

NA = Not available
[a]Alllines of business

SOURCES **1979**—"The Datamation 100," *Datamation*, June 1980, p 87
1982—P Archbold, "The Datamation 100 Welcome to the Club," *Datamation*, June 1983, p 87

to be the leading American PCM firm, with about half of all such installations.[75] The PCM share of the U.S. market for mainframe processors has risen over the last 5 years to perhaps 20 percent. Yet another indication of IBM's strength is that most of the gains of the PCMs appear to have come from sales won in competition with mainframe manufacturers other than IBM.[76]

The PCM portion of the industry is characterized by particularly strong international ties. A number of foreign firms, including several leading Japanese manufacturers, supply IBM-compatible equipment. Amdahl is 28 percent owned by Fujitsu, with which it shares technology. National Advanced Systems, which stopped making its own machines early in 1983, markets large computers built by Hitachi.[77] Several European firms also market Japanese-built PCMs.

International Trade and Investment

As in microelectronics, U.S. computer manufacturers have been heavily oriented toward the world marketplace, which they have supplied through exports and foreign investment, Offshore assembly to reduce labor costs has been far less central to competitive dynamics than in the semiconductor industry, but price competition in microcomputers and other small systems will probably cause more U.S. firms to transfer labor-intensive operations offshore in the future. Point-of-sale investments—primarily in Europe—have been the rule for the major U.S. firms, while—as figure 28 shows—exports from the United States have exceeded imports by wide margins. Nearly half the export shipments go to Western Europe, with Japan and Canada also getting substantial fractions.[78]

Although imports of computers and equipment exceeded $2 billion in 1982, much of this consists of re-imports by U.S. firms following offshore assembly, Detailed figures are not available, but the percentage of computer imports entering under item 807,00 of the Tariff Schedules has been in the range of 40 percent over the past few years.[79] Most of these re-imports come from U.S.-owned plants in Canada; parts and subassemblies also enter from the Far East and Mexico. Of imports originating with non-U. S. firms, Japan is the leading source. In 1980, Japanese manufacturers shipped computers and equipment worth less than $200 million to this country. By 1982, imports from Japan had more than tripled, with Japan's share of U.S. computer imports rising from about 16 percent to nearly one-third.[80] Many of these

[754]' Moving Away From Mainframes: The Large Computer Makers' Strategy for Survival," *Business Week* Feb. 15, 1982, p. 78; "In Focus: 1982 CPU Market Survey," *Datamation*, May 1982, p. 44. Amdahl's 1982 mainframe sales were $312 million. The next largest PCM supplier, National Advanced Systems—a division of National Semiconductor—has about 18 percent of U.S. PCM installations. The core of National's base stems from Itel Corp. 's plug-compatible business, which was acquired by National when the failing company reorganized in 1979.

[76]G. Bylinsky, "The Game Has Changed in Big Computers," *Fortune*, Jan. 25, 1982, p. 82

[77]"Unit of National Semiconductor Ends Computer Production, *Wall Street Journal*, Feb. 1, 1983, p. 41.

'Bin 1980, us. exports of computers and equipment, which totaled $7.54 billion, were distributed as follows:

Western Europe	44,50/0
Canada	10.0
Japan	7.9
Others	37.6

See *Summary of Trade and Tariff Information: Computers, Calculators, and Data Processing Machines*, op. cit., p. 23.

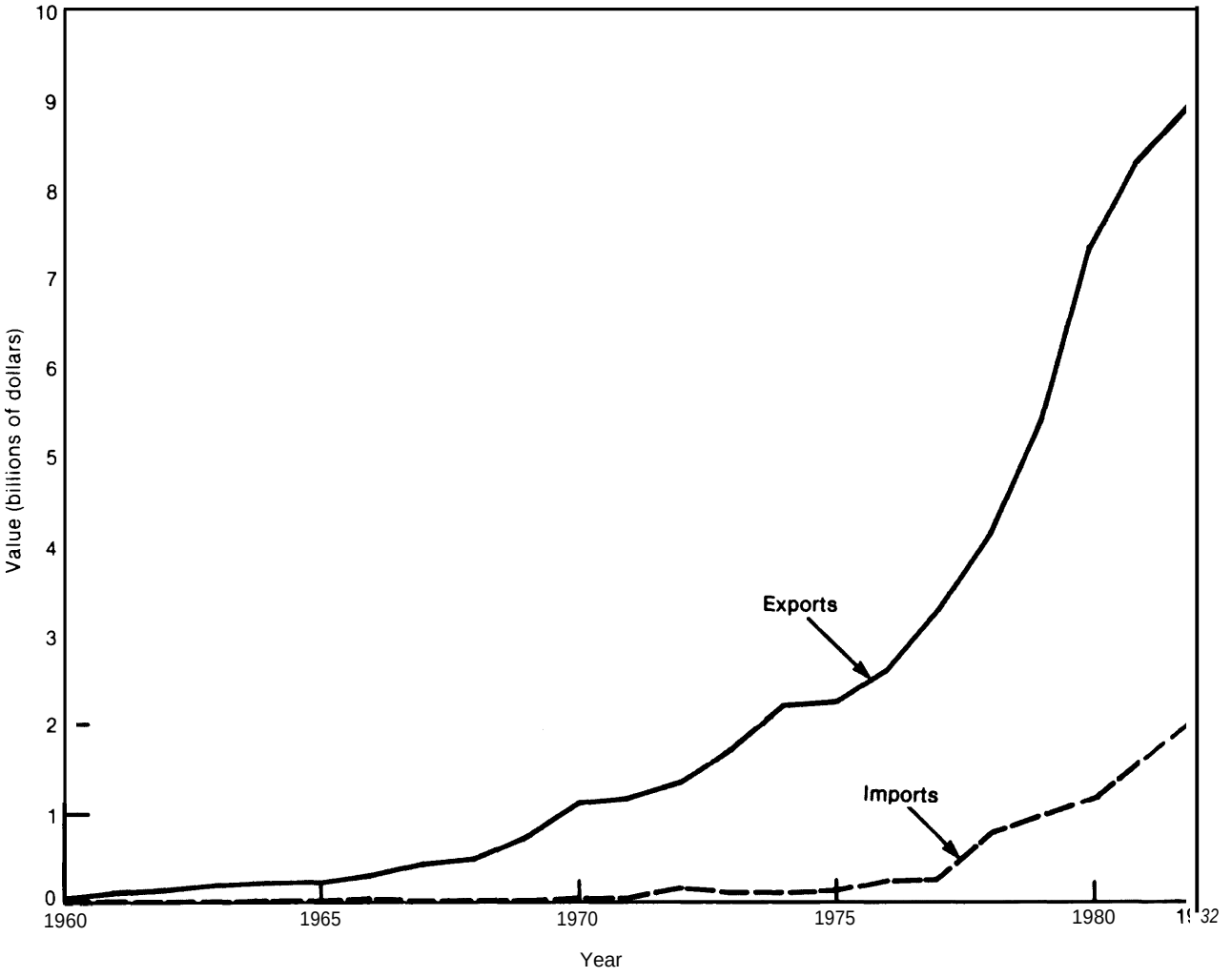
[79]Imports under 806.30 are negligible. The U.S. International Trade Commission aggregates 807,00 imports of computer equipment with those for calculators. Dividing 807 imports for computers plus calculators by total imports for computers gives:

	1976	*1977*	*1978*	*1979*	*1980*
Ratio of 807 to total	*410/0*	360/0	37%	*420/0*	47%

Since *807* imports of calculators are small in value, these percentages overstate the fraction of 807 computer imports only slightly. See *Summary of Trade and Tariff Information: Computers, Calculators, and Data Processing Machines*, op. cit., pp. 11, 20.

'I bid., p. 20; 1983 U.S. *industrial Outlook*, op. cit., p. 27-4.

Figure 28.—U.S. Exports and Imports of Computers and Equipment



SOURCES *796066-Gaps IN Technology Electronic Computers* (Paris Organizationfor Economic Cooperations' and Development, 1989), P.50
1967-81— 1972, 1977, 1980, 1982 editions, U S *Industrial Outlook*, Department of Commerce
1982— Department of Commerce, Bureau of Industrial Economics

shipments have been plug-compatible mainframes distributed by American companies, but Japan has also begun to push into personal and desktop systems as well as peripherals.

No recent estimates of foreign investments by U.S. computer manufacturers are available, but it is clear that these have been large. Many American computer firms do a quarter to half their business overseas, with production facilities as well as sales and distribution affiliates located in countries around the world. Domestic jobs–see chapter 9–total more than 400,000, while American-owned computer firms probably employ several hundred thousand people in other countries.

Computer Industries in the Rest of the World

Computers are sold all over the world; as table 39 indicates, installations outside the industrialized nations lag in value—because most are small—but number about the same as in Europe. However, manufacturing—leaving aside desktop machines—is largely the province of companies with headquarters in ad-

Table 39.—Worldwide Computer Installations

	Number of systems and value of computers and equipment					
	1960		1970		1983[b]	
	Number	Value	Number	Value	Number	Value
United States	5,500	$ 8.8 billion	65,000	$ 92.6 billion	400,000	$300 billion
Japan	400	0.5	6,000	7.5	70,000	50
Western Europe	1,500	2.6	21,000	40.5	225,000	220
Rest of world	1,600	0.8	18,000	9.6	205,000	130
Total	9,000	$12.7 billion	110,000	$150.2 billion	900,000	$704 billion

[a]Excludes desktop and other very small systems
[b]Projected

SOURCES "Japan Takes Aim at IBM's World," *World Business Weekly,* Apr 20, 1981, p 30 Original source, Diebold Europe

vanced industrial economies; the global industry consists basically of the several hundred U.S. firms—more making peripherals than processors—plus their counterparts in Japan, Britain, France, and West Germany. While subsidiaries of Japanese and Western manufacturers can be found in developing countries like Mexico, Brazil, and Taiwan, it will probably be some years before the industrializing Asian nations produce anything other than small and simple systems. Still, countries like South Korea and Taiwan have ambitious plans for entering data processing markets, Sales of computers in Taiwan are growing at about 40 percent annually, and the country is already home to many small software-oriented businesses, as well as a number of firms making microprocessor-based systems.[81] Much the same is true in Korea, where firms that have been making computer terminals are beginning to introduce microcomputers .[82]

In Japan, computer manufacture started late compared to Western Europe and the United States, Whereas American and European firms began during the 1950's more or less on a par in data processing technology—if not in market potential—Japan followed about a decade behind, Table 39 illustrates the gap in terms of installations. Now Japan has the second largest computer industry in the world, although still far behind the United States; sales in Japan are also second only to the United States. As table 40 shows, the Japanese computer market was two-thirds as big as the entire Western European market by 1982. Within Europe, West Germany absorbs the most computers, with the United Kingdom and France following,

Of the major Japanese-owned manufacturers —the same six firms that are the chief competitors in microelectronics—only three (Fujitsu, Nippon Electric, Hitachi) have annual sales of data processing equipment exceeding $500 million (table 41). In 1981 worldwide sales, the largest non-U, S. manufacturer—Fujitsu—ranked between Sperry-Univac and Hewlett-Packard, seventh largest, with barely half the

Table 40.—World Computer Markets

	Sales (billions of dollars)	
	1975	1982
United States[a]	$12.8	$47.2[b]
Japan		
Microcomputers and minicomputers	$0.17	*3.19*
Mainframes	1.89	*2.63*
Memory, storage	0.44	1,60
Other peripherals	0.53	3,61
	$3.03	$11.0
Western Europe		
Microcomputers and minicomputers	$0.37	$ 4.54
Mainframes	2,79	8.00
Memory, storage	1.40	—[c]
Other peripherals	1.24	3.5a
	$5.80	$16.1

[a]See table 35 for U S sales by category
[b]Includes software
[c]Included under 'Other peripherals

SOURCES *1975*—*Electronics* Jan 8, 1976 pp 94 106
1982—*Electronics* Jan 13, 1983 pp 146, 154 table 35

[81]"Buzzword in Taiwan is 'Information'," op.cit.; A Spaeth, "Upstart Taiwan Electronics Firms Are Making 'Their Mark by Design," *Asian Wall Street Journal Weekly,* Dec. 13, 1982, p.7.
[82]"Korea's Electronics Industry Making Rapid Cain\ in Shift to High-Technology Products," op. cit.; A Spaeth, "Asian 'NICs' Rely on Cheap Brainpower To Plan output of More Advanced [;()()li$," *Wall Street Journal,* Jan. 5, 1983, p. 25.

Table 41.—Non-U.S. Computer Manufacturers Ranked by 1981 Sales[a]

Company	Headquarters	Computer-related sales, 1981[b] (millions of dollars)
IBM	United States	$26,340
Digital Equipment Corp. (DEC)	United States	3,587
Fujitsu	Japan	1,950
ICL	United Kingdom	1,513
Olivetti	Italy	1,436
CII-Honeywell Bull	France	1,353
Nippon Electric Co. (N EC)	Japan	1,330
Siemens	West Germany	1,330
Hitachi	Japan	1,290
Wang	United States	1,009
Nixdorf	West Germany	856
Data General	United States	764
Toshiba	Japan	430
Apple	United States	401
Oki	Japan	400
Mitsubishi	Japan	330

[a]Selected American firms included for comparison only, see tables 38 through 38 for complete US rankings by sales.
[b]Fiscal years for Japanese firms plus ICL and Siemens

SOURCES U.S. firms—P Archbold, "The Datamation Top 100," *Datamation*, June 1982, p. 115
Japanese Wins— "Status of Top Computer, OA Semiconductor Companies Studied," *Japan Report*, Joint Publications Research Service JPRS U10319, Feb 11, 1982, p 17 Original source, *Computopia*. (Yen conversions at 220 per dollar),
European fhrrs-"Reviewlng Europe's Top 25," *Datamation*, November 1982, p. 124 Original source, Logica

computer sales of DEC. As table 41 shows, the European firms of any size number but five: ICL in Great Britain, Siemens and Nixdorf in West Germany, Olivetti in Italy, and CII-Honeywell Bull in France.

Europe

Almost from the beginning, American computer firms have been more viable competitors in European markets than local manufacturers.[83] The largest European entrants now have data processing equipment sales not too much greater than Wang's; national industries in Europe have passed through periodic cycles of financial problems, mergers, and government subsidies. ICL lost $245 million in 1981; the firm has had to depend on loan guarantees from the British Government.[84] In West Germany, IBM's market share—about 60 percent—is three times that of Siemens' money-losing data processing division.[85] In Europe as a whole, IBM has more than half of all computer sales by value—90 percent supplied by IBM's European plants—and American firms take about two-thirds of the total market.[86] The U.S. share of computer sales in Europe has, nonetheless, been declining slowly during the past few years.

The only internationally competitive European computer firm to recently emerge has been Nixdorf—a West German manufacturer of small systems intended primarily for business applications. The company has a global outlook; it currently gets less than half its sales in West Germany, nearly 20 percent in the United States.[87] Nixdorf is perhaps the closest to an entrepreneurial firm in the American style that the European electronics industry has seen. The company has actively sought out the best technologies available—e.g., in microelectronics—from both U.S. and Japanese suppliers, and cultivates close ties with customers in its efforts to anticipate user needs, Both atti-

[83]See *Gaps in Technology: Electronic Computers*, op. cit. Also *The American Computer Industry in Its International Competitive Environment* (Washington, D. C.: Department of Commerce, November 1976).
[84]S. Love, "New Talent Spurs Britain's ICI.," *Wall Street Journal*, Mar. 1, 1982, p. 27.
[85]E. DiMaria, "European Makers Move to End Red Ink," *Electronic News*, Nov. 16, 1981, see, II, p. 23.
[86]"European Computers: Pie in the Sky?" *Economist*, Sept. 9, 1978, p. 30; "Reviewing Europe's Top 25," *Datamation*, November 1982, p. 124.
[87]J. Tagliabue, "Nixdorf's Rise From a Cellar," New York *Times*, Feb. 18, 1981, p. D1. The company was started with capitalization of $6,000 in the early 1950's.

tudes have been atypical among European computer manufacturers.

Nixdorf is likely to benefit from the continuing expansion of markets for smaller systems—a trend as evident in Europe as here. Still, most of this growth will probably continue to be taken by American-owned companies. Symptomatic of the difficulties of European suppliers is the case of Philips—a firm that would seem to have as much ability as any in Europe to compete in computer manufacturing. Since the collapse of the Unidata consortium—a joint effort of Philips, Siemens, and CII during the 1970's—Philips has concentrated most of its efforts on small systems. But in contrast to Nixdorf, the Dutch multinational has had little success; at the end of 1981, Philips' share of European small business installations was only 3½ percent by value, as compared to Nixdorf's 10½ percent.[88]

The Japanese are also headed for a greater presence in the European market, but thus far most of their computer sales in the EC have come through ties with local firms. Not only do Siemens and ICL market Fujitsu's large mainframes, but Hitachi processors are sold by Olivetti and BASF.[89] The French remain committed to CII-Honeywell Bull—now nationalized, although Honeywell retains a 20 percent interest—as champion of the domestic market, and presumably the European market as well. However, the chances seem small that the Mitterrand Government will have more success than its predecessors in promoting CII-Honeywell Bull.

In only two countries in the world do American firms have less than half the installed base—a vital predictor of future trends because customers tend to become locked into a manufacturer's product line, largely through their software inventories. The two are the United Kingdom, where government procurement and other policy tools have heavily favored British-built computers, and Japan, where the government has used a variety of measures over many years to protect and support the domestic industry.

Japan

Britain's policies may have kept ICL in business, but the firm is hardly thriving. Japan has had more success; the government played a central role in the development of the country's computer industry, with many of the subsidies given semiconductor manufacturers based on the desire to help build a strong computer sector.[90]

Japanese computer manufacturers have not yet had the export success of the nation's consumer electronics firms, but they have outstripped their rivals in Europe on most indicators of competitive ability if not always in total sales (table 41). In contrast to Europe, the dynamic is upward; Japan's computer firms appear to be the only real threats to American leadership in information processing, Originally, the Japanese were heavily dependent on U.S. technology; now they have excellent capabilities of their own, particularly in hardware. Though still lagging in software, this is a current emphasis of R&D; as discussed in the next chapter, Japanese manufacturers hope to break free of their reliance on IBM software and plug-compatible systems.

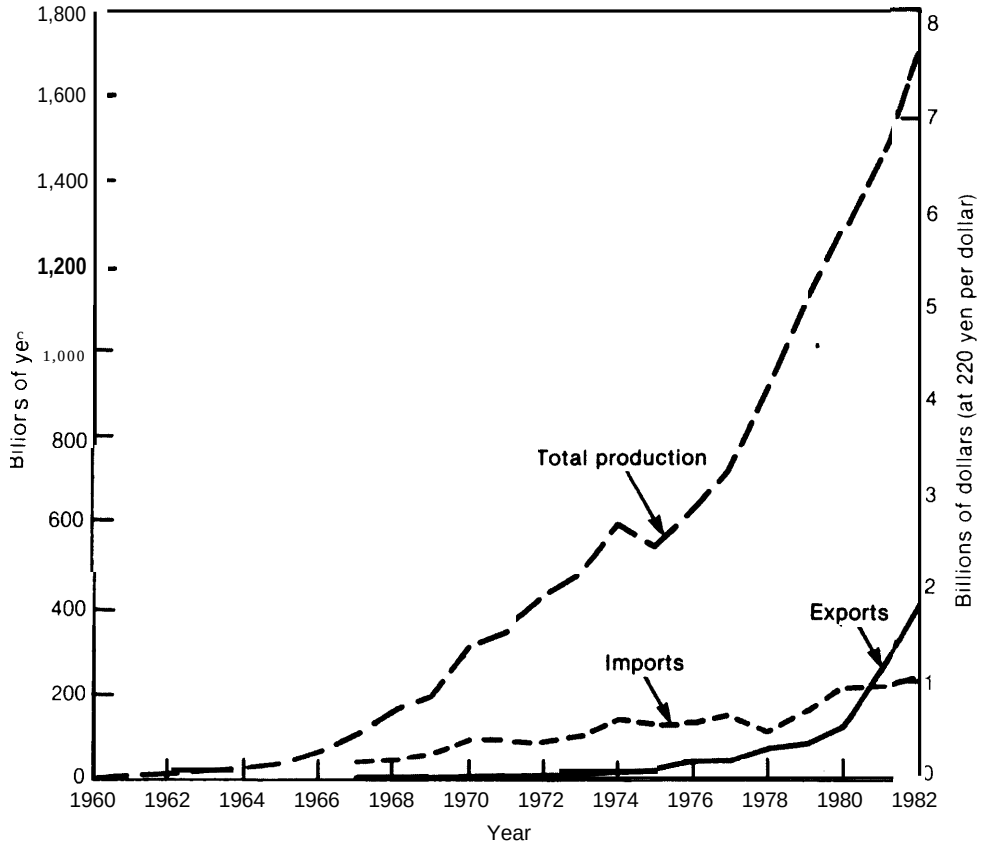
Figure 29 shows how rapidly Japan's output of computers has increased; production volumes were quite low as late as 1970. Now exports have also begun to rise steeply, doubling from 1980 to 1981 and increasing by another 50 percent in 1982. Still, even at the 1982 level–about $1.7 billion—Japan's exports of computers are less than 20 percent those of the United States. Moreover, as figure 30 points out, IBM-Japan is by far the leading exporter; in 1981, this American-owned firm accounted

[88]" Small Business Systems, " *Financial Times,* June 8, 1982, sec. III, p. V. Philips' installed base in these systems ranks ninth by value, Nixdorf's third. IBM and Olivetti were first and second; 5 of the top 10 firms in this survey were American-owned,

[89]G. de Jonquieres, "ICL Launches Japanese Computer, " *Financial Times,* May 7, 1982, p. 7.

[90]See the appendix on "The Development of the Japanese Computer Industry" in E. J. Kaplan, *Japan; The Government-Business Relationship* (Washington, D. C,: Department of Commerce, February 1972], pp. 77-1o1, Also J. Gresser, *High Technology and Japanese Industrial Policy: A Strategy for U. S. Policymakers,* Subcommittee on Trade, Committee on Ways and Means, House of Representatives, Oct. 1, 1980.

Figure 29.—Japanese Production, Imports, and Exports of Computers and Equipment, Including Production and Exports of U.S.-Owned Subsidiaries



SOURCES ***1985-78-Japan*** *Fact Book '80* (Tokyo Dempa Publications, Inc , 1980), pp 173, 174
1978.80–Japan *Electronics Almanac 1982* (Tokyo Dempa Publications Inc 1982), pp 58, 59
1981, 1982— Bureau of Industrial Economics, Department of Commerce

for some 40 percent of Japan's total exports of computers and equipment.

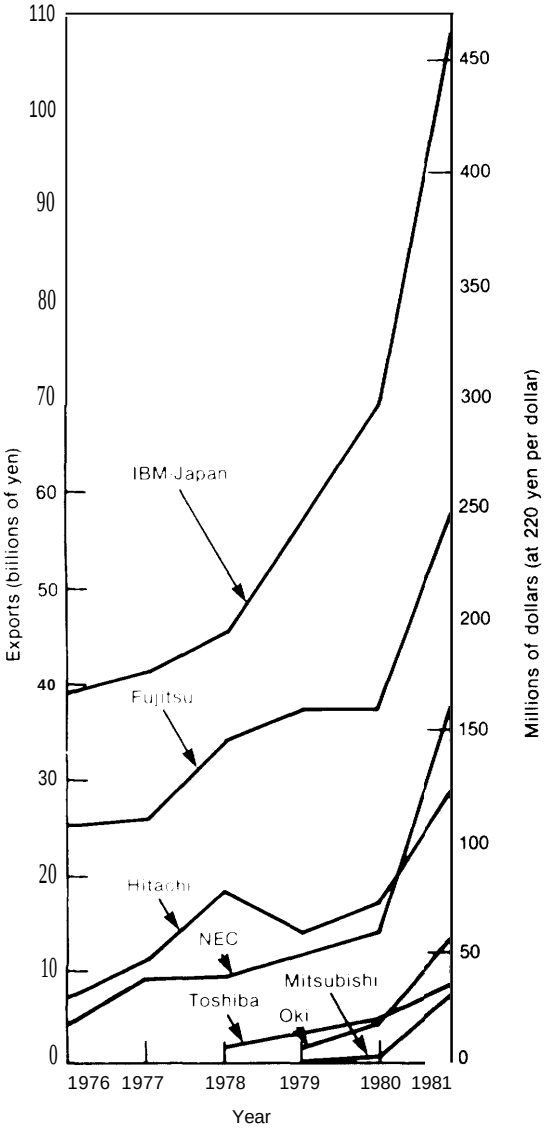
The major Japanese computer manufacturers come from the familiar group of diversified electronics companies. The three largest in terms of data processing equipment sales are Fujitsu, NEC, and Hitachi (table 41). While perhaps 50 firms make small business systems, there are no minicomputer specialists as such in Japan.[91] Like Siemens but unlike most other European and American computer firms, the principal Japanese suppliers get relatively small fractions of their revenues from computers and peripherals—table 42. Fujitsu is something of an exception, as is Oki, but both are still considerably more diversified than the typical U.S. manufacturer of data processing equipment.

As they did in Europe, American computer firms moved early into the Japanese market, but in Japan their penetration was limited by MITI's efforts to protect and nurture a domestic industry. In 1960, imports captured 70 percent of Japanese computer sales, a situation unacceptable to the government; IBM was able to use its patent leverage to establish a wholly owned manufacturing subsidiary, but other production by American firms was restricted to minority interests in joint ventures.[92] Sperry-

[91] "Competing At Home Prepares Japanese Vendors for Export," *Electronics*, Mar. 27, 1980, p. 120.

[92] "The Development of the Japanese Computer Industry," op. cit. IBM-Japan was established in 1960. On other U.S. ventures, see "Can the U.S. Recapture Its Japanese Market?" *Business*

Figure 30.— Japanese Computer and Equipment Exports by "Firm



SOURCE Top Ten Computer Companies' Business Performance in FY 1981 Analyzed, *Japan Report*, Joint Publications Research Service JPRS L 11414 June 29, 1983 p 109 Original source, *Computopia*

Univac, which also had a relatively strong patent position, managed to maintain a place in Japan through a jointly owned sales company, Nippon-Univac, plus a minority interest which it still holds in Oki-Univac, a manufacturing enterprise. NCR owns 70 percent of a Japanese venture that is largely a marketing arm for imported systems. Japanese operations by other American computer firms have been small in scale, most established quite recently. Through such efforts, U.S. companies have managed to retain perhaps 45 percent of computer sales in Japan, including both local production and imports; IBM-Japan accounts for most of this.

Indeed, until 1979 IBM-Japan had a market share greater than any other firm, outstripping all the Japanese-owned manufacturers. Since then, Fujitsu's sales have exceeded IBM's—figure 31. IBM still has the largest installed base in value terms—about 28 percent—with Fujitsu ahead in total number of systems, Part of the reason for IBM-Japan's lagging rate of sales growth compared with Fujitsu, Hitachi, and NEC—all of which, as figure 31 shows, have seen their sales expand rapidly—lies with IBM-Japan)s relatively weak position in smaller systems.

Another factor working to the advantage of locally owned companies has been the Japan Electronic Computer Co. (JECC), a leasing organization supported by loans from the Japan Development Bank. JECC was organized more than 20 years ago under MITI auspices to aid the domestic industry; it purchases systems and leases them to users so that computer manufacturers need not tie up large sums of capital in lease bases. American-owned suppliers have not been allowed to participate. JECC has given smaller Japanese manufacturers like Fujitsu and NEC much more financial flexibility than they would otherwise have had. The leasing program is still seen by both government and the manufacturers as a necessary support for the industry; only Hitachi, with its vast resources, is no longer heavily dependent on sales to JECC.[93] As this implies, the computer operations of Japanese firms have not been very profitable, Although line-of-business figures are not generally available, continued support via JECC—plus the reported inability of firms that received loans and other subsidies

Week, Aug. 25, 1980, p. 73, and "U.S.-Japanese Computer Companies Joint Venture Reported, " *Japan Report*, Joint Publications Research Service JPRS 1./10701, July 30, 1982, p. 16.

[93]M. Inaba, "Say JECC Aid Is Still Vital to Japanese CPU Firms, " *Electronic News*, June 22, 1981, p. 22.

in the early 1970's to pay them back—indicate that a number of Japanese companies may still be losing money in their data processing divisions.[94]

W"Domestic Computer Makers Unable To Return Subsidies," *Japan Report,* Joint Publications Research Service LI1oO4O, Oct. 8, 1981, p. 10. An industry analyst at Nomura Securities has speculated that only Fujitsu and Hitachi are earning profits in computer manufacturing, but that NEC and Mitsubishi maybe breaking even—''Competing at Home Prepares Japanese Vendors for Export," op. cit.

Table 42.—Total and Computer-Related Sales for Japanese Manufacturers

	Sales (millions of dollars					
	1970		1977		1981	
	Total	Computer[a]	Total	Computer	Total	Computer
Fujitsu	$423	$230 (55°/0)	$1,450	$1,030 (70.80/o)	$3,209	$1,950 (60.8"/.)
Nippon Electric Co. (N EC)	691	210 (30°/0)	2,010	510 (25.60/o)	4,854	1,330 (27.40/o)
Hitachi	2,191	330 (15°/0)	5,190	600 (1 1.5°/0)	15,519	1,290 (8.30/o)
Toshiba	1,666	130 (8°/0)	3,950	220 (5.60/o)	9,536	430 (4.5%)
Oki	—	NA	480	170 (34.7%)	986	400 (40.60/o)
Mitsubishi	1,102	55 (5%)	2,960	140 (4.80/o)	6,058	330 (5.4%)

NA = Not available
[a]Estimated.

SOURCES. *1970*— E J Kaplan, *Japan The Government-Business Relationship* (Washington, D.C Department of Commerce, February 1972), p 101
1977—"Status of Top Computer, OA Semiconductor Companies Studied, " *Japan Report,* Joint Publications Research Service JPRS IJ10319, Feb 11, 1982, pp 17, 24; original source, *Computopia*, yen conversions at 288 per dollar
IfXI I-Tables 29 and 41

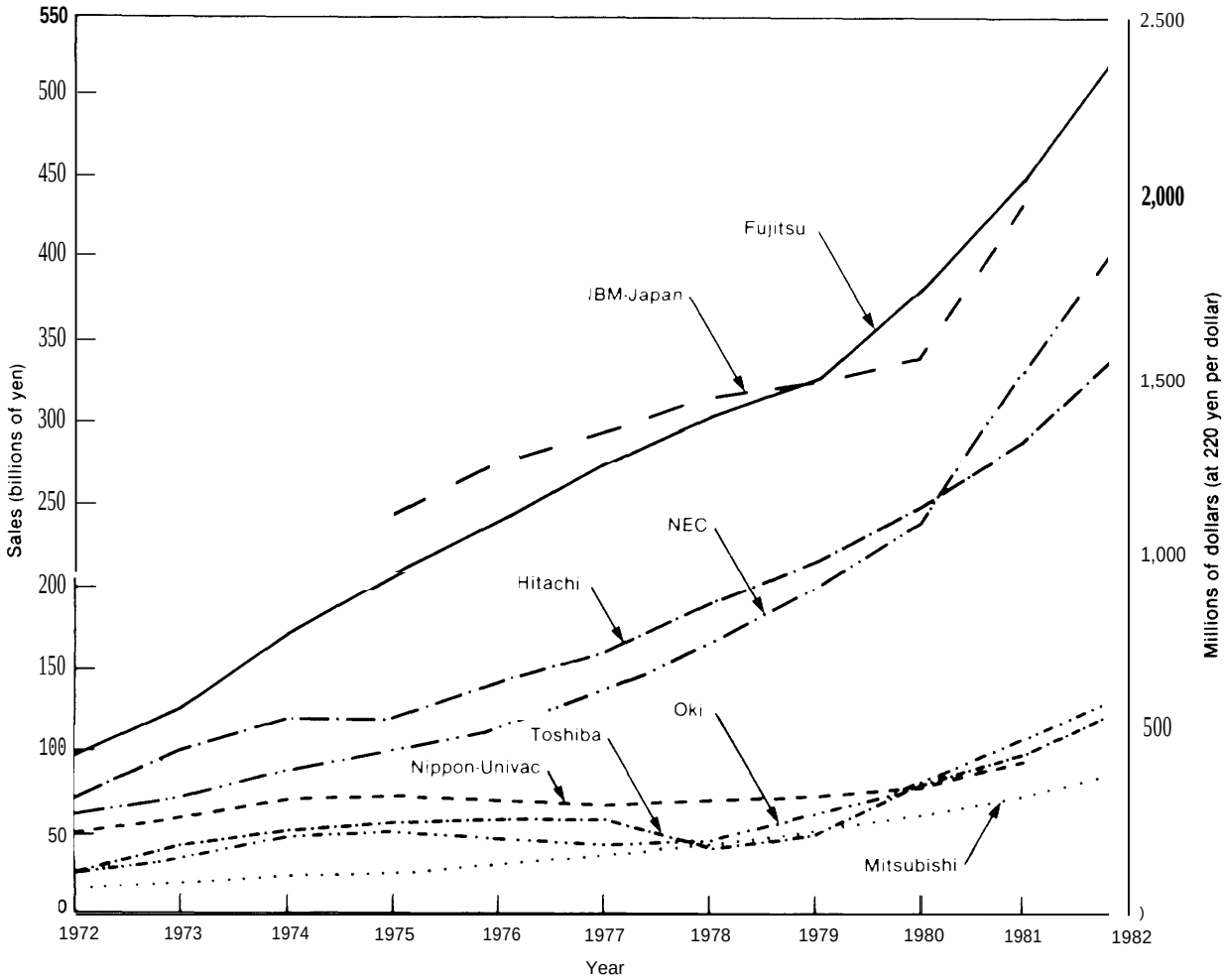
Summary and Conclusions

Industrial structures and patterns of international trade are continuing to shift, though at different rates, in the three sectors of the electronics industry under discussion. In consumer products, U.S. manufacturing has been reconstituted with considerable foreign ownership. The transformation came somewhat later in color TV than in black-and-white TV or consumer audio products, where imports have been dominant for a decade or more, with domestic production at relatively low levels. As a result of unrelenting import competition for color television sales during the 1970's, weaker American manufacturers left the industry—mostly replaced with assembly plants owned by Asian firms. North American Philips, the quasi-independent subsidiary of the Dutch multinational, has also increased its holdings. The size of the color TV market and the protective measures adopted by the Federal Government have helped keep some manufacturing here, although—depending on the firm—as much as half the value may be added overseas, Zenith and RCA have retained their traditional market shares, as has GE, but these companies all perform substantial portions of their manufacturing offshore.

On a world basis, the Japanese have far outstripped other countries in consumer electronics. They have a major share of all markets outside the industrial economies, and have been making steady inroads into Western Europe, where most of the local firms have been small and markets fragmented. Philips, the primary exception to the general weakness of European consumer electronics manufacturers, has mounted a forceful effort to maintain its position. The only company outside Asia to make consumer VCRs, Philips' determination to persist with this line of products, as well as its expansion in the United States, signifies its commitment to a continuing presence in consumer electronics.

Suppliers with headquarters in the developing Asian economies of Taiwan, South Korea,

Figure 31 .—Japanese Computer Sales, Including Exports, By Firm



SOURCES 197280 *Fujitsu and the Computer Industry In Japan* (Tokyo FujitsuLtd June 1982) p 11 Original source Computopia
Japanese owned firms, 1981, 1982 Computer CompaniesMid Term Bus ness Reports Announced Japan *Report* Jc nt Publ ICatiOnS Research Serzie J PRS L 11 I 00 Jan 28 1983 P 73 (1982 estimated)
IBM Japan and Nippon Univac, 1981 U Weil Evaluatingthe Japanese Challenge *Datamation* January 1983 P 133

Hong Kong, and Singapore are following in the footsteps of the Japanese multinationals. Already producing large volumes of components —as well as radios and other audio equipment, watches, and calculators—firms in these countries are strengthening their technological capabilities as a prelude to expanding into new product lines. With infrastructures owing much to the investments of American and Japanese manufacturers moving offshore in search of lower labor costs, several have already proved able competitors in color TV.

The situation is quite different in microelectronics. Here the European industry has never been able to develop a strong independent capability. American investments overseas accelerated through the 1960's; U.S. firms built both offshore plants in developing countries and point-of-sale subsidiaries to serve the Euro-

pean market, While U.S.-owned manufacturers continue to supply nearly two-thirds of the world's semiconductors, a pair of major changes are underway: first, vertical integration is increasing; second, the Japanese are rapidly increasing their competitiveness in world markets.

Captive semiconductor production by integrated manufacturers like Western Electric or IBM is not a new phenomenon, but the number of captive facilities in the United States is on the rise. While merchant semiconductor firms like Motorola or National Semiconductor have been expanding rapidly, captive production has been increasing even faster. The motives for vertical integration are several. Large consumers of semiconductors can help control their costs by manufacturing internally. Others seek a custom design and production capability, assured supplies of low-volume specialty circuits, or simply to keep up with the state of the art, In a few cases, diversification may have been the primary motive for acquisitions of merchant semiconductor firms by larger corporations. While the number of high-volume independent merchant suppliers has diminished as companies like Mostek, Fairchild, and Intersil have been purchased, a new wave of startups—beginning in 1980—may help replenish their ranks, given growth rates comparable to those in earlier periods.

In essence, then, the U.S. semiconductor industry consists of two kinds of manufacturers: merchant firms that sell in the open market, and captives. That some of the merchant manufacturers have now been acquired by other companies has not yet changed these patterns significantly; the formerly independent merchant firms still produce largely for open market sales. Captives, in contrast, rarely sell outside the parent organization. Industrial structures in Japan and Europe lack this relatively clear distinction. Most foreign production takes place in divisions of large, diversified corporations; semiconductors seldom account for even one-third of revenues, often much less. Typically, such companies use a substantial fraction of their microelectronics output in their own end products.

In Japan, the major producers of semiconductors–including Toshiba, Fujitsu, NEC, and Mitsubishi—also make consumer goods or computers or both. These firms specialize to some extent—Fujitsu in computers, NEC in communications equipment and microelectronics, Toshiba in consumer products—but all have multiple lines of business, some extending well beyond the bounds of the electronics industry, Japanese manufacturers are now expanding aggressively into Europe, setting up point-of-sale plants as American firms have been doing for years. While none of the developing countries are as yet factors in IC production, several are making determined efforts to expand from discrete semiconductors into more advanced devices.

The computer industry, which consumes more than 40 percent of world output of ICs, has changed radically over the past two decades. *There is hardly an identifiable computer industry any longer.* As more and more computing power can be packed into a microprocessor or single-chip microcomputer, semiconductor firms like Intel are pointing their R&D efforts toward "systems on a chip. " Others—e.g., National Semiconductor—have entered the market for large computer systems; National's computer division sells IBM-compatible mainframes made by Hitachi.

More broadly, distributed intelligence and the ever-expanding demand for smaller systems are transforming the industry. Lower costs open new markets—typically supplementing existing applications rather than supplanting them. Symptomatic of the changes in the global computer industry is the emergence of DEC—a pioneer in minicomputers and still a specialist in small systems—as the second largest computer firm in the world. In 1981, DEC moved past two mainframe-oriented companies, NCR and CDC, into second place in worldwide sales behind IBM. While IBM is still an order of magnitude ahead of its competitors, too much should not be made of this position; after all, U.S. Steel once held two-thirds of *its* market.

Nevertheless, the world computer industry can still be pictured as IBM on the one hand and everyone else on the other, The difference is that the others are much more numerous and diverse than 15 or 20 years ago, Not only are minicomputer firms like DEC more prominent, but microcomputer manufacturers such as Apple and Tandy now have some of the highest growth rates in the industry. In Europe too—where, as in semiconductors, subsidiaries of American firms have dominated production—the most competitive locally owned manufacturer is Nixdorf, which makes small systems. The other European computer firms—Siemens, ICL, CII-Honeywell Bull—have been growing more dependent on foreign technology, with only the last-named trying to break out of this mold.

Japan's computer industry has been marked by a comparatively strong American presence. While U.S. computer makers have not been able to penetrate Japanese markets as extensively as European, they have had much more success in Japan than American consumer electronics firms; the share of computer sales accounted for by U.S.-owned suppliers—about 45 percent, mostly due to IBM-Japan—is also far greater than the U.S. share of the Japanese semiconductor market. Still, IBM has lately lost first position in Japanese sales to Fujitsu, As this indicates, a ***major difference between Japan computer industry and Europe is that Japanese firms are getting stronger,*** while European suppliers are not. Japan's computer manufacturers have excellent hardware technology, and arc increasing their production and exports at high rates, In this they have been greatly helped by the size and new-found technical ability of the Japanese semiconductor industry. Japan's computer industry is the only potentially serious challenger to the United States now visible. While the Japanese tend to be weak in software and in minicomputers, the country's major producers—aided by government-supported R&D efforts such as the fifth-generation computer project—appear on their way to becoming formidable competitors in the global computer market,