CHAPTER 5

Competitiveness in the International Electronics Industry

Contents

List of Tables

List of Figures

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Overview

According to numerous American business and political leaders, other nations are overtaking the United States in trade competitiveness. Growing import penetration in such industries as automobiles, steel, and electronics—including high-technology products like computer memory chips-has led to discouraging commentaries and a variety of diagnoses. But from their statements, international competitiveness clearly means different things to different people. Some see the United States losing competitiveness as a nation relative to economic rivals like Japan or West Germany; to such observers, the declining U.S. share of global trade in manufactured products—from 25 percent in 1960 to 18 percent in 1980—is prima facie evidence that the Nation is losing competitive vigor. On the other hand, OTA in its past work has evaluated competitiveness on a sector-by-sector basis—believing this to be more meaningful than attempts to generalize about the economy as a whole,

That multiple views on international competitiveness coexist would be of little moment if similar policy remedies followed. But they do not. Viewing competitiveness from an aggregate perspective directs attention toward policies affecting the economy as a whole, and perhaps toward measures intended to promote exports. Policies aimed at improving overall productivity, encouraging capital investment, reducing inflation rates, or stimulating economic growth may have little or no impact on patterns of trade. In contrast, viewing competitiveness in the context of individual sectors—such as steel—is more likely to suggest remedies tailored to the problems of these sectors. Alternatively, the sectoral perspective might suggest that Government support be directed to industries whose international trade position promises to improve. One danger was illustrated by the course of discussions over U.S. industrial policy during 1980, which were dominated by the issue of "winners" as opposed to "losers," or "sunrise industries" and "sunset industries "-a debate that hindsight shows to be beside the point.

This chapter begins by sorting through perspectives on competitiveness, primarily in the context of electronics. Discussion then turns to the practical problem of evaluating competitiveness and attempting to isolate factors that have affected the ability of American electronics firms to compete internationally. Attempts to measure [competitiveness in an industry with rapidly evolving technology are at best indicative. From the viewpoint of Government policy, choices then hinge on dynamics—directions and rates of change, their causes. Projections always carry uncertainty. It may not be easy to discriminate short-term competitive shifts from the longer term secular trends of most concern to policy makers. Some portions of an industry may be in competitive decline while others prosper; a few years later positions may reverse, Within a single firm, various divisions will differ in their ability to compete, Within a division, some product lines may fare better than others. Because technical change, itself not very predictable, is central to competition in electronics, "measuring" competitiveness in any simple sense is impossible. In order to link the technological elements with other business, economic, and policy variables, the chapter concludes with an examination of business strategies,

Comparing strategies pursued in various parts of the world—how firms in several countries have taken advantage of the technologies available to them—yields insights into competitive shifts. Corporate planners have options in deciding how to utilize existing technologies. At the same time, corporate strategies affect the course of technological development itself, as firms decide how to allocate resources for research and product development. In electronics, strategic patterns vary across national industries and among countries. In contrast to manufacturers of semiconductor devices and computers, U.S. consumer electronics firms have seldom approached their markets on a world scale; while taking advantage of offshore production sites and exporting technology when they could, they have otherwise been content with the large and formerly lucrative domestic market, On the other hand, Japanese entrants in consumer electronics-and to some extent the Dutch multinational Philips—produce and sell all over the world. In microelectronics and computers, the situation is reversed; here it is American firms that led—investing overseas and exporting long before Japanese firms were factors in this part of the industry,

Japanese firms now seem likely to take the lead in future generations of consumer electronic products. In part, this competitive success—including the massive inroads into the U.S. market for color televisions summarized in the previous chapter—was fueled by low manufacturing costs and supportive government policies. But compared to the aid Japan's Government has channeled to microelectronics and the information industries, assistance for consumer electronics has been relatively small: low costs and prices (including proven instances of dumping), good products, and aggressive marketing led the way. Technology is a more potent competitive weapon in semiconductors or computers than in consumer electronics—one of the reasons American firms, with their proven ability to turn technology into successful commercial products—have been able to preserve many of their traditional markets. Low costs are still important, but a unique integrated circuit or a better performing computer system offer advantages of a kind that can seldom be achieved in consumer products.

Comparative Advantage and Competitiveness

The Economics of Competitiveness

Is Comparative Advantage Still a Meaningful Concept?

To some, the traditional explanation of international trade flows in terms of comparative advantage is a relic—made obsolete by national industrial policies. Still, without denying the reality of government interventions and their effects—whether these be nontariff barriers restricting inflows of goods and funds for investment, or incentives to attract foreign capital—comparative advantage provides a useful backdrop for more detailed analyses of trade and competition.[1]

Definitions of competitiveness in terms of comparative advantage—with roots going back to the origins of social science--state in essence that nations tend to export goods (or services) that best utilize their available resources, and to import other items; i.e., they export goods in which they have comparative advantage. This is not so obvious as it first appears. For instance, it follows that any nation engaging in international trade must have comparative advantage in some products. Except for financial flows of one type or another, imports must be paid for by the proceeds from exports. Therefore, from the viewpoint of comparative advantage, it is meaningless to speak in terms of a nation being uncompetitive. *If a country trades at all, it must be competitive in something.*

The word "comparative" plays dual roles in the definition. First, how do industries relate one to another *within* a country on their effi-

I For one view of the limitations of the comparative advantage perspective in a context of rapid technological and industrial change, see M. F. Cantley and J. A. Buzacott, "Industry Scale, Free Trade, and Protection," *Scale in Production Systems,* IIASA Proceedings Series, vol. 15, J. A. Buzacott, M. F. Cantley, V. N. Glagolev, and R. C. Tomlinson (eds.) (Oxford: Pergamon Press, 1982), p. 193.

ciency in using resources? In principle, this comparison should yield a list of industries ordered from most to least efficient. (The precise meaning attached to efficiency is not critical, but it refers essentially to costs.) All else equal, nations would be expected to export goods that appeared near the top of their efficiency listing, import those closer to the bottom. Such an outcome does not depend on how these efficiencies compare to the efficiencies of the same industries in other countries. It depends only on the relative standing of domestic industries. The fact is that industries at the top of one country's list can have "efficiency" levels below those of the same industries abroad and still export. The first characteristic of an export industry, therefore, is that it be efficient in its use of resources relative to other domestic industries.

The second comparison adds the international dimension. Here, the efficiency structure of one nation's industries is compared with those of its potential trading partners. Where the efficiency structures of two countries differ —the usual case—trade can be advantageous to both. The United States might in principle be just as efficient in the production of video cassette recorders (VCRs) as Japan; but if U.S. efficiency is greater in, say, agriculture, it would pay both countries to trade—the United States shipping agricultural goods to Japan while importing VCRS, Even given identical cost structures, trade might be advantageous where demand conditions differ between two countries. Of course, such a discussion leaves out a host of other forces—ranging from tariff levels to export subsidies—that can affect trade patterns. Still, comparative advantage provides a starting point for examining these.

Technology plays a central role in electronics. Some countries may possess technological expertise unmatched elsewhere, hence be able to export products that no one else can make. More often, technology is a route to lower cost manufacturing or to products that perform better. A number of nations that could manufacture computers do not because countries like the United States can make better computers cheaper.

While U.S. exports have often been based on technological leads, in other cases trading advantages may stem from natural resource endowments. This country's exports of land-based products—food, fiber, timber, paper—are the consequence of an abundance of arable land combined with high-technology inputs. Conversely, Japan would be hard-pressed to develop agricultural advantages–regardless of technological expertise—because of her scarcity of good land.

Nations may also be able to maintain market-based advantages in particular industries, advantages that can persist over long time periods. The American lead in commercial aircraft, or some types of capital equipment—e.g., gear cutting machines—may not have resulted from unique technological skills so much as that certain kinds of products first found large markets in the diversified and affluent U.S. economy. Likewise, the Japanese lead in VCRs is now so great in terms of production scale and developmental experience that it would be very difficult to overcome.

None of these examples detracts from the primacy of relative costs of production and distribution in determining international trade flows. When a nation has comparative advantage in a given product, that advantage is usually visible as lower costs and prices, Sometimes manufacturing costs themselves may be the chief indicator—this has generally been the case in consumer electronic products. Sometimes price/performance ratios must be examined—the more typical situation for computer systems. In an industry like steel, where it has been clear for more than a decade that Japan has a comparative advantage in production costs with respect to the United States, the crucial questions—particularly for public policy—then concern sources of advantage or disadvantage, from the national perspective how to capitalize on the former while minimizing the latter.

As the discussion above suggests, most cost-based comparative advantages can be explained, at least to first order, in terms of resource availability and technology, Countries with ample supplies of capital relative to labor can expect to excel in industries that rely on capital-intensive production methods—e.g., synthetic fibers or primary metals. On the other hand, where production methods call for large numbers of unskilled workers, nations with abundant supplies of such labor—hence low labor costs—are likely to be the more efficient producers. Clothing and apparel, where much of the output is still hand-stitched, are well-known examples. In consumer electronics, low labor costs have helped Asian nations such as Japan, South Korea, and Taiwan achieve strong competitive positions; although automation has increased, assembly remains labor-intensive. Several American industries that have been losing competitiveness depend on substantial inputs of *both* labor and capital. To make either steel or automobiles requires large capital investments (in most but not all cases), while labor content is also high. Labor is expensive in the United States, while the Nation's advantages in technology and capital are not so great as 25 years ago. These long-term shifts are creating difficult problems for this pair of traditionally important American industries.

Consequences

For every comparative advantage, such as the United States has had in computer systems, there must be a comparative disadvantage, as now found in steel. Given flexible exchange rates, the value of a country's exports will normally counterbalance its imports almost exactly, since in a very real sense nations must use the proceeds from exports to purchase their imports. While this may seem straightforward, the consequences are not so obvious, Listed below are four general conclusions that follow from the earlier discussion,

1. *If a nation engages in international trade, some of its industries are by definition competitive, but some are also uncompetitive.* It is, to reiterate, impossible for a trading economy to lose competitiveness overall, since the very existence of trade implies that some sectors are price competitive while others are not. From a comparative advantage perspective, it makes no sense to state that the United States is losing its ability to compete. What can happen is that, over time, shifting patterns of comparative advantage may leave the United States less competitive in industries that once were leading exporters.

Some observers argue that the competitiveness of the United States has declined because its percentage of total world exports of industrial products has fallen relative to nations like West Germany or Japan. Such changes, however, are virtually inevitable in a world where industries in other countries have been growing much faster than those in the United States —overseas growth built in many cases on technologies painstakingly developed here. Similar fates are likely to befall the countries that today are experiencing the highest rates of economic expansion. Such nations as Brazil, South Korea, Mexico, and Taiwan are steadily increasing their share of world trade in manufactures. As these and other economies continue to industrialize, the current leaders are likely to find themselves losing ground in sectors that might now be mainstays. Certainly Japan's relative advantages in steel or consumer electronics are not nearly so great as they once were.

2. *If a nation overall rate of productivity growth—however productivity be defined and measured—is lower than in other countries, this need not result in losses of competitiveness for all that nation's industries, provided exchange rates are free to adjust.* Instead, real per capita income will decline relative to other countries, This may be a serious consequence, but should not be confused with impacts on *competitiveness.* Productivity growth does affect international trade flows, but again in a relative way: firms and industries where productivity growth is lower than average can expect to find themselves moving downward in a nation's efficiency ordering.

Nothing has yet been said about U.S. levels of productivity, cost, or efficiency compared to other countries, The comparisons have been internal. But it does follow that, if U.S. per capita *income* is to remain high, productivity levels must keep pace with those of our trading partners. At the same time, the sad fact is that an American firm or industry might be *more* productive—or otherwise efficient in its use of resources—than its overseas rivals and still not be competitive. The examples drawn on earlier can illustrate the point. In American industries like steel, apparel, consumer electronics—even shoes—labor productivity is as high or higher than in most foreign countries, yet these industries are in competitive difficulty. (The primary exceptions to this statement come when recessions in the United States are out of phase with those in other parts of the world; productivity levels depend on capacity utilization and can drop rapidly during downturns.) While these industries may be more efficient than their ***international*** rivals, other domestic sectors do better still. U.S. manufacturers of color TVs have not been sufficiently more productive than the average U.S. company to maintain their competitiveness; other American goods are more attractive to our trading partners, import competition in TVs stiffer, The first comparison for domestic industries is then their performance with respect to the rest of the domestic economy, again leaving aside distorting factors such as trade barriers or subsidies.

3. This conclusion follows: When *industries experience relatively rising costs in world markets, and lose market share both at home and abroad,* ***the price system*** *may* ***be signaling that resources should be reallocated internally—i. e., that domestic restructuring is necessary.*** To restore the competitiveness of declining industries would often require productivity improvements—for instance, through improved manufacturing technologies—greater than experienced elsewhere in the economy.

This may seem an especially harsh reality. It implies that a firm can take advantage of the, latest developments in product technologies, manufacturing processes, or both—but still not improve its ability to compete. Whether or not it can strengthen its position will depend on factors such as:

- the attributes of the technologies the company invests in (or the other investments it makes),
- the subsequent impacts on productivity compared with the rest of the domestic economy,
- responses to the investments by both domestic and foreign competitors, and
- the opportunities available to ***other*** trading sectors both here and abroad—far from last in importance.

It is an unpleasant fact that the realities of global comparative advantage may leave no simple remedies for a firm or industry bent on regaining its competitiveness. Substantial capital investment might be necessary to maintain the status quo but insufficient for improving competitive ability.

A brief example will illustrate: American automobile firms have been undertaking extensive programs of product redesign, accompanied by investments in new manufacturing facilities, intended to restore price competitiveness and profitability. The investments are huge, and clearly necessary if the industry is to again be competitive. Still, to succeed, these spending programs must do more than keep the U.S. industry on a par with productivity levels in Japanese automobile firms–if only because wages here are considerably higher. These wage levels reflect, not only the high productivity levels attained by U.S. automakers over the years, but also the lead in ***aggregate*** labor productivity that the United States still maintains with respect to Japan. To be competitive, the U.S. automobile industry must find ways to exceed the productivity levels in the factories of its overseas rivals—the same problem American steelmaker have faced since the 1960's. Given the available production technologies, this might not in fact be possible; certainly the steel industry has not found the key.

4. A further conclusion, relating to Government initiatives aimed at improving overall productivity: if such policies succeed—that is, ***if average productivity across all industrial sectors were to increase faster here than in other countries—then some formerly competitive American industries might become uncompetitive,*** Productivity improvements do not occur uniformly across an economy; some firms and industries improve faster than others. In terms of competitiveness, when some improve others will decline—even if the declining firms or in-

dustries experience productivity improvements of their own, and even if they improve faster than their rivals overseas.

This is a nontrivial conclusion. Phrases such as “getting the economy moving again” or “re-industrializing America” often seem to suggest that all industries can begin to compete internationally once new policies—whether changes in Government regulations, a revised tax structure, encouragements for exporting—are put into place. Unfortunately, this is highly improbable, if not impossible. The actual outcomes will depend on ***relative*** impacts—for instance, on how changes in tax law affect capital investment decisions and hence manufacturing efficiency across industries. Likewise, Government programs aimed at encouraging exports—removing disincentives, promoting American goods overseas, even providing subsidies such as tax benefits or low-interest loans—are unlikely, by themselves, to have more than marginal effects on competitiveness. Export incentives are puny weapons for combating structural problems, and—as experiences in several European countries show—even massive subsidies may be little help to an industry whose costs are too far out of line.

Many of these points apply across firms within an industry as well as across industries. Manufacturing sectors are typically populated by a spectrum of companies ranging from most to least efficient. In a relative price sense, some of the producers in a given country maybe fully competitive while others face difficulties. A particular Government policy might help all firms in a given industry; an alternative measure might help some firms but not others; still other policies might hinder all uniformly. In electronics, tax credits for research and development (R&D) are more likely to aid semiconductor firms intent on being at the leading edge of the technology than those that concentrate on low-cost production of standard devices, In a complex economy like that of the United States, it is not easy to determine a priori the outcomes of any particular set of policies. Even if the objective is to aid all firms, this may be impossible, A neutral policy—either among firms within an industry, or among industries within the economy—is a theoretical outcome that is seldom very closely approached. On the other hand, differential effects can rarely be quantified with much precision—and if they could, political choices among alternatives might be more difficult than they are now.

The essential lesson is that any policy adopted by Government will result in winners and losers, In an open economy, it is not possible to simultaneously help all sectors compete with foreign enterprises, The nature of the economic process dictates that choices be made when formulating public policies—choices that discriminate implicitly if not explicitly among sectors, and sometimes among firms.

Market Distortions and Nonmarket Factors

In assuming that prices in world markets depend only on costs and on the qualitative characteristics of goods that lead customers to perceive value in them, the previous section left aside many of the forces affecting competitive events. In reality, market distortions of several types can affect prices, as well as resource allocations and other economic decisions. One example occurs when governments provide otherwise uncompetitive industries with subsidies—direct payments, preferential allocations of credit, tax benefits, protection from import competition, As such a list suggests, distortions can be introduced by policies having targets—whether direct or indirect—quite apart from international trade, Several European countries openly subsidize industries in order to maintain employment levels, Some of these same countries point to the alleged advantages American high-technology firms get from R&D expenditures by the U.S. Department of Defense.

Pricing practices can also create distortions—e.g., dumping, normally defined as selling exports at prices less than charged domestically. Dumping is considered an unfair tactic under the rules of GATT (the General Agreement on Tariffs and Trade, ch. 11); governments typically attempt to counter such distortions in rather direct fashion, aiming to improve the operation of the price system. At least in principle, dumping margins can be offset by added tariffs, subsidies by countervailing duties. Remedies are less straightforward when the sources of impacts on pricing decisions are remote from the marketplace. The Tokyo Round Multilateral Trade Negotiations, completed in 1979, addressed one of the more complicated of these: implicit subsidies to exporters. Examples include government payments for R&D directed at domestic objectives —such as military security—which also, possibly as a side-effect, improve international competitiveness. In the United States, technologies such as semiconductors and computers (in their early days), jet engines, and nuclear powerplants have benefited from such expenditures, All have been strong export sectors for the U.S. economy. In recent years, countries like Japan and France have targeted commercial technologies and commercial industries quite overtly (ch. 10). While the Tokyo Round negotiations resulted in a new subsidies code to be implemented through GATT, this is only a small step toward resolving such issues.

In other cases the problem may not be distorted price signals, but market outcomes judged unacceptable. The most common instance—at least in terms of the frequency with which the argument is invoked—has probably been the uncompetitive industry claimed essential for national security. A number of countries have refused to allow open competition in computers because they believe domestic manufacturing is vital to their military strength. In the United States, spokesmen for the machine tool, steel, and automobile industries have advanced the national security argument,

At other times, unfettered competition is opposed for social or political reasons, The U.S. textile and apparel industry receives trade protection partly because it employs large numbers of low-skilled minority workers who might have difficulty finding jobs elsewhere. When, in early 1981, the Japanese were persuaded to limit exports of automobiles to the United States, the ostensible reason was to give American firms time to recover from recession and adjust to rapidly shifting market conditions; this step was taken even though there were few indications that trade restrictions would be a significant aid to recovery. In consumer electronics, orderly Marketing Agreements have been negotiated to soften the impacts of rising import levels. In these and other cases, political pressures—here and abroad—often carry more weight than economic indicators. The latter, for example, might instead suggest a need to shift resources to more competitive sectors. It is precisely when political pressures are most intense that the benefits of alternative policies should be widely aired before decisions are reached; the travails of the American steel industry have been aggravated by refusals, spanning many years, to directly confront the fact of shifting comparative advantage.

The Role of Technology

Any given technological development—a new or improved product, a more efficient manufacturing process—is likely to make some countries more competitive, others less competitive. For example, user-friendly software for numerically controlled (NC) machine tools would improve productivity most in countries that have a large base of NC machines coupled with a shortage of skilled parts programmers. More generally, even if the technology is widely available and all nations are able to implement it, some economies will benefit more than others. If a new manufacturing process reduces labor intensity, the competitive gain will be greatest for countries with high labor costs, least for those with large numbers of available workers. Even the most sophisticated new consumer electronic products may continue to be manufactured largely in the Far East so long as production requires sizable labor inputs. The effects of new technologies on international competitiveness depend, therefore, on attributes which must be related on a case-by-case basis to the resources available in each country and their costs, the mix of products manufactured and sold, and existing patterns of trade, Impacts of R&D projects—developments in both products and processes—are inherently

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difficult to predict. This can be troublesome for policymakers. When, if ever, does it make sense for government to select promising research areas for generalized support? To provide direct funding intended to maintain existing technological leads or foster new competitive enterprises? To support the development of avowedly commercial products? Different countries give different answers at different times. Even when the thrust of an R&D strategy might seem sensible, the consequences can be other than anticipated, It is entirely possible that a program sponsored by the U.S. Government could result in new products or processes better suited to the economic environments of our competitors.

"Technology gaps" have been an important source of U.S. comparative advantage in the past—notably in computers and semiconductors. Europeans tended to believe, as recently as the late 1960's, that technology gaps favoring the United States would be a permanent —and undesirable—feature of international trade, z These technological advantages have never resided so much in fundamental knowledge—whether of the sciences or engineering—as in the abilities of American firms to build on the existing knowledge base. *Applying* new technical knowledge can be a greater challenge—a different kind of challenge—than generating that knowledge in the first place; the guideposts are seldom so clear, the skills differ. In sectors as dissimilar as agriculture and electronics, the United States has been at the forefront in R&D and its applications; in both, exports by U.S. multinationals have been characterized by continual product/process developments. Even so, in microelectronics, these commercial developments have often proceeded without a well-established foundation in the physics and chemistry of electron devices. Such patterns are not uncommon; computer software, which has very sketchy theoretical foundations, is another case. Under such circumstances, the successes and failures of individual firms at product development have more direct consequences for competitiveness than do government R&D policies, although the latter help shape and direct technical progress.

Today, it is difficult to maintain purely technological leads. Unless knowledge of the technology is coupled with unusual resource requirements—large capital investments, sophisticated research facilities—diffusion among industrialized nations will be rapid. Moreover, the flow of technical information is no longer so one-sidedly *from* the United States overseas as during the 1950's and 1960's. Firms in many countries now have the ability to locate and license the technologies they need, or to quickly duplicate products and processes developed elsewhere.

In essence, this means that gaps in technology should be viewed as largely self-closing, if only because it is easier to catch up by imitation than to create new knowledge. While some Americans continue to lament the passing of clear-cut leadership by the United States, there is little to be done except to work hard on our own technical abilities; it is plain that other countries can make a great deal of progress with imported technologies provided they have capable people and adequate capital for investment. virtually all the nations that compete with the United States have taken advantage of this avenue. Japan consciously followed a strategy of purchasing technology from European and American companies.[3] Importing foreign technology has, in fact, been a central element in Japanese economic development since the late 19th century.

Although Japan has recently been the most conspicuous in adapting foreign technologies, virtually all countries lean in one way or another on more advanced economies to foster development. Nations such as Taiwan and Korea are doing so today. During the 19th century, and earlier in the 20th, the United States

'See, for example, J. J. Servan-Schreiber, *The American Challenge (New* York: Atheneum Press, 1968).

[3] T. Ozawa, *Japan Technological Challenge to the West, 1950-1974: Motivation and Accomplishment* (Cambridge, Mass.: MIT Press, 1974).

imported a good deal of technology—e.g., for making iron and steel. In the postwar period, German expertise in rocketry helped build the U.S. space program. When the United States develops a synthetic fuels industry, it will depend to considerable extent on the technology base developed earlier by countries without our petroleum reserves.

In essence, flows of knowledge among developed countries have returned to a situation more like that before World War II; diffusion of technology has also been accelerated by the activities of multinational corporations. Particularly in electronics, foreign investments by U.S. firms have aided infrastructure] development in many countries, industrial as well as industrializing. Even in the absence of joint ventures or other corporate connections, electronics firms in many parts of the world now have the ability to monitor and learn from developments elsewhere, taking advantage of the multiple pathways by which technology moves inter nation ally.

From the standpoint of the individual firm, that technology transfers take place so rapidly makes R&D more rather than less essential. Companies that are leading try to stay ahead. Those that are behind must do their best to utilize the technologies available to them. The United States still maintains technological leads in electronics—computer software, minicomputers, microprocessor designs, office automat ion equipment such as word processors. These leads are not as large, nor as broadly based, as a few years ago. Because commercial advantages are short-lived, continuous effort is required; in today's economy, cutting R&D expenditures is often tantamount to accepting a position of dependency on technology developed elsewhere, Nations without the resources to stay at the leading edge may have no alternative. On the other hand, economies now at the forefront have evolved industrial structures adapted to a leadership position. To slip back means a painful adjustment-not only technical stagnation, but marked shifts in trade patterns.

Other Perspectives on Competitiveness

Productivity

Some commentators hold that an industrial economy is losing competitiveness if its aggregate productivity-i,e., gross domestic product (GDP) per capita—is growing more slowly than the GDPs of its rivals. The United States, by this definition, would be declining in competitiveness relative to most other industrial nations. Q Great Britain is the obvious example of a nation losing competitiveness, in this view, over several decades.

To what extent are definitions of competitiveness based on relative productivity levels meaningful? The question hinges on the relation between aggregate productivity, or GDP, and economic competition, This relation is not a close one; as pointed out in the previous section, even countries with very high rates of productivity growth cannot be competitive in all industries. Japan's agricultural sector is inefficient and unable to compete internationally–as a result of which farmers have used their political power to exact trade protection from the Japanese Government. Nor do rapid increases in productivity necessarily correlate with technical leadership. Japan, with unmatched productivity improvements over the postwar period, has depended on the United States and Europe for much of its technology. Early applications of robots—an area where Japan has lately gained a justified reputation for leadership (ch. 6)–were based on equipment imported from the United States. In electronics, Japanese companies have only recently begun to compete in product lines character-

[4] See U.S. *Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-ISC-135, July 1981), p. 62, for trends in gross domestic product in four countries compared to the United States.

ized by the newest technology; for the most part, inroads have been in such products as radios, TVs, and standard semiconductor devices. As Japanese firms move into high-technology product lines, these patterns change; still, they belie the significance of aggregate trends in productivity or GDP by themselves. Indeed, for many years other countries expressed little concern over Japan's competitiveness despite the explosive growth of that nation's economy—some even continued to denigrate Japanese products as the cheap and shoddy output of low-cost labor.

Nevertheless, relative productivity gains—considered either in the aggregate or on a sector-by-sector basis—are central to the dynamics of any nation's economy. Differing rates of productivity growth will, over time, lead to shifts in the structure of international trade and thus the competitive positions of firms and industries throughout the world, In the United States, sectors where the pace of technological change has been modest—steel, automobiles, shoes, consumer electronics—have borne the brunt of restructuring; penetration of American markets varies considerably among these industries, but in each the Federal Government has resorted to trade restrictions to control imports and blunt competitive pressures. At the same time, even in such industries, the stronger U.S. firms have often maintained their ability to compete with overseas rivals; most often, the companies displaced were in trouble before imports became a factor. In consumer electronics, Zenith and RCA have lost little in the way of market share, though imports and U.S. investments by foreign corporations have driven others from the business. In steel, domestic minimills have steadily won sales in selected product lines from larger American steelmaker; they have done so in the face of stiff import competition, Thus, the primary effect of import competition may be to accelerate processes of industrial adjustment already underway. Market penetration by imports in such industries need not imply that an economy is in overall decline. These same industries may eventually find themselves revitalized; indeed, many economists contend that exposing industries to competition is crucial to their continued healths This is an attitude long reflected in U.S. antitrust law.

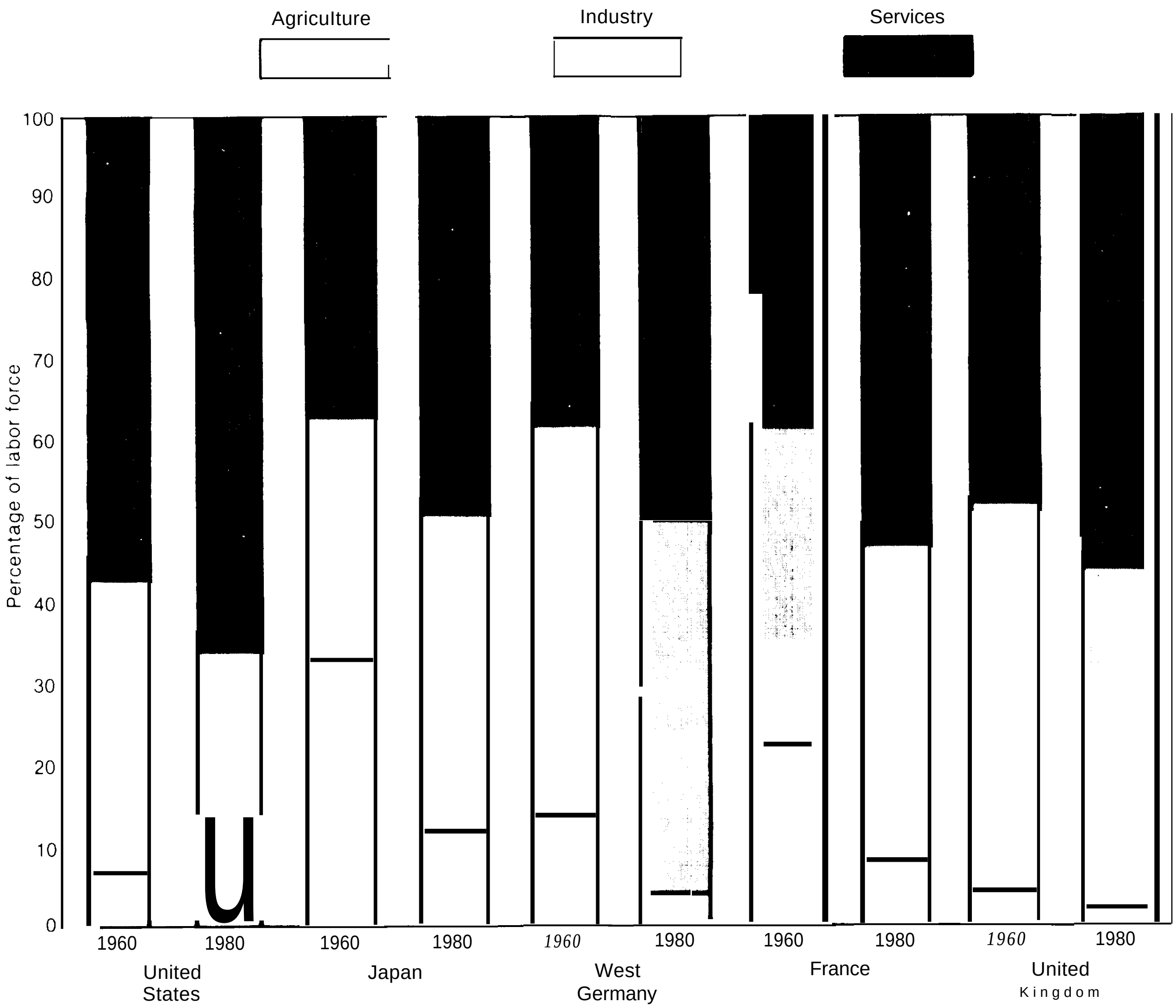
One reason for slow productivity growth in the United States is simply this Nation's greater industrial maturity compared with many of its rivals—shown, for instance, by the much greater proportion of economic activity devoted to services than manufacturing. As figure 32 indicates, by 1980 two-thirds of the American work force was employed in the service sector. Other industrial countries continue to employ more of their people in industry, fewer in services; even in the United Kingdom, services account for only a little over 55 percent, Productivity improvements in the service sector are more difficult to achieve—or at least to measure. Despite the much lamented decline in U.S. productivity growth, the *manufacturing* portion of the American economy continued to increase its productivity about as fast during the 1970's as over the preceding 20 years.[6] Even if productivity improvements have lagged in the service sector, the shift has brought compensations internationally. Revenues to American firms for such services as the engineering and construction of public works projects—airports, hospitals, dams—have increased rapidly. As one result, other portions of the economy have moved downward in the rank ordering of U.S. comparative advantage, In other words, the United States is substituting exports of services for shipments of industrial products, importing more of the latter. The substitution need not imply either rise or decline in competitiveness,

Of course, greater aggregate productivity in the United States as measured by GDP per capital—one of the fundamental indicators of living standards—is a desirable goal wholly apart from its possible influence on competitiveness, But public policy instruments directed at the

[5]For a well-known statement of this view, see B. Klein, *Dynamic Economics* (Cambridge, Mass: Harvard University Press, 1977).

[6]*U. S. Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles,* op. cit., table 10, p, 61. Annual productivity growth in manufacturing was 2,4 percent from 1950 to 1970, 2.3 per-cent from 1970 to 1979.

Figure 32.— Distribution of Economic Activity in Several Countries



SOURCE *World Development Report* 1982 (Washington D C World Bank, 1982)

general dilemma—i.e., macroeconomic and market promotion policies—would be more likely to achieve such objectives than measures aimed at improving the positions of particular industries. The tax reductions and savings stimuli embodied in the Economic Recovery Tax Act of 1981 are examples of steps that should help improve productivity. Still, even if they lead to greater productivity growth, there may be little change in the competitive positions of many American firms. All else equal, aggregate productivity improvement will be reflected in shifting exchange rates, which in turn will increase the price competitiveness of some industries while decreasing that of others,

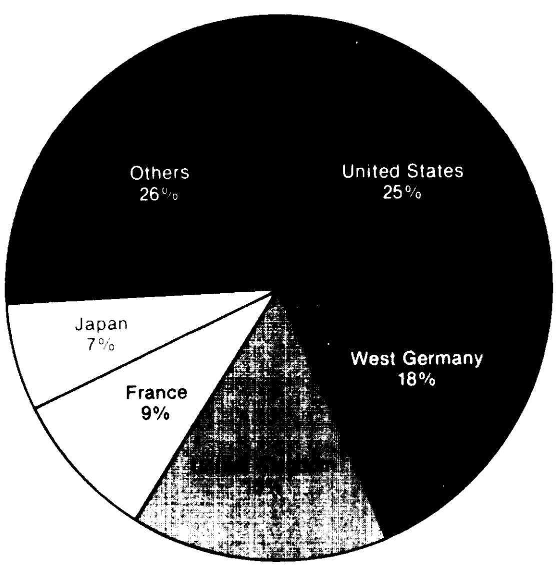
Market Share

Another common perspective on competitiveness starts with market shares of different countries. In this view, a drop in the U.S. share of world manufacturing exports could indicate a loss in competitiveness. The popularity of market share as a measure of corporate performance helps account for the application to international competitiveness. For measurement purposes, markets can be defined globally, nationally, or regionally. Figure 33 compares the U.S. share of world trade in manufactures to the shares of several other countries. Perhaps the most striking point made by the figure is the huge expansion in total world trade: a sixteenfold increase between 1960 and 1980; changes in country market shares, in contrast, are matters of a few percentage points. The United States is now less prominent among exporting nations, but to transfer a parameter such as market share—with real though limited meaning in a corporate setting–to the arena of trade between nations risks misunderstanding. Losses in the U.S. share of world markets are virtually inevitable as other nations progress economically. Starting from a lower postwar base, growth rates elsewhere have frequently exceeded those here. As a result, the United States has been left with a smaller portion of total world output, and a smaller share of trade; to some extent, market share is nothing more than a surrogate for comparing economic growth rates.

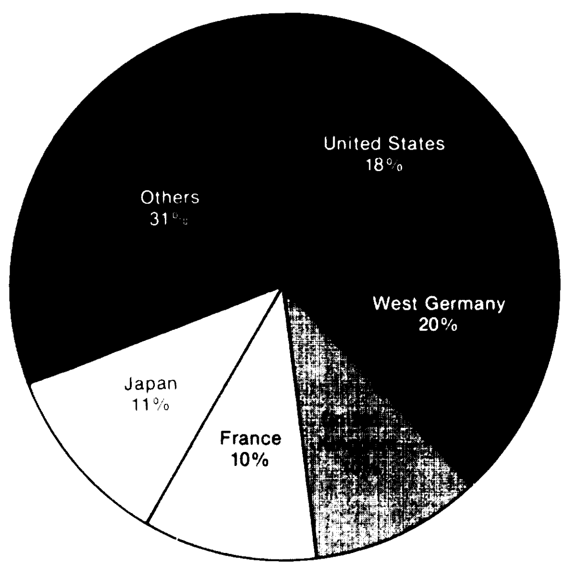
Rather than worldwide exports, would shares of the U.S. domestic market or particular third country markets make better indicators of competitiveness? If the U.S. market is the basis for comparison, the expansion of trade as a percentage of GDP must be considered. Growth in trade—exports as well as imports—has exceeded income growth in the United States, as table 43 indicates. That growth in imports exceeded that for national income does not, by itself, imply a loss of competitiveness; indeed, the growth rate for exports over the period in the table is a bit higher,

If the intent were to evaluate competitiveness by examining the exports of advanced economies to nations in the developing world—where the United States has, on the whole, declined—the question is then whether American corporations have slipped in their ability to compete with foreign exporters. Is this so?

Figure 33.—World Exports of Manufactured Goods[a]



1960
Total $55 billion



1980
Total. $880 billion

[a]Exports of 14 major industrial nations excluding exports to the United States Total export figures are approximate

SOURCE *International Economic Indicators*, Department of Commerce, International Trade Administration, March 1978, p 59 and December 1981, p 34

Table 43.– U.S. Gross Domestic Product (GDP), Exports, and Imports

	Value in billions of constant 1972 dollars	
	1960	1980
GDP	$732.0	$1452.4
Total U.S. exports	38.4	161,1
Total U.S. imports	30,7	109.1

SOURCE Department of Commerce, Bureau of Economic Analysis

Not necessarily, and for several reasons—the first being rates of economic growth in particular developing country markets. Long-established ties still link traditional trading partners-e. g., France and her former colonies. Such patterns tend to be rather stable; the proportion of U.S. trade with Canada and Latin America remains high, European firms tend to have a greater presence in African markets, Japan has high export shares in the Far East. If market position in the developing world were to be treated as an indicator of competitiveness, relative shifts in the position of a country such as the United States might simply reflect the economic growth rates of traditional trading partners relative to other developing nations. Moreover, changes in the American share of exports might indicate nothing more than a varying mix of goods and services sent abroad. If the United States is moving toward increased exports of technologically sophisticated products and services—and if the imports of developing countries tend to be lower in technology–then U.S. market share might decline for this reason alone. Should it be taken as a sign of reduced competitive ability that Japan replaces the United States in exports of automobiles to, say, Canada at a time when American exports of computers to both Canada and Japan are rising? Finally, U.S. trade performance on a relative basis could slip because of the activities of multinational corporations. American firms have invested heavily abroad compared to their counterparts in other countries, Foreign direct investment by U.S. corporations averaged $15.5 billion annually over the period 1977-81; in contrast, West German companies invested an average of $3.9 billion, Japanese $2,8 billion, while British firms spent $5.8 billion.[7] Overseas manufacturing by subsidiaries of American multinationals may substitute for goods earlier shipped from the United States. Furthermore, subsidiaries may themselves export, adding to the shipments of countries with which the United States competes. Does this diminish U.S. competitiveness? It would be hard to argue for such a conclusion in the common case of subsidiaries that owe much of their competitive advantage to technology and skills developed by the American parent.

The point is not to slight the significance of relative market shares, but to note that trade statistics reflect economic currents that may be unrelated to competitive ability. Furthermore, wholly exogenous events can have great impact on comparative trade figures. Virtually all the countries with which the United States competes depend far more heavily on imported energy. Changes in oil prices have much greater effects on the trade positions of such countries; when energy costs jumped in the mid-1970's, European and Japanese imports swiftly rose in value terms, creating sudden trade deficits. Among the consequences, exchange rates eventually adjusted to bring exports more closely in line with new levels of imports (while many countries were able to cut quantities of energy imports, the value of these imports still tended to increase). One result was a reduction in the U.S. share of world exports. Again, there is no reason why this should imply a shift in competitiveness.

Indicators Based on Technology

According to yet another view, U.S. competitiveness has declined because other nations have gained ground in technical ability--i.e., the technology gaps that once benefited the United States have narrowed or vanished.

[7] *International Economic in dicators,* Department of Commerce. International Trade Administration, June 1982, p. 54. The figures for the United Kingdom exclude investments by oil companies. Investment levels fluctuate markedly from year to year; for instance, U.S. foreign investments fell by more than half from 1980 to 1981,

While often true in particular cases, such conclusions can only be substantiated by careful examination on a technology-specific basis; generalizations about technological capability are often suspect. Moreover the implications for competitiveness are not always straightforward; many Japanese companies have followed behind and benefited from the experience—including mistakes—of innovators in the United States.

Attempts to develop indicators of technological competitiveness founded on some basis other than case-by-case evaluations have generally focused on patents, occasionally on dates of introduction of new products or processes. By such measures, the relative position of the United States has been declining in many industries.[8] Yet patent statistics or product/process introductions are highly imperfect measures of technical competence, particularly if used in isolation. There are simply too many factors other than the characteristics of the technology that affect them. In some portions of electronics-semiconductors for one-firms tend to view patenting as a routine tool of business. Rather than a means of "protecting" technology, or capitalizing on it in any concerted fashion, a patent may be something to be bartered. Under such circumstances, correlations between patent statistics and technological ability have little meaning. Some observers point to the high rates of patenting by Japanese electronics firms (see ch. 10, table 77) as a foreboding sign; however, it seems clear that reward systems in Japanese firms encourage patenting regardless of the value of the technology patented.[9] Even in the United States, only a small fraction of the patents granted could be considered meaningful advances in the state of the art.

Patents or similar indicators give an especially oversimplified picture in industries like electronics where technological change is rapid and product cycles can move more quickly than the patenting process. Again, there is no substitute for case-by-case analysis. In semiconductors, American companies are generally still the first to introduce new or improved designs for microprocessors or more specialized memory circuits—static random access memories (RAMs), various types of read-only memories (ROMs)—but today their lead is brief. Where new products from American firms win acceptance in the marketplace, Japanese manufacturers have been quick to follow with cheap, reliable devices of their own. They appear to have taken the lead in dynamic RAMs, a product where the path of technical evolution is well marked, with little uncertainty over what the market wants.[10]

Likewise in the computer sector, several countries can match American capabilities over a range of hardware. This rough technological parity does not so readily translate into competitive ability. Selling computers demands much more than hardware; commercial success depends heavily on software—a field in which American companies maintain a useful lead, even more so as software costs continue to rise compared to hardware. Also important are service, a good appreciation of user needs, and other customer support functions. Although prospective mainframe purchasers tend to have a relatively sophisticated understanding of the technologies offered by competing manufacturers, customers for small business or home systems may know less about computers than about the family car. Selling

‘*Science Indicators 1980* (Washington, D. C,: National Science Board, National Science Foundation, NSB-81-1, 1981), pp. 16-22.

‘A number of other factors act to encourage patent registrations in Japan, including very low fees. See S. Fleming, "IFO Offers View of Rise in Japanese Patents, " *Financial Times, May 7, 1982.*

[10]Pilot production of 256K RAMs by the major Japanese manufacturers began at the end of 1982—evidently well ahead of the plans of American merchant manufacturers, though Western Electric announced a 256K chip in mid-1983. See "Recent Developments in Japanese 256K DRAM Production, " *Japan Report,* Joint Publications Research Service JPRS L/11128, Feb. 8, 1983, p. 39. Nonetheless, introduction dates do not tell the whole story, Hitachi was the first to announce a 64K RAM for the merchant market, early in 1978. (IB M's 64K chip entered volume production the previous year.) However, Hitachi's design required two supply voltages, was rapidly superseded by single-supply designs from other manufacturers, and never mass produced. See "64K RAM Sweepstakes: Round 4 Winner Is . . . ," *Morgan Stanley Electronics Letter,* June 29, 1979, p. 1; E. W. Pugh, D. L. Chritch-10W, R. A. Henle, and L. A. Russell, "Solid State Memory Development in IBM, " *IBM Journal of Research and Development,* vol. 25, 1981, p. 585.

in such markets is just as much an art as designing the system in the first place. But the main point is that even in rapidly evolving technologies, the United States cannot expect to maintain the kind of technological leads that existed in the 1950's and early 1960's. Other countries can now keep close—perhaps abreast —in fields they choose to emphasize, if not across the board.

While there is no need for pessimism, it should be clear that the United States cannot live off its past achievements. U.S. R&D expenditures fell as a proportion of GDP for 15 years before beginning to turn back up at the end of the 1970's. Meanwhile countries like West Germany and Japan have been stepping up their research spending, at the same time devoting far smaller fractions to military R&D. Still, the United States continues to spend substantially more on R&D than any other country. " Furthermore, if the United States is able to borrow from other countries as they have borrowed from us, increased R&D spending in other nations could ***help*** U.S. competitiveness. In any event, figures on royalty and license payments continue to show the United States maintaining a large and growing surplus against other industrial nations; although technology gaps may be shrinking, the United States is still predominately a source of knowledge rather than a user of skills developed elsewhere. [12]

[11] *U.S. Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles,* op. cit., pp. 62-64, See also ch. 10 of the present report.
[12] *U.S. Industrial* Competitiveness: *A Comparison of Steel, Electronics, and Automobiles,* op. cit., pp. 64-65.

Other aspects of the U.S. environment for technology development, several discussed more thoroughly in subsequent chapters, do give cause for concern. As one example, this country has been lagging in the education of the technically trained people upon whom technological progress depends.[13] Japan, with half the population, now graduates more electrical engineers than the United States. And, far more than here, the people occupying leadership positions—whether in business or government—in Japan, West Germany, or France tend to have technical backgrounds, These signs suggest that other nations may be better placed to understand and exploit future technological opportunities.

Furthermore, the United States allocates as many as 25 percent of its best technical people to defense-related R&D and production, a higher percentage than most other countries except for the Soviet Union and its allies. While it is true that military research sometimes spills over into commercial products, with benefits for technological competitiveness—as happened with computers, aircraft, semiconductors, and nuclear power—it is also true that these are the exceptions, Certainly the fears expressed by Europeans in the "technology gap" debate of the 1960's proved exaggerated: U.S. spending for defense and space has by no means allowed American firms to continue dominating high-technology markets.

[13] Ch. 8; see also J. A. Alic, M, Caldwell, and R. R. Miller, '"1'he Role of Engineering Education in Industrial Competitiveness " *Engineering Education,* January 1982, p. 269.

International Competition in Electronics

Evaluating Competitiveness

Assessing the competitiveness of the United States is more difficult in electronics than in most industrial sectors. This is partly a matter of the diversity of the industry; few parallels exist between the current situation in consumer electronics and that in computers. The importance of the technology and its rate of change means among other things that production costs—often the primary determinant of a nation's ability to compete—are less central. Certainly this is true compared to, say, agriculture or steel. But if cost is less critical in computer manufacture than for color TVs, it is never irrelevant—certainly not for firms trying to compete with IBM.

Manufacturing costs in electronics are closely tied to a firm's ability to utilize product as well as process developments. In most parts of the industry, the advantages of incorporating new *product* technologies as a means to lower costs—more generally of providing greater value per dollar—far outweigh those of simply manufacturing conventional designs more efficiently. Even in mature segments of the industry such as color TV, advances in microelectronics may lead to new product features or simpler and cheaper design approaches not feasible earlier.[14] Companies that fail to keep pace find their vulnerability heightened, particularly at the low-priced end of the market where import competition is stiffest.

Because of the changing technology, trends in the usual indicators of competitiveness—such as labor productivity (output per hour)—are either unavailable or of little relevance to electronics .15 While chapter 9 examines productivity in electronics for insights into impacts on employment, output per man-hour or value-added per man-hour has less to tell about competitiveness. Today's TV set is a different product than those of 10 years ago. Labor productivity statistics ordinarily assume that goods remain qualitatively the same—a ton of steel, a bushel of wheat. The more their characteristics change over time, the less meaning productivity trends convey. The problem extends to many economic sectors, Even steel or wheat change; the physical properties of steel improve with better control of chemical composition and processing, the nutritional value of wheat increases as hybrid varieties are introduced, But the rates of change are slow compared to electronics.

14 For example, digital rather than analog Circuitry for Processing incoming TV signals carries the potential for greatly reducing numbers of chassis parts, thereby cutting assembly costs. In addition, many of the adjustments needed during manufacturing could be eliminated. See T. Fischer, "Digital VLSI Breeds Next-Generation TV Receivers, " *Electronic.~*, Aug. 11, 1981, p. 97. Ch. 6 outlines reductions in parts counts in TV chassis over the past decade. These reductions have helped keep prices stable despite inflation.

15 Comparative shifts in labor productivity over time are one of the more useful measures of changes in the competitiveness of a nat ion's industries, See U. *S. Industrial Competitiveness; A Comparison of Steel, Electronics, and Automobiles*. op. cit., ch. 4, especially pp. 54-58.

Technological advance also means that many products selling in large volume today did not exist a few years ago—thus productivity gains cannot be calculated at all. How can productivity improvements be evaluated for integrated circuits (ICs) with a lifetime of 4 or 5 years from large-scale production to obsolescence? Can measures of productivity such as value-added or output per worker-hour for a 64K RAM manufactured in 1983 be compared to those for the 4K RAMs of 1975? What does labor productivity mean for pocket calculators—where this year's offering may be twice as powerful as last year's? Although manufacturing costs can be a vital ingredient in determining sales volumes for all these products, conventional approaches to international competitiveness must be applied with care.

Regardless of the pitfalls and uncertainties, policy guidance demands insights into whether the United States is gaining or losing ground. Electronics is a high-technology field par excellence, one in which this country has been a leader for decades, If U.S. competitiveness declines here, there is more to worry about than the shifting patterns of comparative advantage that affect textiles or even steel. The concerns extend beyond declining productivity growth, beyond the possibility of relative losses in per capita income; while these are far from trivial matters, it is fair to say that a loss of technical leadership in electronics would do much greater harm. The Nation's military security depends in many ways on electronics technology. Even more, decline would have dire implications for the future vitality of the entire economy. If the United States were displaced as the primary technical innovator in electronics it would be a symptom that this country was following Great Britain on the path to industrial decay,

But is this the case? Much that has been said on such matters is impressionistic and emotional—all the more reason to collect and evaluate the evidence with care. The remainder of this chapter examines the question of U.S. competitiveness in electronics primarily through examination of business strategies. While consumer electronics, semiconductors, and computers are treated separately, some of the distinctions risk becoming artificial; semiconductor manufacturers, following their earlier attempts to enter consumer markets with products such as watches and calculators, are busy designing "systems on a chip" to help them move into markets for industrial end-products. Meanwhile, computer firms integrate backward to make ICs. Desktop computers sold at retail blur the line between consumer and original equipment markets. Are personal computers a product of the consumer electronics sector or the computer sector? The microcomputer market was developed first by entrepreneurial firms, later by companies like Tandy Corp.—largely consumer oriented. Now that Digital Equipment and IBM have entered, vastly different enterprises-in size, style, market power—are competing with one another. I B M's tactics, involving heavy reliance on outside suppliers (including imports of industrial robots from Japan to be controlled by the company's personal computer) mark a turning point for a firm that in the past has designed and produced virtually all its own hardware and software-evidence of the flux within this part of the industry.

While many industries go through periods of rapid expansion and change, evaluations of competitiveness are more problematic in the midst of such a process. The marketplace will eventually sort out the winners and losers in desktop computers, but no one can predict with much confidence which firms will survive and prosper, Because in the end a nation's international trade position is built on the successes and failures of individual business enterprises—the competitive tactics and strategies pursued, here and abroad—the remainder of the chapter discusses competitiveness from the strategic perspective. While such an approach does not result in direct indicators of competitiveness, it leads to an understanding of the dynamics of trade and competition not possible by other means.

International Business Strategies

Corporations compete on much more than product technologies and efficiency in manufacturing; success depends on effective approaches to markets, approaches that take account of a particular firm's strengths and weaknesses. As Texas Instruments' experiences with digital watches and small computers exemplify, state-of-the-art technology is no guarantee of ability to bring to market products that consumers will purchase.

The following pages review some of the moves and countermoves by participants in world markets for electronic products. That strategic considerations are vital comes as no surprise: explications of corporate strategy are a staple of the business press; they provide fodder for professors of business administration, handsome fees for management consulting firms, And for good reason. A not inconsequential part of U.S. economic growth can be traced to the ability of American firms to move rapidly into emerging markets, to commercialize evolving technologies—ability embodied in the managers, technical staffs, and other employees of these companies. The success record of American corporations extends to technologies originating in other countries. The technical underpinnings for digital computers have been fed by the efforts of engineers and scientists in many parts of the world. One aspect of the American genius has been turning arcane developments such as the computer into thriving commercial industries. The skills needed for success in the marketplace can be quite different from those called on in basic research. The British built the first jet transport plane, but are no longer much of a factor in the industry; today, the Comet is remembered chiefly for its lessons in metal fatigue.

Most privately funded R&D—in the United States as elsewhere—is directed toward product development. Marketing strategies based on product differential ion have a place even at the leading edge of microelectronics or computer technologies. Bell Laboratories devotes around 90 percent of its efforts to development, 10 percent to basic research (a considerably higher proportion of basic research than found in most electronics firms), That an R&D organization known best for its more fundamental work—including research that provided much of the foundation for solid-state electronics—in fact gives most of its attention to development points to the central importance of such activities. As the focus on development suggests, many of the "technology gaps" separating the United States from its competitors have been associated with product design rather than underlying differences in technical capability. The microprocessor was an innovation in the semiconductor design; it did not depend on new manufacturing technology, still less on improved understanding of the physics of electron devices,

More recently, American electronics firms have sometimes found themselves in reactive positions rather than leading in product and process developments, Innovation remains a source of U.S. competitive advantage, but other countries have become more active in introducing new products, as well as new manufacturing techniques. This has been one cause of slipping U.S. competitiveness in industries like steel and automobiles; while innovation in the electronics industry has certainly not stagnated, the U.S. lead is no longer unchallenged. Executives of American firms have repeatedly found themselves responding to competitive thrusts from foreign firms rather than taking the initiative. These thrusts have involved imaginative, well-researched, and well-designed products, In electronics, new competitive pressures have come most notably from the Japanese, but in some cases also from countries that are still industrializing.

Strategies in Consumer Electronics

More than in any other industry, Japanese companies have come to dominate world markets for consumer electronics, Beginning with portable radios, the Japanese moved successively into a broad range of other products: monochrome TV, high-fidelity sound systems, CB transceivers, pocket calculators, color TV, VCRs. Many of these were developed first in the United States. Video recorders are a telling example; Japanese firms make well over 90 percent of the world's VCRs—a product with origins in the laboratories of Ampex and RCA. The product development, manufacturing, and export strategies followed by Japanese firms in consumer electronics—discussed below in the context of the U.S. market, although applying with only minor variations to export thrusts into Europe as well—have often been transferred to other parts of the industry.[16] Thus, they are a logical starting point for an examination of business strategies in electronics,

Japan

Efforts by Japanese firms to sell TVs in the United States—beginning in the mid-1960's—included three parallel strands, First, the export drive began with a focus on market niches that appeared to be served inadequately or not at all by American manufacturers—the kind of opportunity that firms anywhere look for when attempting to enter new markets (app. C describes how Phase Linear, an American manufacturer of stereo components, created a new market category with its first product). The second strand in the Japanese thrust was to draw on product technologies and manufacturing experience gained in their highly competitive, if protected, home market—as well as in exporting to other Far Eastern nations; Japan's manufacturers had a strong foundation for selling in the United States. Third, TV shipments were part of a continuing effort by Japanese companies to export a succession of products of increasing technical sophistication. The strategy, while carried out by firms that competed among themselves, plainly was guided and encouraged by the Japanese Government through MITI (the Ministry of International Trade and Industry) and other agencies.

Success was by no means guaranteed. In the 1960's, the U.S. TV market was served by more than a dozen domestic entrants, These in-

[16] See, for example, R. Ball, "The Japanese Juggernaut Lands in Europe," *Fortune, Nov.* 30, 1981, p. 108.

eluded some of the largest merchandisers and electrical equipment manufacturers in the country. Firms like RCA, Zenith, GE, Sylvania, and Magnavox had patiently constructed nationwide distribution networks. Their dealers generally handled servicing and repairs as well as sales. Much of the production of smaller companies consisted of private-label sets for retailers like Sears, K Mart, and J. C. Penney. Although the market was still expanding rapidly, its structure was relatively mature, Such a market is not an easy one to enter, especially from abroad.

The Japanese manufacturers recognized their disadvantages: 1) lack of an established distribution and service network; 2) lack of recognized brand names, a deficiency accentuated (at that time) by the lingering reputation of Japanese goods for shoddy quality. These factors argued against direct competition with entrenched industry leaders such as Zenith and RCA.

The Japanese sought ways around these barriers through both technical developments and marketing strategies. First of all, manufacturers in Japan moved quickly toward solid-state chassis designs, following their earlier successes in exporting transistorized portable radios. The intent was to lower manufacturing costs over the long run, and—perhaps more important—improve reliability and reduce the need for service (ch. 6). Japanese TV manufacturers could not be certain of reaching either objective, American producers chose to stay with older technologies, partly in the belief that it was too early to expect improvements in either costs or performance from solid-state components.

The development of solid-state TV designs in Japan during the ***1960's*** illustrates the selective nature of government assistance. The Kansai Electronic Industry Development Center served as the coordinating body for a multiyear R&D project directed at using ICs in TV chassis, The cooperative effort, with funding from MITI, included five Japanese consumer electronics manufacturers, seven parts suppliers, four universities, and a pair of research institutes.[17] Despite this, perhaps the most important policy support came through TV broadcasting; Japan's Government has gone farther than most by actively promoting such new technologies as stereo sound for TVs, multiplexing to give multiple language capability, and direct satellite broadcasting. Such measures have fueled demand in the domestic market, helping build a base from which Japanese manufacturers could achieve scale economies and export.

The second leg of the Japanese plan centered on their selection of products. Here—as later the case in automobiles—the choice may have been more fortuitous than brilliant. The first Japanese exports were small-screen sets (ch. 4, especially table 9), where they had experience, and where solid-state designs contributed to light weight and portability. For a variety of reasons, the product lines of American firms were thin in this part of the market. The Japanese emphasis on small-screen TVs turned out to coincide with rising demand for second sets in American homes, demand that was more price elastic than for the first of a family's purchases.

Design improvements such as solid-state chassis helped Japanese exporters bypass traditional distribution channels. Greater reliability reduced the need for service and repair facilities, as well as for large stocks of spare parts, opening the way for distribution through outlets where low price would have immediate impact, Japanese exporters first sold their TVs through private-brand and discount retailers, a tactic that had worked earlier with portable radios.[18] AS part of their marketing plans, it appears that exporting firms frequently induced retailers to carry their product lines by offer-

[17] E. Sugata and T. Namekawa, "Integrated Circuits for Television Receivers," *IEEE Spectrum*, May 1969, p. 64. Three of Japan's largest TV manufacturers were included: Matsushita, Sanyo, and Mitsubishi.

[18] Toshiba began supplying Sears with small-screen color sets as early as 1964. This marked the beginning of Japan color TV exports to any country, and the beginning of U.S. imports of this product. See "International Technological Competitiveness. Television Receivers and Semiconductors, draft report under National Science Foundation Grant No. PRA 78-20301, Charles River Associates Inc., Boston, Mass., July 1979, p. 2-18.

ing higher than normal margins.[19] In essence, the Japanese tried to make TVs an "off-the-shelf" item. Note again that this strategy depended on producing TV sets with considerably greater reliability than had been common.

Instead of head-on competition with entrenched American producers, the Japanese thus located a market niche that was relatively open, and offered low-priced but well-designed TVs of high quality through price-sensitive retail outlets. Indeed, price was a dominant aspect of the Japanese thrust; dumping complaints brought by U.S. interests were repeatedly upheld, as discussed in chapter 11. Still, low prices by themselves were far from sufficient for the steady expansion of exports that followed this opening wedge. In a pattern now familiar, Japanese exporters widened both their product lines and distribution channels. Eventually, they began to assemble TVs in the United States. Japanese manufacturers now compete virtually across the board with American consumer electronics firms, utilizing many of the same retail outlets.

Some accounts have emphasized the dependence of Japanese pricing strategies on the closed nature of their home market. This was a central claim in the dumping proceeding initiated by the Electronic Industries Association in ***1968.*** In this view, low-priced Japanese exports were only possible in the early years because of trade protection that kept imports out of Japan; closing their domestic market to TVs produced by more advanced American and European firms allowed the Japanese to charge high prices at home, effectively subsidizing their exports. Investigations following the 1968 dumping complaint provided support for these allegations.

On the other hand, dumping in international markets implies monopolistic pricing by Japanese firms that, most observers concede, compete intensely within Japan. The implication, then, is that these companies colluded only with respect to exports—or that manipulation by higher authority, presumably MITI or some other agency of the Japanese Government, took place behind the scenes. Such possibilities cannot be rejected out of hand, but are not wholly consistent with the rest of this view: that Japanese TV manufacturers took advantage of their protected domestic market to generate the economies of scale needed to compete in the United States. From the perspective of highly competitive Japanese firms, price-led expansion at home might well have seemed a more attractive way to maximize learning and scale benefits.

The American Response

Exports to the United States by Japanese consumer electronics firms were by no means new. As early as 1954, Japanese companies had begun to manufacture transistors, with much of the output going into portable radios. Within 5 years, fully **80** percent of the radios produced in Japan were solid-state, many of them destined for sale in the United States.[20] In exporting radios, the Japanese gained valuable experience that could be brought to bear on the more lucrative TV market.

As a consequence of the Japanese emphasis on small-screen TVs-and also because of the market focus of American producers—most imports have been lower priced models, as shown by the consistently lower percentages in the value column of table **44.** Conversely, American manufacturers have continued to concentrate on higher priced, more profitable sets—large screen and console models. While imports have moved up-scale over the years, they still account for a considerably smaller proportion of the market in dollar terms than in units. Now that many Japanese companies assemble TVs here, more of the imports come from Taiwan and South Korea. Firms in those countries have followed Japan's lead in emphasizing low-priced, small-screen sets.

[19] L. Landro, "Technology, Competition Cut Price of Electronics Gear as Quality Rises, " *Wall Street Journal* Dec. 1, 1981, p. 37.

"J" The U.S. Consumer Electronics Industry and Foreign Competition, Executive Summary," final report under EDA grant No 06-26-07002-10, Department of Commerce, Economic Development Administration, May 1980, pp. 46-47.

Table 44.—imports of Color Televisions as a Percentage of Total U.S. Sales

	Imports as a percentage of unit sales	Imports as a percentage of value of sales
1968	11 .0 "/0	5.1 "/0
1970	17.0	8.4
1972	14,9	8.3
1974	16.0	9.6
1976	35.9	18.9
1978	26.4	15.7
1980	11.3	7.4
1982	19.1	12,8

SOURCES *1968-72*—"The U S Consumer Electronics Industry and Foreign Competition," final report under EDA grant No OE-26-O7OO2-1O, Department of Commerce, Economic Development Administration, May 1980, pp A-75, A-76
1974-82—Electronic Market Data Book 1983 (Washington, D C Electronic Industries Association, 1983), pp 15 and 31

Table 44 also points to the reactive strategies of the major American TV makers; when confronted with low-priced import competition, U.S. producers essentially ceded that portion of the market.[21] Part of the reason was simply that, even in the absence of imports, profits would have been lower on small-screen sets. Given expanding markets, the strategies pursued by American firms enabled them to utilize their production facilities in optimal fashion, at least in the shorter run. With the portable radio experience in the background, U.S. manufacturers must have been well aware that concessions at the lower end of the TV market would give the Japanese a foothold—making for stiffer competition in later years across the rest of their product lines, Viable counter-strategies needed to be developed—and were. At present, the major U.S. manufacturers have strong product offerings in all parts of the market, small sets as well as large.

Domestic firms found themselves in different situations as a result of import competition, and reacted in different ways. The major producers, RCA and Zenith, each held between 20 and 30 percent of the market in terms of unit sales, higher in value terms, at the end of the 1960's. Through the 1970's—and today—each has retained a market share in the vicinity of 20 percent (ch. 4, table 10; RCA's market share dipped below 20 percent once, in 1975); brand recognition and strong distribution networks, combined with an emphasis on larger sets, lessened their vulnerability to imports. Both Zenith and RCA automated some of their facilities to hold down costs, and moved other production overseas. Firms with smaller market shares, on the other hand—especially those that depended heavily on private label sales–quickly felt the impact of Far Eastern competition. For several, lower production scales—and higher manufacturing costs—combined with foreign competition to move their operations into the loss column. Companies like Philco, Admiral, Warwick—most recently Sylvania—left the market.

Prominent in competitive responses by the U.S. industry were efforts to persuade the Federal Government that Japanese imports were entering via unfair trade practices. While companies like RCA and GE that get substantial revenues from overseas sources have taken a

Photo *credit RCA*

Color TV assembly

[21] The U.S. Consumer *Electronics Industry* (Washington, D. C.: Department of Commerce, September 1975), p. 1 1.

"free trade" stance, others, whose orientation has been primarily domestic, have been vigorous in pursuing trade remedies over many years. The intent has been to raise import prices through antidumping penalties or countervailing duties. Chapter 11 outlines the sequence of events; briefly, collection of additional duties imposed on TVs from Japan was delayed for years by a series of interdepartmental disputes within the Government. Petitions seeking adjustment assistance under the Trade Expansion Act of 1962 were denied in 1973, as were parallel efforts to have countervailing duties assessed on Japanese TVs. Attempts by American interests—labor unions and suppliers were active along with domestic manufacturers—continued in one form or another from the late 1960's on through the 1970's, indeed are still underway. But from the viewpoint of U.S. producers, these efforts to stimulate Government action that would raise import prices were less than successful, Even so, the constant stream of claims that competitive tactics by Japanese firms were both unfair and damaging had considerable political impact: a reluctant administration was forced in 1977 to take action. The results were the import quotas termed Orderly Marketing Agreements (OMAs) mentioned in the previous chapter. The initial OMA with Japan was followed in 1979 by agreements with South Korea and Taiwan.

A second response by domestic firms was technological. Far Eastern competition forced U.S. TV makers to move into solid-state designs both to lower costs and to improve reliability. But these efforts came too late for many American manufacturers. Japanese exporters had achieved the volume required for economies of scale, and could continue to drive prices downward. By 1971, Matsushita was the biggest manufacturer of TVs in the world, and 5 of the top 10 firms were Japanese (ch. 4). These companies were expanding worldwide, while the efforts of even the strongest U.S. firms were largely restricted to their home market. Meanwhile, American consumers were choosing small-screen TVs—where imports were strongest—in ever-larger numbers. Table-model and portable sets went from 12 percent of U.S. color TV sales in 1965 to 68 percent in 1974.[22] Those American suppliers that remained economically viable did so in part by improving labor productivity at relatively high rates; they also transferred many of their more labor-intensive manufacturing operations overseas.

The U.S. response was, therefore, mixed. On the one hand, American firms sought trade protection—a reaction not untypical of businesses experiencing foreign competition in lucrative domestic markets, particularly when they find themselves in this situation for the first time. On the other hand, a number of U.S. manufacturers successfully reduced costs, enhanced quality, and managed to keep most if not all of their traditional market share; RCA and Zenith together still account for some 40 percent of U.S. color TV sales, But the majority of American companies were unable to keep pace in the newly competitive environment.

Foreign Markets

U.S. and Japanese consumer electronics firms have approached markets in third countries quite differently. Companies like RCA have sold technology overseas—most recently, RCA has licensed its new video disk technology in Europe—but have seldom embarked on major efforts to market consumer products elsewhere, The exception is ITT—an American-owned firm which is one of Europe's larger producers of color TVs but does not manufacture consumer products in the United States. In contrast, Japanese manufacturers have exported products as well as technology; in recent years they have also invested extensively in industrialized as well as developing countries.

In Western Europe—which offers a market for color TVs about the size of that in the

[22] *Electronic Market Data Book 1975* (Washington, D. C.: Electronic Industries Association, 1975).

United States—Japanese firms have made significant inroads. For many years, trade barriers and patent protection helped European producers fend off imports (ch. 4). Now many of the barriers are weakening. Nearly half the high-fidelity equipment sold in Germany is al ready imported from plants in the Far East. 23 The Japanese share of the West German color TV market more than doubled from 1979 to 1981, reaching an estimated 15 percent. Color TVs are made in the United Kingdom by five of the major Japanese manufacturers; a substantial fraction of the output is shipped to other European nations. One-third of the picture tubes used in TV sets manufactured in Europe are imported from Japan; few if any of the 10 remaining factories making picture tubes in Western Europe are profitable. Japanese eports of VCRs to European countries more than doubled in 1981, and doubled again —to nearly 5 million--in 1982; threatened with dumping complaints, Japan recently agreed to limit VCR shipments to the European Communit y.

Japan's entry into the European TV market has been remarkably similar to that here. As the PAL licensing agreements continue to expire, the Japanese will broaden their product ranges; they are now beginning to compete in the upper reaches of the European market. One response by local firms has been to move toward Tv broadcasting accompanied by stereo sound. Through a new round of restrictive licensing practices, European companies hope to keep the Japanese out of new high-end products .

Japan's electronics firms have also been active in the Far East, where the U. S. presence is limited to offshore production. Still, as Asia has developed economically, the advantages of Japanese manufacturers have diminished. Markets are expanding in Taiwan, South Korea, Singapore, and Malaysia—with local industries aiming both to export and to supply rising domestic demand. While it is no surprise to find Japanese firms with a greater presence in Asia, one might expect the situation to be reversed in Latin America. But here too, many of Japan's TV makers have established subsidiaries, joint ventures, and licensing agreements—in addition to their export activities. The U.S. presence, except for assembly plants in Mexico that ship back across the border, appears limited to scattered licensing arrangements .24

Japanese consumer electronics firms have taken a long-term approach to the development of world markets. They have been willing to adapt their strategies to the constraints imposed by foreign governments, and to local laws and regulations. Where governments have limited imports, they have invested. Where investment is restricted, they enter into joint ventures. As one example, Toshiba commissioned a Costa Rican company to make Toshiba-brand TVs in 1971, several years before color broadcasting began in that country. Later, Toshiba purchased part of the local firm, establishing a joint venture for manufacturing a broader line of their consumer electronic products. In pursuing such activities, Japanese firms have taken significant risks. They have invested in economically depressed regions, in countries where the initial markets for their products have been small, and in regions of questionable political stability. In their early years, many of these operations probably lost money. Now, Japanese companies are firmly established in such countries, and appear well positioned to take advantage of growing demand in nations ranging from the Arab states to the People's Republic of China. If American firms were, at this late date, to try to emulate the Japanese strategy and compete on a global scale, they

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[23] J. Gosch, "German Consumer Firms Face Bad Times," *Electronics*, Sept. 11, 1980, p. 97. Also see "Philips—An Electronics Giant Rearms To Fight Japan," *Business Week*, Mar. 30, 1981, p. 86. For Europe as a whole, three-quarters of all high-fidelity equipment is imported. On TVs and VCRs, below, see J. M. Geddes, "West German TV Producers Plan Stereo Sets," *Wall Street Journal*, June 24, 1981, p. 34; J. Tagliabue, "Europeans Battle Japanese TV Tubes," *New York Times*, Feb. 10, 1982, p. D4; A. Sato, "Japanese VTR Output, Exports Soared in 1981," *Asian Wall Street Journal Weekly*, Feb. 22, 1982; E. J. Dionne Jr., "Japan Video Accord Leaves Europeans Wary But Hopeful," *New York Times*, Feb. 22, 1983, p. D5.

[24] "Sources of Japan's Competitiveness in the Consumer Electronics Industry: An Examination of Selected Issues," prepared for OTA by Developing World Industry and Technology, Inc. under contract No. 033-0110.0, p. 130.

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would face a formidable task in overcoming the head starts of their rivals,

Other Consumer Electronic Products

Not only home entertainment goods like VCRs, but pocket calculators, electronic watches, and CB radios are now produced mostly in the Far East. The older, established consumer electronic firms in the United States—those that have made radios, TVs, audio equipment—seldom participate in these markets. More often, the American entrants have been small specialty manufacturers, semiconductor firms, or suppliers such as Tandy, which sells under the Radio Shack name. U.S. electronics companies with little prior experience in the consumer arena attempting to diversify have, not surprisingly, sometimes misjudged demand, introduced products that proved to have little appeal to customers, or failed to establish adequate distribution channels. Among the semiconductor firms, even the most successful—e.g., Texas Instruments—have had a difficult time learning to develop and market consumer products. [25] profits have not always been high enough to convince U.S. entrants to persevere, particularly where foreign firms with low production costs were already well established.

What then of the future? Will American firms attempt to develop new strategies for marketing future generations of consumer products? How will their approaches contrast with those of manufacturers in other parts of the world? Some of the trends can be discerned, at least as they relate to product developments. Bottom-end pocket calculators will offer more features as sophisticated models evolve into hand-held computers. Watches may incorporate games, calculators, perhaps even radios. Speech synthesis—and later voice recognition—will appear, enabling TVs, for example, to switch channels in response to spoken commands, Integrated home entertainment systems combining TV reception, video tape and/or disk players, and computing capability will be developed, with component TV one of the first steps,

To a considerable extent, the future of the U.S. consumer electronics industry will depend on its ability to keep up in such products, How successful will American manufacturers be? On the one hand, new product offerings like the RCA video disk system are favorable signs. Although thus far something of a disappointment in the marketplace, RCA's investment in the video disk demonstrates that U.S. Consumer electronics firms are still willing to take risks. Zenith's venture into personal computers is another indication that American suppliers are not ceding their home market to foreign producers; so are the efforts of smaller companies marketing electronic games, projection TVs, and innovative audio products. At the same time, the failure of U.S. companies to participate in the manufacture of VCRs will make it more difficult for them to regain product leadership.

With U.S. sales of VCRs growing rapidly, the approaches of Japanese and American firms now stand in stark contrast. Broadcast videotape recorders were introduced by Ampex in 1956, with RCA following in 1959; at least eight Japanese firms–starting with these U.S.-developed technologies—pursued consumer versions during the 1960's, with various degrees of resource commitment and success. [26] None of the American consumer electronics firms followed suit, although some made attempts later on. Sony's Betamax, which opened the market, was in fact a fourth-generation machine—the result of many years of persistent and often-disappointing efforts, The other major VCR system—developed by Matsushita (a third, built by Philips, has only a small share of the market)—was also the result of years of engineering, and a number of false starts. U.S. firms were unable or unwilling to match these

[25] See, for example, B, Uttal, "Texas Instruments Wrestles With the Consumer Market, " *Fortune,* Dec. 3, *1979, p. 50,*

[26] See W. J. Abernathy and R. S, Rosenbloom, "'l'he Institutional Climate for Innovation in Industry: The Role of Management Attitudes and Practices, " *The 5-Year Outlook for Science and Technology 1981: Source Materials,Volume 2* (Washington, D, C.: National Science Foundation, NSF 81-42, 1981), pp. 411-416, for a fascinating case study of the com mere ialization of consumer VCRs,

development programs, and now have chosen to sell Japanese VCRS under their own brand names.

The point is that, once having lost product leadership-as has occurred with VCRs–American firms will find it increasingly difficult to compete in new technologies, and may eventually find themselves importing or adapting other products as well. Because U.S. manufacturers cannot expect cost advantages, they may be left with only their distribution systems and brand recognition as prime competitive weapons. To a considerable extent, Japanese firms have already countered these advantages; thus, the long-term prospects for American firms in consumer electronics do not appear bright.

Semiconductors

Technological forces have dictated the marketing strategies of semiconductor companies in all parts of the world since the inception of the industry. The case study on 4K RAMs in a p penal ix C points to the i mportance of e ngineering capability for U.S. merchant firms such as Mostek or Intel, Technology is no less important now than a decade ago, when the 4K RAM was being developed-but as late as the mid-1970's the business strategies of foreign semiconductor manufacturers were of little interest to Americans. As the 4K RAM case demonstrates, U.S. firms appeared to have little to fear from producers in Japan--certainly not from those in Western Europe, But from a minor position in 4K chips, Japanese firms went on to claim about 40 percent of the world market for the following generation of 16K RAMs. By 1982, the perception was widespread that U.S. firms had "lost" the market for dynamic RAMs. Certainly this is an overdramatization, and the RAM market can by no means stand for the industry in microcosm; but the picture has changed. How did it change so fast?

During the 1970's, Japanese companies exported considerable numbers of electronic components--including transistors—to this country, but the major growth segment, ICs, was dominated by American suppliers. Even though Japan's Government protected the local industry, U.S. shipments took a substantial part of the expanding Japanese IC market. Customers in Japan depended on American firms for devices that domestic manufacturers could not provide—high performance or large-scale chips, custom parts, even some types of linear circuits needed for consumer products. As the technological level of Japan's semiconductor industry caught up with that of the United States, many of these imports were replaced by indigenous production. The phenomenon, termed import displacement, has been characteristic of Japan's computer industry as well. Displaced items quickly become potential exports for Japanese firms.

During the 1970's, awareness of the possible consequences of foreign competition grew within U.S. industry and Government, although the production and trade data showed little cause for concern. The Federal Trade Commission, reporting on interviews conducted in 1976, stated: ". . . a number of company executives expressed the opinion that competition from foreign companies would be much tougher to handle than competition from other U.S. companies in the next 5 or 10 years. In contrast, some other executives felt that U.S. companies would not have a difficult time maintaining their technological lead over foreign companies."[27] Hindsight shows those of the first persuasion closer to the mark.

One sign that patterns of international competition would change came from subsidies and promotional efforts adopted by foreign governments with the aim of fostering indigenous production. Japan, France, West Germany, the United Kingdom—all in one way or another marked the semiconductor industry as critical to continued economic vitality, an in-

[27] *Staff Report on the Semiconductor Industry: A Survey of Structure. Conduct and Performance* (Washington, D. C.: Federal Trade Commission, Bureau of Economics, January 1977), p. 130.

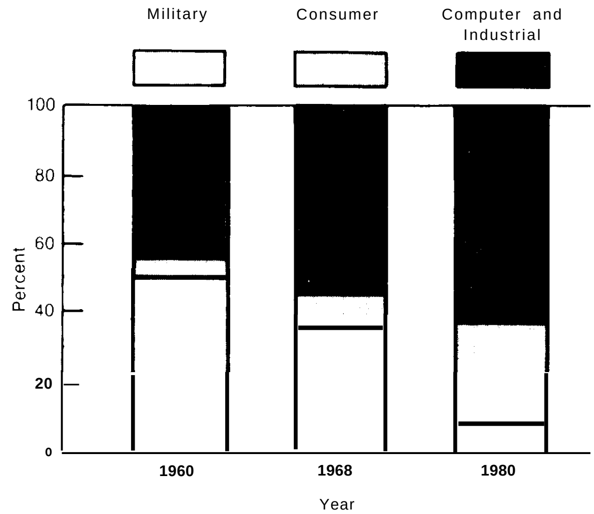
dustry not to be given over to foreign interests. Since the United States was far ahead in both technological expertise and production volume, the implicit targets were American companies, not excluding those that had invested in local production facilities. These government-led attempts to build competitive semiconductor industries have had mixed results. Joint projects involving public and private sectors in Japan were quite successful—in semiconductors as in earlier Japanese industrial policy initiatives. European attempts have been far less fruitful, for reasons that may have as much to do with the characteristics of the industry and marketplace on the continent as with the policies pursued.

United States

Applications of semiconductors reflect ongoing synergistic relationships among merchant suppliers and their customers. Purchasers outside electronics have lately presented growing market opportunities—e.g., in automobiles. Nonetheless, from a technological viewpoint, firms building computer- or microprocessor-based systems remain the most influential customers (fig. 34). Manufacturers of consumer electronics, communications systems, instruments and controls, and office equipment have considerable impact as well. While most of the attention below goes to merchant firms, captive operations have played a vital role in the technological development of the U.S. industry. Furthermore, production decisions by the larger integrated manufacturers sometimes have major consequences for the merchant market,

Figure 34 shows that the phenomenal expansion in semiconductor output during the 1970's was accompanied by a major shift from defense purchases to consumer and industrial applications; competitive success in the most rapidly growing market segments depended on the ability to make the transition from specialized military requirements to the demands of private sector customers. Some companies that fared quite well in the military market could not compete effectively for commercial sales,

Figure 34.— Distribution of U.S. Semiconductor Sales by End Market



SOURCES 1960, 1968 Innovation, Competition, and Governmental Policy in The Semiconductor Industry Charles River Associates, Inc final report for Experimental Technology Incentives Program, Department of Commerce March 1980, p 213
1980 *Status 80 A Report on the Integrated Circuit Industry* (Scottsdale, Ariz Integrated Circuit Engineering Corp , 1980) p 34

where the needs of customers are more diverse, and nontechnical dimensions like price and delivery schedules more important.

Factors in Strategic Decisions

Competitive strategies adopted by merchant semiconductor firms revolve around factors such as size, market power and technological capability, internal need for devices (if any), and stage of development relative to others in the industry. A company's technical strengths shape its product line, Process technology—whether a manufacturer is strong in bipolar or MOS (metal-oxide semiconductor), which varieties of MOS a firm knows best—is one aspect, design capability another. Some companies are known for innovative circuit designs, others for prowess at mass production—some for both. Smaller entrants tend to specialize; only a few merchant suppliers have broad product lines (the world's semiconductor manufacturers supply perhaps 50 billion devices a year—of 100,000 different types—to several hundred thousand customers).

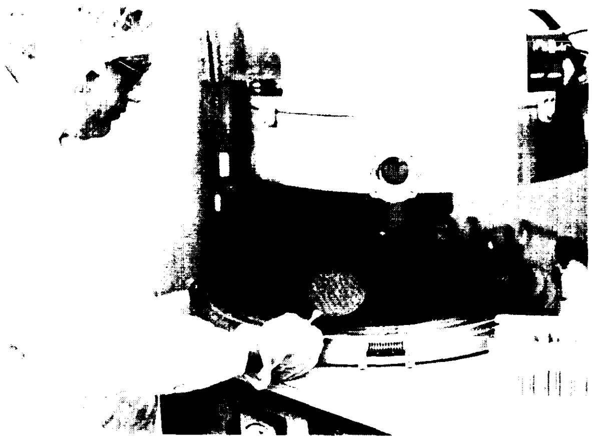


Photo credit Western Electric Co

Technician loading plasma reactor with semiconductor wafers

A number of U.S. merchant manufacturers have integrated to some extent into systems. A few, such as Texas Instruments, have always been diversified. Others have been purchased by larger enterprises but still sell the great bulk of their production on the open market (ch. 4, table 24). As merchant suppliers expand, so does the range of their product offerings, Smaller companies with limited resources aim at niche markets, Newer entrants set out to develop specialized or custom devices of less interest to larger corporations; the 1981 startup Linear Technology—a spinoff from National Semiconductor—specializes in linear ICs, in which the founders have expertise.

Captive semiconductor producers have different strategic aims. While most of the larger computer firms make some of their own logic chips, IBM has traditionally produced most of its memory circuits as well. The company consumes so many that, for products such as RAMs, on occasions when it chooses to purchase from outside vendors it can account for a sizable proportion of total demand (the company is probably the largest single purchaser in the merchant market, as well as the world's largest producer of semiconductors). This then affects the business decisions of merchant suppliers: IBM's external purchases were a powerful and rather unpredictable force on the market for 16K RAMs at the close of the 1970's, the company's unexpected entry contributing to shortages of these devices. Capacity shortfalls by American firms—primarily stemming from failures to invest in additional production facilities in the wake of the recession of 1974-75—left an open door for Japanese IC suppliers to sell in this country.

Captive manufacturers contribute in a major way to the overall strength of the U.S. position in microelectronics through their R&D activities; in particular, IBM and AT&T's Bell Laboratories have been responsible for much of the basic research underlying the semiconductor industry in this country, indeed around the world. Merchant firms—because of the pace and intensity of product development, the continuing cycles of improvement in design and production that characterize succeeding generations of ICs—must set different priorities; they also have more limited resources for R&D.

Technological Factors

A company introducing a new device must assume that even if their design is at the forefront of the state of the art it will be superseded later if not sooner. Timing is critical; technological windows sometimes open, providing opportunities for leapfrogging the competition. Companies that quickly mastered production of dynamic RAMs, or concentrated on microprocessor design architectures in attempts to tie up large portions of that market, were aiming at such advantages, Needless to say, some firms have better records at exploiting these opportunities than others. A number of companies that had been strong in bipolar technology–including Fairchild and Texas Instruments—did not move as rapidly into MOS as the competition; Texas Instruments staged a quick recovery, while Fairchild has continued to lag. Mostek, as its name connotes, was founded with the intention of specializing in MOS; the company has emphasized memories, designing their own RAMs—the de facto industry standard 4K RAM was a Mostek design (see app. C)—while serving as an alternate source for microprocessors. Electronic

Arrays, now owned by Nippon Electric, had specialized in read-only memories (ROMs). Other firms seeking to exploit particular technological paths have had less success: American Microsystems' work on v-MOS ICs is one example, RCA's pursuit of silicon-on-sapphire c-MOS another. Internationally, Japanese firms moved into MOS ICs much more rapidly than the Europeans, most of whom are still well behind their competitors in the United States or Japan and relying on technology imports to try to catch up; this has been one of the objectives of Le Plan des Composants—a major industrial policy effort by the French Government (ch. 10). In the United States, some firms —Signetics, Monolithic Memories—continue to specialize in bipolar devices. IBM likewise remains relatively stronger in bipolar than MOS; the speed advantages of bipolar circuits have led many computer manufacturers to continue emphasizing the older technology.

Quality and reliability comprise another competitive realm where strategies depend both on circuit design and manufacturing practices (ch. 6). While Japanese firms have zealously publicized the quality and reliability of their ICs —in much the same way that Japanese consumer electronics firms used reliability as a wedge into the American TV market—domestic producers like Advanced Micro Devices have also pursued an image of quality and reliability as a marketing tool.

Products and Prices

One of the attractions of memory circuits—in addition to the vast market—is the relatively orderly and predictable progress of the technology itself; circuit design is vital—along with excellent process capability—but more straightforward than for logic or microprocessors. Everyone in the industry knows that the next generations of dynamic RAMs will be 256K chips, followed by 1 megabit; circuits offered by various firms are much more similar than the designs of competing 16-bit microprocessors, One result is the fierce price competition that has often seemed the dominant characteristic of the memory market. Progress in static RAMs, and in the various types of ROMs, is likewise rather easy to predict. Under such circumstances, Japanese suppliers quite naturally emphasize memory products.

In contrast, market acceptance of logic circuits or microprocessors is less predictable. Investing in a new microprocessor design—the 32-bit Intel iAPX 432 cost more than $100 million to develop—is risky, but the potential rewards are great; designs with an edge over the competition—in performance, ease of programing, adaptability to a wide range of applications—sell for premium prices.[28] Furthermore, microprocessors—best thought of as families of related ICs rather than unique devices—have longer product cycles, extending the period over which investments can be recouped. Memory circuits are manufactured as long as demand holds up, but sales tend to peak and decline more rapidly than for other device types. Five or six years elapsed between the onset of high-volume production for 8-bit microprocessors and mass production of the succeeding generation of 16-bit parts, while lifecycles for RAM chips—though slowly lengthening—have been perhaps 3 years, sometimes less.[29]

Abbreviated product cycles dictate strategies aimed at profitability within a narrow time window, along with continuous efforts to develop new or differentiated offerings. The latter can be original designs but need not; second-sourcing has been widespread for many years, in part because customers often insist on more than one supplier before they will design an IC into their end products. Thus, second-sourcing can accelerate market expansion for everyone, Semiconductor firms choose to become alternate sources for chips developed

[28] On the costs of microprocessor design, see R. N. Noyce and M. E. Hoff, Jr., "A History of Microprocessor Development at Intel," *IEEE MICRO,* February 1981, p. 8. Intel's first microprocessor, a 4-bit device, was designed in 9 months by a single engineer; 100 man-years went into the iAPX 432.

[29] Intel's 8080 family—introduced in 1974 and the largest selling 8-bit microprocessor—will no doubt remain in production for many more years, Worldwide, more than 10 companies still produce 8080 chips. Mostek—an alternate source for another popular 8-bit processor, the Z-80—for a number of years produced more of these devices than Zilog, the originator. See "The Antenna," *Electronic News,* Mar. 12, 1979, p, 8; "Eight-Bit Level," *Electronic News,* July 5, 1982, p. 12.

by other companies to beef up their own product lines, perhaps by complementing circuits they already build, as well as to reduce market risks and save on R&D expenses. From the viewpoint of the originator, it may be more sensible to settle for a smaller piece of a rapidly expanding market than to try to keep others from duplicating an IC design. Attempts to prevent duplication are virtually impossible if a circuit finds an enthusiastic reception in the marketplace. As one consequence, formalized alternate sourcing agreements have largely replaced the copying that was once commonplace. Sometimes alternate source manufacturers acquire the originator's technology —e.g., mask sets for lithography. Other times only drawings or specifications are provided. The recent agreement between National Semiconductor and Fairchild, the latter acquiring the right to build National's model 16000 microprocessor in exchange for developing a complementary line of peripheral chips, is an increasingly popular route.

Cost reductions via the learning curve (ch. 3, fig. 5) help shape competitive strategies, As production volumes increase, yields rise and manufacturing costs drop. Pricing decisions have often been based on projections of expected cost reductions into the future, For a firm early to market with a new design, cost advantages over potential rivals can build rapidly, increasing with leadtime. Firms that are late to market face a dilemma; they may have to choose between foregoing participation or pressing on with their own design in the hope that it too will win acceptance, In early 1982, with six Japanese entrants mass-producing 64K RAMs, versus only two American manufacturers, a number of U.S. firms were confronted with such decisions; Advanced Micro Devices, for one, decided not to build a 64K chip,

In different circumstances, then, firms assume different strategic postures. Companies entering the market with a new device, particularly one incorporating proprietary technology—product or process—may have several advantages over competitors that follow. An early entrant will normally try to remain ahead on the learning curve, keeping production costs below those of its rivals, margins above. Companies with proprietary designs often license alternate sources, but at least at the outset second-source suppliers will be at a cost disadvantage. If the initiator decides to follow a pricing strategy keyed to anticipated cost improvements, follow-on firms may find it difficult to make a profit. Texas Instruments, for instance, has had the reputation of practicing advance pricing whenever possible, In a very real sense, then, later entrants can be at the mercy of innovators should the latter choose to cut prices and exercise the cost advantages of being farther down the learning curve. On the other hand, an innovating firm might choose to increase margins by holding price levels high. Under such circumstances, an alternate source may itself be able to carve out a place through price. One facet of Intel's corporate strategy has been to choose products where it could enter the market first, reap high profits, then move on—leaving later sales, at lower margins, to others, Nonetheless, in many cases, especially where the innovating company is small, lining up an established supplier as a second source may be a prerequisite to sales in any volume.

A further strategic choice, increasingly critical for American firms, is whether to design and produce commodity-like chips or to concentrate on custom or semicustom devices, The first option entails high-volume production of ICs that are, or may become, shelf items—standard circuits serving the needs of customers who design them into end products, The alternative, customizing, can be accomplished in a variety of ways; semicustom chips such as gate arrays or programmable logic arrays are specialized only at the last stage of processing. Regardless of the technological approach, firms in the custom or semicustom business create specialized ICs meeting the needs of one or a few, rather than many, purchasers. Because circuit design is expensive, prospective order quantities must be large enough to cover engineering costs; alternatively, the buyer must be willing to pay a higher price, Custom chips for automotive applications are an example of the high-volume case, military systems of custom chip markets where production volumes tend to be small. Occasionally, end users design their own ICs and contract out production.

At the center of competitive strategies in semiconductors—as for many industries—then lies the choice of products. Firms with broad product lines may offer devices based on a variety of technologies while attempting to stay at the technical frontier with only some of these. Others—such as Mostek in the mid-1970's—operate within narrower boundaries where they attempt to be leaders. Some entrants are content to follow the obvious trends, offering unique designs infrequently while relying on other strengths—perhaps low prices or a reputation for quality—to attract customers, In its early years, Advanced Micro Devices took such an approach (see app. C).

Beyond these common themes, mostly hinging on aspects of the technology, companies plan their strategies according to the strengths and weaknesses they perceive in their own positions compared to those of their rivals. No single company has the resources to manufacture and sell all the tens of thousands of semiconductor products now marketed in the United States—one of the reasons for the periodic emergence of startups, Extensive product lines can confer advantages where customers prefer to deal with only a few vendors; broad-line manufacturers may also be able to achieve economies by spreading marketing costs over many items. Nonetheless, such factors are secondary compared to choice of product and process technology, along with a variety of ingredients that could be labeled "entrepreneurship.' Successful new companies have frequently been established to exploit a particular product, often one that larger companies have failed to pursue—perhaps because of limited resources, or simply a judgment that the potential market was too small,

No matter the decisions they themselves take, managers of semiconductor firms can be certain of two features of their market: 1) competition will eventually drive prices downward (it has been extremely difficult to capture significant monopolistic profits from new technologies), and 2) just as inevitably the pace of technical advance will render new product offerings obsolete within a few years at most. The price history of the 64K RAM illustrates the first point: offered in sample quantities at $100 each in 1979, and $20 to $30 during 1980, prices dropped to the $10 to $15 range in early 1981 and $5 to $7 a year later; during 1981, 16K RAM prices were driven down from $4 to about $1, largely as a result of price declines for 64K parts.[30] Such pricing trends have meant that all firms, U.S. and foreign, have had to work continuously at cost reduction, In contrast to numerous other industries, passive or reactive pricing policies are hardly possible; although product differentiation is a viable alternative under some circumstances, price competition in semiconductors is a constant force–enough by itself to set this industry off from many others. The second market characteristic, rapid technological change, has forced managers and technical personnel alike to adapt constantly; firms that have remained wedded to older technologies have faltered or disappeared from the marketplace,

International Dimensions

From an international perspective, the larger U.S. merchant firms have shared three major strategic thrusts: 1) offshore manufacturing to reduce labor costs, 2) foreign investment to serve overseas markets, and 3) attempts to do business in Japan. This last effort–on which a number of companies are just embarking, or reembarking after past rebuffs—may prove critical to the continuing ability of U.S. merchant firms to compete with large, integrated Japanese manufacturers, particularly in commodity products like memory.

Offshore manufacturing investments have been concentrated in developing Asian nations, Generally, the more labor-intensive assembly operations—e.g., wire bonding and encapsulation—have been moved. In the semi-

30A, Alper, "Buyers Hedging on Long-Term 64K Pacts Until U.S. Firms Ramp Up, " *Electronic News,* Feb. 8, 1982, p. 1; C. H. Farnsworth, "Japanese Chip Sales Studied, " New *York Times,* Mar. 4, 1982, p. D1. Prices for 64K chips eventually fell to lows of about $3 during the 1982 slump.

conductor industry, the stimulus for these transfers has not been import competition, as in consumer electronics, but domestic rivalry. Transfers offshore began in the early 1960's, long before Japan appeared a significant threat in semiconductor production. By 1970, American companies operated more than 30 subsidiaries in such locales as Hong Kong, Singapore, Malaysia, the Philippines, and Mexico.[31] Relocating labor-intensive production operations has been especially attractive because transportation costs are low; chips are often shipped by air. A cost comparison illustrating the advantages of offshore assembly is included in appendix B (table B-2).

A second international involvement of U.S. semiconductor companies has been point-of-sale production to serve developed country markets, Investments in point-of-sale plants began about the same time as offshore assembly, but from the standpoint of industry strategy the motives were quite different. These have been twofold, First, foreign governments have often taken steps to make local production attractive, or, conversely, to make exporting from the United States onerous. European countries, in particular, have relied on incentives combined with tariff and nontariff barriers to attract U.S. high-technology investments. Second, point-of-sale production can become a competitive necessity to the extent that other firms have already made such moves.

Efforts to establish sales, production, and/or R&D facilities in Japan—now a bigger market than all of Europe—comprise the most recent overseas thrust by American firms. While Texas Instruments had been able to establish a wholly owned subsidiary in Japan, other American firms were kept out until recently. Semiconductor manufacturers attempting to invest in Japan suffered much the same fate as other U.S. companies; the Japanese Government, through the Foreign Investment Council, MITI, and other agencies, controlled inward investment flows and for the most part prevented the establishment of manufacturing facilities under foreign ownership.[32] Joint ventures in which a Japanese company held the majority interest met a more favorable response. The purpose was obvious: to provide shelter for Japanese companies which at the time were well behind in semiconductor technology. MITI believed—with good reason, if the European case is indicative—that allowing American firms to produce in Japan would stifle the domestic industry, particularly when it came to more advanced device types. In acting this way, the Japanese Government was behaving much like others that have sought to protect infant industries, but Japan has often been accused of maintaining protectionist measures long past the point at which her industries have been able to fend for themselves,

In any event, as a consequence of protectionism in Japan, American suppliers were forced to adopt business tactics different from those pursued on the continent. Most responded to MITI's entreaties and entered into licensing agreements with Japanese producers.[33] Such steps were entirely rational, provided the U.S. firm could be reasonably certain the technologies transferred would not find their way into products they would face at home or in third-country markets. With this proviso, it would pay to sell technical knowledge, the proceeds from which could then at least partially offset the costs of generating that knowledge, The outcomes of licensing agreements with Japanese firms have led to many second thoughts within the American industry. Nonetheless, clear-cut cases in which U.S. technology was an irreplaceable ingredient in the growing capability of Japanese semiconductor manufacturers are rare, particularly in later years—the exceptions being perhaps developments flowing from Bell Laboratories.

31 W. F. Finan, "The International Transfer of Semiconductor Technology Through U.S.-Based Firms," National Bureau of Economic Research Working Paper No. 118, December 1975, p. 57 This figure excludes point-of-sale facilities in industrial oat

32 M. Y. Yoshino, "Japanese Foreign Direct investment," *The Japanese Economy in International Perspective*, I. Frank (cd,] [Baltimore: Johns Hopkins University Press, 1975), p. 248.

33 See, in particular, 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. Finan points out that American firms generally did *not* transfer proprietary information to licensees (p, 9).

Texas Instruments became the single exception to MITI's licensing rule—in reality only a partial exception. Because it held a series of fundamental patents covering ICs, Texas Instruments was in stronger position than other American companies. As a condition for licensing its patents to Japanese firms, Texas Instruments demanded that it be allowed to establish manufacturing operations there. When MITI refused—consistent with its decisions regarding other electronics firms—the stage was set for prolonged negotiations.[34] Texas Instruments and MITI eventually compromised in a 1968 agreement permitting a joint semiconductor manufacturing venture with Sony. Four years later, Sony sold its share to the American company.

Thus, Texas Instruments, although reportedly subject to a production ceiling, became the only U.S. semiconductor firm to both manufacture and sell its devices in Japan, just as IBM had—a few years earlier—become the only American company to build computers there. (IBM was also able to gain entry by taking advantage of its patent position.) Only recently, as the Japanese have gained confidence in their own technical abilities, has MITI softened its attitude toward foreign investment; a growing number of U.S. electronics manufacturers are now contemplating wholly owned subsidiaries in Japan. While the longer term consequences of these decisions are not yet clear, investment *within Japan could—given the examples of other industries—prove a vital support for American firms seeking to compete with Japanese rivals in third-country markets as well as in Japan.*

Current Trends

The competitive strategies of American semiconductor firms have been aimed first and foremost at survival in a highly competitive, rapidly changing market. Companies big and small have had to stay abreast of and adapt to technological change. Flexible management and organizational structures have been a necessity. The usual explanations for the exits of a number of large corporations during the earlier years of the industry revolve around rigid decisionmaking styles.

More recently, the character of the market has been shifting; American companies have been forced to alter their thinking. In some respects the changes are a continuation of familiar patterns: more complex ICs–large and very large-scale integration (VLSI)—make still more applications cost-effective, creating new and different puzzles for chip-makers. More fundamentally, VLSI has altered the cost structure of the industry in at least two ways. First, production is growing more capital-intensive; new sources of financing are needed to purchase more expensive manufacturing equipment (ch. 7). Some of the capital has come via mergers, which have changed the industry's structure. The second way in which VLSI is affecting the structure of the industry stems from shifts in product design. What had been a hardware-oriented business is now systems- and software-based as well. ICs are becoming more than components, To tap the vast potential markets made possible by microprocessors coupled with cheap memory, semiconductor manufacturers must commit substantial resources to computer-aided design and software development, This comes at a time of intensifying international competition—but with or without the Japanese in the picture, the problem facing U.S. merchant firms is one of locating sources of new capital in substantial amounts while battling to preserve even their existing profit margins. As companies devise their responses, several trends are emerging,

Greater vertical integration will probably have the farthest reaching consequences. Larger merchant companies—e.g., Texas Instruments, which has entered a variety of consumer markets, including that for personal computers—are taking advantage of broad-based positions in microelectronics to integrate downstream into the manufacture and sale of final products, The reasoning behind such decisions is straightforward. If much of the technology of data processing and other electronic systems is incorporated in ICs, why not make

[34] J. E. Tilton, *International Diffusion of Technology: The Case of Semiconductors* (Washington, D. C.: The Brookings Institution, 1971), pp. 146-147.

end products too, increasing value-added and profitability? To this strategy—essentially an offensive one—could be added a defensive element. For semiconductor manufacturers with the resources to contemplate entry into systems markets, greater vertical integration reduces vulnerability in the event that customers begin to integrate backward into device production. The fact is that backward integration is on the upswing, as manufacturers of computers, office equipment, consumer durables, and a host of other products sense the need to develop inhouse capability in microelectronics. One path is purchase or merger with a semiconductor company. Merger activity in the industry has been high since the latter part of the 1970's; by 1983 only a few of the larger, broad-line merchant suppliers remained independent.

Mergers have been of several types: some semiconductor firms have been absorbed into conglomerates—one example is United Technologies' purchase of Mostek. Other acquisitions have been more directly motivated by internal needs, as in General Electric's acquisition of Intersil. Foreign takeovers have been prominent—Schlumberger's purchase of Fairchild. Sometimes the apparent motive on the part of the semiconductor company is the need for new financing; this was no doubt a factor with Mostek, explicitly so with IBM's purchase of a substantial interest in Intel. The motives of foreign investors have varied: buying an American firm can be a quick way to get technology as well as a convenient entrance into the U.S. market.

In a related development, many American semiconductor companies are seeking alternatives to "going it alone" in the development of new technology-largely because of rising costs. New variations on accepted technology sharing arrangements have been devised. Some semiconductor manufacturers have prevailed on customers for assistance in developing specialized chips and software. Both General Motors and Ford have supported such efforts. Semiconductor firms have also sought new ways to share product development costs among themselves, sometimes through extensions of past practices in second-sourcing, where it is becoming common for such agreements to spell out in considerable detail the R&D and/or circuit design obligations of each partner.[35]

Arrangements in which two or more companies independently develop different members of a family of chips fall at one end of the R&D spectrum—complementary product development. At the other end, closer to basic research, industry groups are moving toward cooperative rather than independent but complementary projects, The Semiconductor Industry Association and the American Electronics Association have each established programs that will channel contributions from member firms to university projects. The Semiconductor Research Cooperative is funding research directly, while the Electronics Education Foundation aims to improve training in electrical and computer engineering, primarily through fellowships and faculty support.[36] Another effort, Microelectronics & Computer Technology Corp., will be an independent profit-seeking R&D organization capitalized by the participating firms.[37] At least six universities are also establishing centers for R&D in semiconductor technology and/or systems applications of microelectronics.[38] Whether all these efforts will survive and flourish remains to be seen.

The emerging strategic picture in the United States, therefore, is fluid and uncertain. Semiconductor manufacture, along with other portions of electronics, is undergoing far-reaching restructuring, with outcomes that are hardly obvious. Given settlements in the IBM and AT&T antitrust cases, the way also seems clear

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[35] For examples, see S. Russell and S. Zipper, "Intel, Motorola Tighten Hold on General-Purpose MPUs: See Peripherals Key Market for Niche Suppliers," *Electronic News*, Mar. 8, 1982, p. 1. U.S. merchant firms are also negotiating such agreements with Japanese manufacturers—S. Russell, "Zilog, Toshiba to Swap MPU, CMOS Technology," *Electronic News*, Apr. 19, 1982, p. 53; "National Semiconductor Sets Venture With Japanese Firm," *Wall Street Journal*, Jan. 23, 1983, p. 22 (the Japanese participant is Oki).

[36] S. Russell, "SIA Eyes $5 M Funding for Research Cooperative," *Electronic News*, Dec. 21, 1981, p. 6.

[37] C. Barney, "R&D CO-01) Gets Set To Open Up Shop," *Electronics*, Mar. 24, 1983, p. 89.

[38] C. Norman, "Electronics Firms Plug Into the Universities," *Science*, Aug. 6, 1982, p. 511.

for continued expansion by these two giant semiconductor/communication/computer companies. AT&T's manufacturing arm, Western Electric, plans to be the first American firm to deliver 256K RAMs—a rather spectacular entrance into the merchant market. Other firms—Xerox is one—are also contemplating broad, systems-oriented strategies. Meanwhile, smaller companies continue to seek specialized product niches that will prove lucrative while not attracting large and powerful competitors. And in the background are the Japanese, adding another dimension that will continue to influence the strategies of American firms both domestically and internationally.

Japan

Until half-a-dozen years ago, few in the U.S. semiconductor industry gave much thought to Japan as a serious competitive threat. Japanese manufacturers—almost exclusively divisions of large corporations—mostly produced devices for consumer products; even today, nearly half of Japan's semiconductor output goes to consumer applications.[39] During the 1970's, Japan's budding computer manufacturers depended on American suppliers for advanced ICs. While Japanese companies were clearly on the way to the skill levels needed for more advanced devices, the prevailing belief in the United States was that they could not really hope to catch up. The primary concern was the closed Japanese market. American companies had been prevented from establishing a presence remotely comparable to that which they had achieved in Europe; customers in Japan bought only those devices that were not produced locally.

Today the situation seems quite different. Japanese firms have emerged as viable global competitors in VLSI devices. Although their prowess has centered on memory chips, they have made up a great deal of ground in logic circuits and other device types as well. By 1980, the gravity of the threat had become obvious; quite suddenly, Japanese firms captured nearly half the American market for 16K RAMs. Two years later, Japan's manufacturers seemed well on their way to comparable levels of penetration in the next-generation 64K RAMs; indeed, as sales began to build, the Japanese share soared toward 70 percent. While there is considerable feeling that ultimately they will not be able to hold more than about half the U.S. market for 64K chips, any temptation to underestimate the capabilities of Japan's semiconductor manufacturers has long since passed. Seemingly countless studies recount the strategic attack, tracing the targeting practices of government and industry.

[39] *Japan Electronics Almanac* 1982 (Tokyo: Dempa Publications, Inc., 1982], pp. 142, 143.

From Linear to Digital Circuits

Firms in Japan had long since become major producers of linear semiconductors, a mainstay in consumer electronics. By the early 1970's, some American companies began to abandon this part of the market, especially as domestic sales seemed to be drying up. Leading U.S. producers put their resources into rapidly expanding digital IC technologies. Meanwhile, for the Japanese, strength in consumer devices was both a blessing and a curse. While giving their engineering staffs experience in circuit design and—more important—in high-volume production, the concentration on linear circuits did little to raise overall levels of competence. At the time, the primary customers for digital ICs—computer manufacturers—were a relatively minor component of Japanese demand.

This was the situation when, in line with its longstanding policy of fostering internationally competitive industries, MITI acted to break the impasse created by the focus on consumer products, The agency helped fashion an R&D program intended to increase Japan's capabilities in large-scale digital ICs, particularly MOS devices, and accelerate movement toward VLSI. The organization of the program, which began in late 1975, is described in chapter 10; five companies and three separate laboratories were involved in the 4-year effort. Funding—totaling about $300 million—was provided partly by the participants and partly by government. The program has had far-reaching impacts—as much through diffusing technology and training people as through the technology developed. A parallel government-sponsored VLSI program—this one focused on telecommunications—was carried out in the laboratories of Nippon Telegraph and Telephone (NTT), which had the most capable microelectronics R&D organization in Japan.

MITI's objective was not only to aid Japan's semiconductor manufacturers: the VLSI program was part of a much more extensive effort to move the nation toward knowledge-intensive products with high export potential. Like its counterparts within the governments of other industrialized countries, MITI recognized that semiconductors would be fundamental building blocks for many sectors of the Japanese economy. Supporting the computer and information industries was the first step. MITI was fully aware that technical competence in digital ICs would be essential, and that without some form of stimulus private companies would find it difficult to shift rapidly from linear to digital devices. From MITI's perspective, support for "cooperative" R&D was a natural extension of past efforts in other industries; the VLSI program itself has been followed by related work in computers and robotics, as well as further microelectronics projects.

Still, by American standards, MITI's subsidies were not large. Individual U.S. firms like Texas Instruments had R&D budgets that came close to matching the yearly outlays of the VLSI project; IBM's corporate R&D spending was an order of magnitude larger. Of course, participating Japanese companies continued their internally funded R&D programs; MITI spending thus gave a substantial incremental boost to Japanese semiconductor research, reducing risks and supporting longer term work. Even so, total expenditures in Japan remained well below those here. Nor did the VLSI project result in large and direct benefits to Japanese firms, at least in terms of product offerings. A great deal of attention in the United States has centered on the thousand or so patents associated with the program, but it is not clear what value these have. There are no signs of major innovations. Primary attention went to process rather than product technologies; one-third of the funds were spent in the United States simply on purchases of state-of-the-art manufacturing equipment. This suggests that the major thrust was to develop skills in low-cost production of commodity-like devices such as RAM chips.

Two aspects of MITI's approach deserve particular emphasis. First, *subsidization of microelectronics R&D was only the opening move in a broader strategy for building a competitive computer and telecommunications sector.* Hindsight provides ample corroboration of what was in fact an explicit goal: MITI's subsequent support of computer and software development, as well as the Japanese Government's reluctance to allow open competition for NTT procurements. NTT was a principal—though independent—actor in the VLSI program; the government evidently hoped to restrict its high-volume purchases to domestic manufacturers (the company does not produce its own semiconductors), helping generate the economies of scale so necessary for international competitiveness,

The second point—suggested by MITI's level of support, generous for a government R&D program but certainly not enough by itself to boost the Japanese industry past American firms—is that *the VLSI project was never conceived purely as an exercise in technology development.* Consistent with the usual Japanese approach to government-supported R&D, it was intended to focus industry efforts, help train engineers from private firms in state-of-the-art technologies, diffuse these technologies within the Japanese industry—in other words, to overcome weaknesses in Japan's technological infrastructure created in part by the lack of personnel mobility (ch. 8).

This makes it doubly difficult to assess the contribution of the VLSI project. While separating what might have happened from what did occur is impossible, pieces of evidence do exist: for instance, MITI excluded Oki Electric from participation and subsidies, yet Oki managed with NTT's help to develop a 64K RAM that the company now exports in considerable volume. Many of the events of the past few years—the upsurge in Japanese production and exports of RAMs—would probably have occurred in any event, albeit at a slower pace; memory chips were obvious targets for Japanese firms confident of their abilities to mass-produce relatively straightforward designs to high quality standards. They were also needed for the computers that these same firms were determined to make in greater numbers.

In the United States, the impact of the VLSI project has been exaggerated. It has come to symbolize not only direct subsidization of commercially oriented R&D but also interfirm cooperation that might be illegal under American antitrust law. In fact, as pointed out in chapter 10, cooperation among Japanese companies has been rather limited—evidence of the strength of the barriers within the Japanese industry that MITI was trying to overcome; this aspect has been overplayed by American manufacturers understandably distressed at inroads by overseas competitors, While the VLSI project makes a convenient target, by itself it is a far-from-adequate explanation for penetrations of what had been traditional American markets. Indeed, government policies in support of Japan's information industries have ranged far beyond R&D subsidies, Among the other policy tools have been:

- preferential government procurement;
- favorable credit allocations, especially during the formative years;
- special depreciation and other tax measures; and
- grants for training and education.

Domestic firms have been effectively protected from import competition as well as from production within Japan by foreign-owned concerns. Protection of growing industries through government action is hardly unique, but can only be judged to have succeeded if the protected companies eventually emerge as viable competitors. In microelectronics, the "infant industry" approach has been attempted elsewhere, most notably in several European nations, but only Japan has achieved success. Japanese industrial policy is discussed in detail in chapter 10; here the point is that none of the policy measures adopted by Japan's Government, taken separately, appear to have been major forces in the ultimate growth and maturation of the semiconductor industry. Taken *together, they paint a different picture—one* in which industrial policy provided vital guidance and support for the development of an independent capability in semiconductor design and manufacture. *Cumulatively, the policies of Japan Government have had a major impact.*

Strategy and Structure

Despite MITI's pervasive influence, the competitive strategies of individual Japanese semiconductor manufacturers are governed first by the basic structure of the industry, which is populated by companies for whom microelectronics comprises a relatively small part of their business. Most of these companies—Oki and Nippon Electric being partial exceptions—are large, integrated firms whose sales consist predominately of final products such as computers, consumer electronics, and telecommunications systems, Table 45 shows that only for

Table 45.—Proportion of Sales Accounted for by Semiconductor Products[a]

Japanese firms (1981)		U.S. firms (1979)	
Nippon Electric Co. (N EC)	19.8%	Mostek	93%
Fujitsu	12.9	Advanced Micro Devices	89
Oki Electric	9.8	Intel	75
Toshiba	8.1	Fairchild	69
Hitachi	5.3	Texas Instruments	36
Mitsubishi	5.3	Motorola	31

[a]Including internal consumption.

SOURCES Japanese Firma-Table 29 (ch 4).
U.S. Firma—"S.S. and Japanese Semiconductor Industries A Financial Compare son," Chase Financial Policy for the Semiconductor Industry Association, June 9, 1980, p 15

NEC and Fujitsu—the latter Japan's largest computer manufacturer, with heavy internal consumption—have semiconductors contributed a proportion of total sales even half as great as for those U.S. merchant firms that are least dependent on their semiconductor divisions—Motorola and Texas Instruments. Semiconductors account for less than one-tenth the sales of the other Japanese manufacturers. In this, they are closer to American companies like Rockwell or RCA, which nonetheless differ in being primarily suppliers of specialty rather than mass-market circuits.

The fact that the major semiconductor suppliers in Japan build end products creates potential intracorporate synergisms absent in companies that are primarily chipmakers. While some U.S. managers view integration as dysfunctional, likely to sap entrepreneurial drive and retard innovation, it has been an advantage for Japanese companies—which have different sets of strengths and weaknesses than American firms. To begin with, the same half-dozen corporations that produce most of Japan's ICs account for perhaps two-thirds of demand; given the focus on vertical integration and internal production, it should be no surprise that U.S. suppliers have had difficulty selling in Japan. Second, as the next chapter points out, the quality of Japanese ICs has been high–again, this might be foreseen, given that firms producing for internal consumption will find themselves bearing high downstream costs when quality lags. A further synergism associated with size and diversification stems from the ability to tap cash flows generated in other lines of business; these funds can be channeled to R&D or added production capacity, matters amplified on in chapter 7. Further, diversified companies can more easily tolerate short-term losses resulting from price-led penetration of new markets. Diversified Japanese companies have combined such tactics with an emphasis on quality—both image and reality—to drive boldly into markets once the province of American firms. Indeed, few other strategies could have worked. Unfortunately, from the standpoint of smaller and less diversified U.S. merchant manufacturers, unrelenting price competition in products representing a substantial part of their total business leaves few options for counterattacks.

The Japanese strategy—protecting domestic semiconductor manufacturers from overseas rivals while providing modest R&D subsidies and at the same time fostering domestic competition—parallels that in television. It has yielded equally impressive results: deep penetration in targeted markets based on low prices and quality levels above previous norms. There has been a fortuitous element as well; unexpected demand swamped U.S. suppliers during 1979 and 1980. As a result of continued capacity expansions during the preceding market slump, Japan's producers were ready to fill the void.

Some spokesmen for the American industry find other familiar features: claims have been repeatedly voiced that the Japanese practice price discrimination, maintaining high margins in protected home markets while slashing prices in the United States and Europe, Such tactics would imply either explicit or implicit monopolistic agreement among Japanese manufacturers—e, g., tacit acceptance of existing market positions at home, with price cutting confined to foreign markets. Even so, questions of dumping are problematic for integrated firms; companies making ICs for both internal consumption and open-market sales have a good deal of latitude in allocating costs and setting prices. Dumping, as defined under GATT rules and the laws of most countries, would be difficult to prove; nor would the usual rationales for prohibiting dumping necessarily be very relevant.

MITI's push toward ICs for computers and communications has contributed to Japan's strength in world markets for memory chips. At the same time—one legacy of the industry's roots in devices for consumer applications—Japanese product lines remain more narrowly based than those of the leading American suppliers. Microprocessors are a case in point; the major Japanese firms all continue to produce American designs. NEC, Toshiba, Mitsubishi, and Oki sell members of the Intel 8080 family; at least three Japanese firms are building Intel's 16-bit 8086.[40] Although several Japanese manufacturers have designed microprocessors for internal use, these have not found other markets. And if made-in-Japan dynamic RAMs now claim a major share of worldwide sales, the overall Japanese presence in the United States remains modest. In 1982, imports from Japan accounted for about 5½ percent by value of total U.S. integrated circuit consumption; although increasing rapidly (fig. 26, ch. 4), Japanese imports remain small in absolute terms. Still, the inroads have come in a market segment that American manufacturers rightly view as critical; U.S. firms heavily dependent on memory products have been severely affected, In other product categories, Japanese competition is also stiffening; a major effect was to further depress prices and profits during 1981 and 1982, when domestic firms were troubled by a deep recession,

In the longer term, American semiconductor manufacturers have every reason to be wary of continued pressure from powerful multinationals with headquarters in Japan—firms that have already demonstrated their ability to compete successfully in major world markets for other technically demanding products. The U.S. merchant manufacturers have their own advantages—they do well some things that Japanese firms do poorly–but they cannot expect an easy time of it in the future.

‘R. H. Silin, *The Japanese Semiconductor Industry: An Overview* (Hong Kong: Bank of America Asia, Ltd., January 1979), p. 148; "Background of VLSI War With United States Reviewed, " *Japan Report,* Joint Publications Research Service JPRS L/10662, July 16, 1982, p. 43.

Computers

If American manufacturers were for many years unchallenged in world markets for semiconductors, the United States has been still more preeminent in computers. Even in Japan, American-owned firms continue to account for over 40 percent of mainframe sales; the U.S. share of the Japanese market for small systems is lower, but such firms as Data General and Hewlett-Packard have recently established production facilities there. In Europe, U.S. companies are far out front except in the United Kingdom, where the government has actively supported ICL through procurements and subsidies. American-owned enterprises account for nearly three-quarters of all computer sales in Europe.

This section again concentrates on the United States and Japan. While Japanese computer manufacturers have not yet proven notably effective competitors outside their home market, they are at present uniquely situated to launch a campaign aimed at the U.S. position—in part because of their newly acquired strength in microelectronics, in part because of their active pursuit of joint venture ties with suppliers in Europe and the United States. It is too early to predict the extent to which the Japanese strategy may succeed, but structural changes in the world computer industry are creating new opportunities for firms everywhere. The Japanese will probably be able to exploit at least some of these, certainly better than European producers.

The Environment for U.S. Suppliers

By virtually any standard, the United States has far and away the most computer-intensive economy in the world, a position it can expect to maintain indefinitely. From the early days of the industry, the number of computers installed in the United States mounted at a pace that kept the total about an order of magnitude greater than for all of Western Europe.[41] By 1981 there was a computer terminal for every 48 people employed in the United States; by

[41] *Gaps in Technology: Electronic Computers* (Paris: Organization for Economic Cooperation and Development, 1969), p. 16.

1986 there should be 1 for every 10.[42] American leadership in design, production, and sales—as well as utilization—is reflected both in trade data, where the computer industry continues to be a prodigious net exporter, and in the prominence of U.S.-owned subsidiaries in other parts of the world.

Strategic Patterns

For many years the story of American supremacy in the global computer industry was the story of one company—International Business Machines, Although IBM trailed Remington Rand, builders of the Univac, in marketing early computer models, by the late 1950's IBM had gained the huge lead it still enjoys. For the other old-line firms—including Burroughs, NCR, Honeywell—competition has mostly meant jockeying for places in the residual market left by IBM; these companies have found it difficult to reach the Wale needed to offer a full product line and to' support a sales/service organization competitive with IBM's. In general-purpose mainframes, IBM has accounted for 60 to 70 percent of the *world* market over the years, with lower figures in such countries as Japan and the United Kingdom balanced by even higher percentages elsewhere. To be sure, numerous entrants—mostly American—have attempted to carve out competitive positions against IBM, with much more success in rapidly growing markets for small systems than in mainframes. Companies ranging from Digital Equipment Corp. or Control Data in the United States to Fujitsu in Japan and Nixdorf in West Germany have established themselves solidly in some portions of the market. But none has come close to IBM's overall sales, despite the rapid shifts in overall market structure described in the previous chapter,

Most of IBM's American competitors have taken a straightforward approach to their situation: following IBM's lead in the development of faster and larger systems, trying to maintain product lines that match up reasonably well while at the same time staking out their own territory—e.g., Control Data in high-performance scientific machines, Burroughs in small business systems (on the latter, see the case study in app. C). In these efforts, American computer firms have been aided by the technological lead of the U.S. semiconductor industry, Although IBM has relied heavily on internal semiconductor design and manufacture, other firms—whether or not maintaining captive production facilities—have been able to take advantage of components available on the merchant market that were often superior by conventional yardsticks to IBM's devices, This is one of the reasons IBM has itself begun to purchase ICs on the outside. A major element in the strategies of other mainframe suppliers (excluding those making plug-compatible machines] has been to expand into new applications while tying their installed base to proprietary software—thus keeping old customers. None have had more than limited success; other mainframe-oriented firms have generally been a good deal less profitable than IBM, and have made little headway in eroding IBM's market share, Several have done better abroad; Honeywell's joint venture in France has been a greater force in the European market than the parent has been in the United States.

The Impacts of Microelectronics and Reliability Improvement

Because the market has enlarged and changed so radically, focusing on the older mainframe companies hardly gives a fair sampling of current strategies. As figure 35 indicates, market growth for general-purpose mainframes—the mainstay of the industry just a few years ago—is now much slower than for other types of systems. As sales of minicomputers, small business installations, and desktop and personal machines exploded, competitive dynamics altered fundamentally. Newer entrants have staked out major shares of markets for products like word processors. These structural shifts are continuing—indeed accelerating.

What are the implications for international competitiveness? As in semiconductors, prod-

[42] L. M. Branscomb, "computer Communications in the Eighties—Time To Put It All Together," *Computer Networks*, vol. 5, 1981, p. 3.

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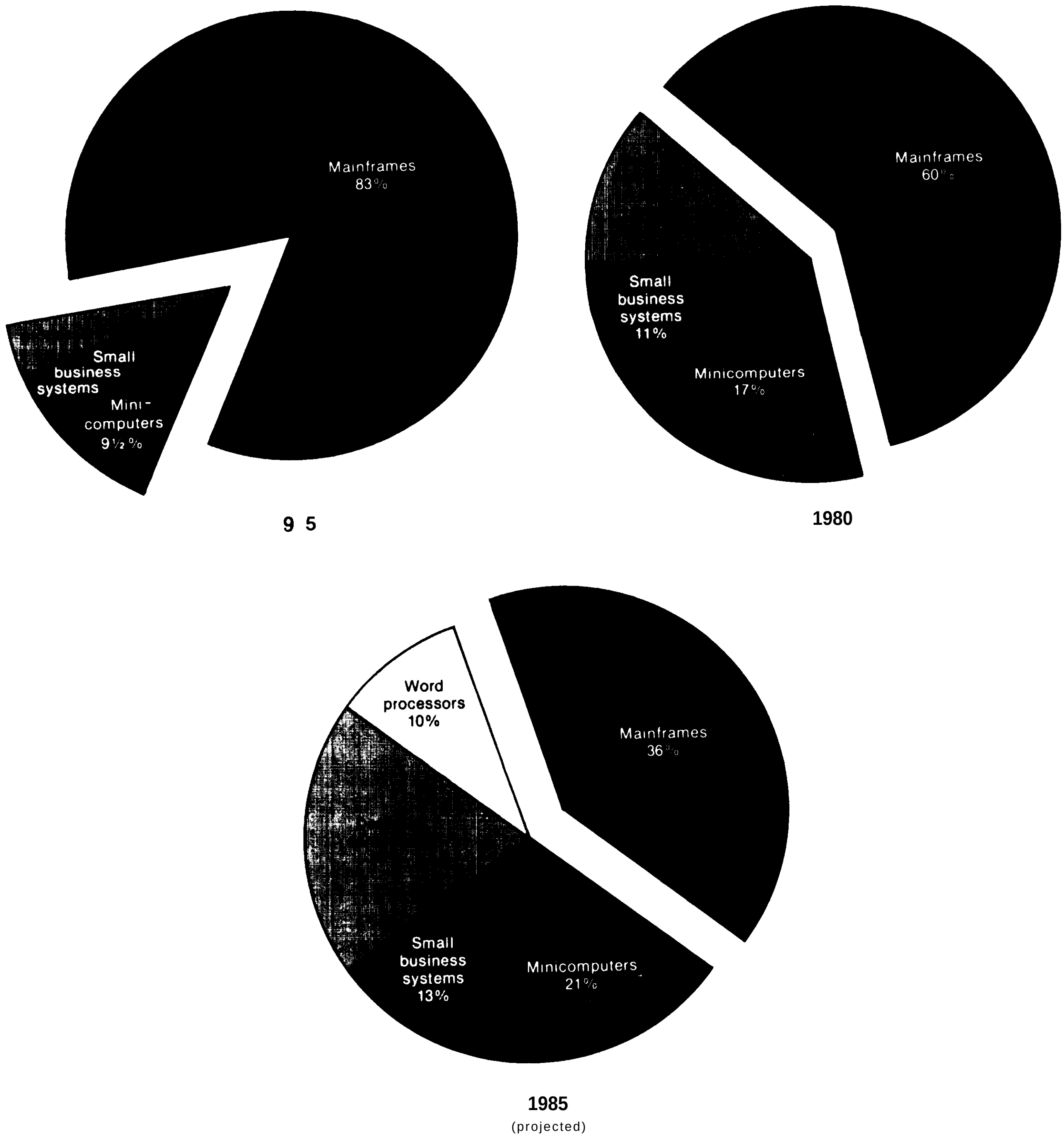
Figure 35.—Market Segmentation of U.S. Computer Sales by Value



SOURCE "Moving Away From Mainframes The Large Computer Makers' Strategy for Survival, " *Business Week,* Feb 15, 1982, p 78 uct planning decisions in the computer industry are shaped by technical possibilities. Specialized machines of all sizes have long had their place, but the turn toward small and versatile computers is a direct consequence of twin driving forces: advances in software for networking and distributed processing, plus advances in microelectronics. Computer systems need no longer be structured around a single processor. A central unit can be surrounded by a number of satellites, or the entire processing load can be shared throughout a network. Given cheap microprocessors and single-chip microcomputers, designers can put "intelligence' where they want it, Computer firms that fall behind in such developments—more broadly, manufacturers of systems incorporating machine intelligence, not all of whom think of themselves as part of the computer industry—will be poorly placed to compete in future markets.

Improvements in system reliability—flowing partially but not wholly from the growing reliability of microelectronic devices—yield another powerful driving force. Mean times between failure for computer systems have been increasing steadily despite greater complexity. Today's computers are orders of magnitude more dependable than those of even a decade ago; this not only cuts operating and maintenance costs but helps expand applications. Computers can now be used in a host of applications where the dangers of a failure were formerly too great–real-time air traffic control, electric utility load management, critical industrial processes.

Ever-greater reliability combined with ever-greater computing power per dollar has eaten away at IBM's traditional strengths—customer support and service, plus the ability to lock in customers via a product line broad enough to satisfy virtually every need. Now, so many applications have opened up that no one company can hope to cover them all; in many of these, IBM's market power—so valuable in selling general-purpose mainframes—has been, if not irrelevant, at least a far smaller advantage. New entrants can specialize in systems for banking or distributed word processing. Startups of earlier years—Data General, Prime, Tandem—have become substantial multinationals in their own right. Independent software vendors are creating a whole new industry.

Better reliability—in addition to broadening the applications of computers—has had a second, equally important, impact. As in consumer electronics, it has allowed manufacturers to skirt traditional distribution channels and reach customers through new outlets. This trend—which began as early as the 1960's with systems houses that purchased minicomputers and peripherals in quantity, assembling them, together with software, to supply turnkey installations—also promises to continue and perhaps accelerate. Greater reliability has reduced the need for onsite maintenance and repair; where field service was once a vital element in any marketing strategy, smaller manufacturers are now less constrained by the need to finance service networks. Moreover—while hobbyists, engineers and scientists, and many businesses could be reached through specialized distribution channels–selling personal or desktop computers to the general public requires retail distribution. This, in turn, is realistic only if the need for aftersales service is modest. Currently, the personal computer market is moving through a transition paralleling the earlier shift in color TV—desktop machines are becoming off-the-shelf items rather than products sold and serviced by specialty outlets. The personal computer is a product in which IBM had no great advantages beyond name-recognition and abundant internal resources for product development. While these are far from trivial assets, IBM will probably not be able to duplicate its position in mainframes in the far more diverse and competitive desktop market, just as the company has not been able to do as well in small business systems, supercomputers, or word processors. The general point is: to be in the computer business no longer necessarily means confrontation with IBM; it need not entail attempting to cut into the installed base of any mainframe manufacturer, much less trying to match IBM's hardware or software across a broad spectrum of products.

Even in small systems, only a few companies have been able to span a major portion of the market. Some—e.g., Hewlett-Packard—have specialized in powerful machines for sophisticated customers. Others, like Wang and Datapoint, have aimed at business applications, Digital Equipment Corp. (DEC)—which started as an OEM supplier—now has a relatively broad product line, including personal computers, As in the semiconductor industry, managers have had to search for market opportunities that match their organizations' strengths. Their choices and decisions, constrained by resource limitations and conditioned by government policies, will determine the future competitive posture of the U.S. industry. Mistakes will be made, and weaker companies—most likely those making peripherals, office automation equipment, and desktop computers—will find themselves being absorbed or merged with competitors.

Product Strategies: Hardware and Software

The mainframe-oriented companies do retain advantages in structuring complex and far-flung information systems. Designs for such systems are often shaped by existing software inventories, The original supplier has an easier time achieving compatibility; indeed, computer firms have had a good deal to gain by making it difficult for competitors to reverse-engineer their software and develop compatible systems. Some have gone so far as to replace portions of the system software with "firmware" stored in ROM chips which can be changed from time to time. Generally, such efforts have been intended to thwart plug-compatible manufacturers.

The importance of software extends far beyond the system level. Machines capable of data processing for business needs are now within the financial reach of even the smallest firms—and, of equal significance, can be used by people with little special training, Software that is user-friendly, as well as reliable, is a key element in selling to those without previous data processing experience. As the case study in appendix C points out, credit for the success of IBM's System/32 small business computer goes in large part to the specialized applications programs that were available, Even more, as hardware costs fall, specialized software becomes the pacing factor in applications ranging from office automation—where much of the competition for word processor sales revolves around software—to industrial robots. Limited growth in software productivity and high associated costs (ch. 3) are problems that now confront all firms in the industry, here and overseas; among the possible solutions are multinationalized software generation. In the future, the importance of software compared to hardware can only increase; the exceptions are perhaps at the very high and very low ends, where supercomputers remain hardware-intensive and small machines selling for less than a thousand dollars compete on the basis of price.

From a slightly different perspective, software can become a constraint: switching to new software, particularly system software, is time-consuming and expensive. Customers with extensive data processing installations and large software inventories become locked in because of the high costs of transferring. This is a constraint on the system manufacturer as well, who may be burdened with obsolescent software that cuts into potential performance. The picture is somewhat different for computers sold to purchasers who are technologically adept—e.g., OEMs who integrate computers into their own products, or those with needs in engineering or science. Such customers commonly have the internal resources for solving their own software problems, and find shifting to new systems, though a difficult task, not an insurmountable one. Still, given their software investments, virtually all customers have strong motives for replacing or augmenting their equipment with new models from the same manufacturer—and manufacturers strong motives for ensuring software compatibility within their product lines. Therefore, once markets begin to mature, a manufacturer's share of the installed base becomes a good indicator of future prospects; competitors need hardware that is substantially better or cheaper to stand much chance of convincing customers to switch allegiance, Brand loyalty has been high in general-purpose data processing markets, largely for such reasons.

Plug-compatibility is aimed at breaking this cycle. Originally referring to peripherals such as disk drives, plug-compatible manufacturers (PC MS) later moved into mainframes that can operate on IBM software; now some build equipment compatible with DEC minicomputers or IBM Personal Computers. Basically, the PCM strategy has been to make equipment that can be used interchangeably with IBM's, while undercutting the latter's price/performance ratios .[43]

The forces outlined above shape the strategies of companies striving to keep up in the marketplace. New approaches to product development are appearing throughout the industry; even IBM has begun to purchase more hardware outside, as well as software. In another new departure for the company, IBM has started selling disk drives on an OEM basis. As in semiconductors, technology-sharing agreements have become more common—cross-licensing of patents, direct purchases of technology, joint development—as firms conserve resources through specialization. This is the idea behind Microelectronics & Computer Technology Corp.—spearheaded by Control Data and presumably aimed not only at oncoming competition with the Japanese but the continuing struggle of smaller entrants with IBM. Movement toward technology purchases and technology sharing appears to have even more momentum in Europe, despite earlier failures of joint efforts like Unidata. Siemens, ICL, and Olivetti are among the companies now marketing Japanese-built mainframes in Europe.

International Aspects

The picture that emerges in the U.S. computer industry is one in which the long-dominant leader is being challenged on all sides, Structural change has been driven largely by the technology—although occasionally market demand outstrips what the industry can supply, as happened with word processors—and it is difficult to predict where it may lead. Some observers believe that IBM's market power will continue to deteriorate, even in areas where the firm's position has heretofore seemed unassailable. Others think the future lies with large and powerful companies able to combine far-flung communications and information networks into vast integrated systems. In fact, both views are probably correct, given the fragmentation and specialization brought by cheap hardware.

American computer manufacturers, living nervously with rapid technical change at home, face another series of choices in foreign markets. Governments in industrialized nations where American subsidiaries have long been dominant continue to follow policies transparently intended to reduce that dominance, Such policies are nothing new: France's Plan Calcul was set forth more than 15 years ago, and the Governments of Great Britain and Japan have, over the years, found many ways to support local computer manufacturers. While most such policies have had only limited effects in the past, certainly in Japan the technological fervor is now intense,

If competition from Japanese computer firms is on the rise, American entrants are themselves fashioning new international strategies. Already DEC operates six plants in Europe and three more in the Far East. A partial list of other American minicomputer manufacturers with foreign production facilities would include Hewlett-Packard, Wang, Data General, Datapoint, and Texas Instruments. U.S.-based multinationals specializing in desktop machines include Apple, with plants in Ireland and Singapore, and Tandy. Manufacturers producing plug-compatible mainframes have also begun to expand abroad: Amdahl has opened an Irish facility intended in part to supply the Common Market, as has Trilogy Systems.

The rules of the competitive game are in particular flux in lesser developed parts of the world. Developing countries are putting in-

[43] The founder of Amdahl, the leading supplier of PCM mainframes, has said that surviving in competition with IBM requires costs that are 15 percent lower or performance that is 20 percent better, See "Makeshift Marriage, " *The Economist,* Aug. 11, 1979, p. 78.

dustrial policies to work attracting technology and fostering local computer manufacturing. Mexico's approach has been to restrict imports, limiting sales to companies that agree to establish production facilities. With an annual market now approaching $500 million, Mexico has been able to attract a pair of U.S. minicomputer firms willing to live with these rules. Brazil's Government has reserved the domestic minicomputer market for locally controlled enterprises; transfers of technology have been encouraged, but foreign investments are limited to minority interests. While American companies have generally chosen to stay out, several European and Japanese firms have agreed to participate—no doubt hoping for benefits similar to those now flowing to the Japanese consumer electronics manufacturers that accepted such conditions in earlier years.

How will the onset of local production in developing countries affect international competition in computers? While any answer remains conjectural, it would be foolish to dismiss the possibility that some of these nations may evolve into viable forces in the marketplace. Although their ability to compete will probably be restricted to simpler products over the foreseeable future, developing economies will begin by building equipment such as terminals, printers, and disk drives, where labor is a major cost element. It is not a big step from making TV receivers to producing the simpler types of computer terminals—indeed a step that countries like Korea and Taiwan have already taken. With the experience gained in such products, and with protected markets contributing to scale economies, a number of the newly industrializing countries could move fairly quickly into world markets.

As a final point, again consider software development. By its nature, programing has been labor-intensive–therefore increasingly costly in high-wage nations. Software generation depends on people with ability and experience—including an understanding of the problems faced by users, Such factors have prevented the transfer of this work to developing countries, even those like India where the raw programing skills might be available. Nonetheless, several industrializing nations are attempting to improve the capabilities of their labor forces so that they can produce software needed in advanced economies. Countries like Singapore, Hong Kong, and Taiwan are seeking to create "software centers" where Western computer manufacturers could establish subsidiaries that would transfer skills and provide training for the local work force while also producing much-needed software. Once the people were available, locally owned companies could take over at least some of the work.

Japan

Objectives announced by Japan's Government over the past few years herald a competitive onslaught directed at the U.S. computer industry. MITI is sponsoring a pair of long-term R&D projects dealing with computer systems, plus several related efforts.[44] The fifth-generation computer project—the origins and organization of which are described in chapter 10—is software-intensive, directed at artificial intelligence, information organization and management, and natural language input and output. In the second project, MITI is helping fund the development of a supercomputer intended to surpass the most powerful offerings of American companies like Control Data and Cray. A related lo-year project will support development of the high-speed microelectronic devices needed to implement the software concepts of both fifth-generation machines and supercomputers. The goal is nothing less than to thrust Japanese companies into the forefront of world computer technology, to leapfrog the United States in the design and marketing of both hardware and software. The objectives of

'*Outline of Research and Development Plans for Fifth Generation Computer Systems* (Tokyo: Japan Information Processing Development Center, Institute for New Generation Computer Technology, May 1982); *Computer White Paper: 1981 Edition* (Tokyo: Japan Information Processing Development Center, 1982], pp. 59-75; "Machinery, Information Industries '81 Programs Outlined, " *Japan Report*, Joint Publications Research Service JPRS L/10086, Nov. 2, 1981, p. 21; "Archetype of Fifth Generation Computer Described, " *Japan Report*, Joint Publications Research Service JPRS 1./11007, Dec. 14, 1982, p. 49; "MIT I Project To Develop Supercomputer Starts in January, " *Japan Report*, Joint Publications Research Service JPRS L/10348, Feb. 23, 1982, p. 34.

these programs are by no means unique to Japanese manufacturers; they are squarely in the mainstream of the evolution of computing. It is the strength of Japan's commitment—the backing by MITI and other government agencies, the lo-year schedules—that differentiate them from efforts in other countries.

As the rhetoric associated with such programs makes clear, Japanese firms, with the help of their government, hope within 10 or 15 years to lead the world in computer technology. Despite Japan's relatively successful experience with previous government-sponsored R&D efforts—the Pattern Information Processing System (PIPS) project, the VLSI project—this is a tall order. At present, the market position of Japanese manufacturers is modest; as of 1981, American-owned companies held more than three-quarters of the world computer market in value terms, Japanese-owned companies only about 7 percent. Still, Japan is now the second largest supplier of general-purpose computers to the world market, with a very high rate of export growth (ch. 4, fig. 30). The country is also second only to the United States in intensity of computer utilization. After the experiences of consumer electronics, automobiles, and semiconductor memory chips, few in the American industry would take Japan's goals lightly.

Nevertheless, because of the role that factors such as installed base and software inventories play in the marketing of computer systems, Japanese manufacturers must begin with the knowledge that—no matter how good their technology—they cannot hope to come close to the United States for many years. In this sense, the computer market is not at all like that for semiconductors, where purchasers quickly switch suppliers to take advantage of low prices, quick delivery, or new device types. Success in niche markets for computer systems is quite possible, indeed a necessary first step, but breadth in an industry expanding in as many different directions as information processing can only be a long-term undertaking, The U.S. position, both in technology and market share, is simply too strong. Leaders in Japanese Government and industry recognize their weaknesses, and have made plans accordingly.

Technology

Carefully targeted R&D is a central strand in the Japanese computer strategy, as in earlier ventures into other industries, Japanese producers and their government realize, just as they did in microelectronics, that international competitiveness in computers cannot be attained so long as they rely on technology from the United States, The reasons are twofold, First, American firms are far less likely to license technologies than in the past, The Japanese know that computer manufacturers in the United States, unlike at least some of their predecessors in other sectors, are acutely aware that technical leadership is a primary source of competitive strength, and that to make their technology too easily available would weaken their own position, The second reason is even more fundamental. In the basic building blocks of computer hardware, semiconductors, Japanese firms are near parity with American companies; in some areas they may be ahead. Japan can hardly depend on imported technology; rapid progress toward an eventual goal of leadership in information processing requires extensive indigenous capability of the sort that Japanese firms now have in high-density memory chips,

The Japanese also recognize that their shortcomings in the marketplace are not so much matters of hardware as of software and related applications-based constraints, Several Japanese firms now offer computer hardware as powerful as any. However, IBM's huge installed base and vast catalog of applications programs have forced Japanese competitors, as those elsewhere striving to break into the mainframe market, to build plug-compatible machines that run on IBM software. To get around this impediment is perhaps the major reason for the fifth-generation project. While companies like Amdahl have demonstrated that a comfortable business can be built supplying PCM mainframes, markets tied to another manufacturer's software are inevitably limited. Japan's gamble is that it can jump ahead of American entrants with families of computer systems having performance capabilities that will render present-day software inventories obsolete. This goal has shaped the hardware and software R&D planned for the fifth-generation project: to take full advantage of emerging microelectronics technologies in more closely linking the needs and abilities of people with the capabilities of the system. If these objectives are met, individuals—even those with little training—will be able to communicate with fifth-generation machines through ordinary language in spoken or written form, as well as through graphical or pictorial images. Such systems would not only be user-friendly, but might ultimately display something of the independent decisionmaking capability associated with human reasoning. * If the technical objectives of the fifth-generation project—and similar efforts in other countries—are achieved, even novice users would be able to harness enormous computing power. The commercial potential is immense.

Government Assistance

The Japanese Government has supported R&D activities in information processing over many years. MITI has been selective in financial aid, directing funds to potential bottlenecks, exemplified by the VLSI program's support for digital ICs, or to R&D that could help Japan's industries leapfrog the competition, the intent of the fifth-generation computer project. Funding for the latter is projected at about $500 million over a 10-year span (1981-91); the supercomputer project is expected to get another $100 million over roughly the same period.** A parallel microelectronics project—which goes by names such as "R&D on New Function Elements''—has a budget of about $150 million and is scheduled to run from 1980 to 1990, Money will go to three major development efforts:[45]

- Three-dimensional circuit elements—which can be visualized as more-or-less conventional ICs stacked atop one another, increasing the density.
- High electron mobility transistors (HEMTs), one variety of which consists of very thin layers of semiconducting materials such as gallium arsenide or gallium aluminum arsenide; HEMTs offer potentially higher switching speeds, hence faster computers.
- Radiation-hardened devices suitable for use in extreme environments such as nuclear powerplants or outer space (resistance to heat and vibration is a related objective).

The first two especially will support both supercomputer and fifth-generation projects. Among related government-sponsored programs, another of major significance for the corporate strategies of Japan's computer manufacturers has aimed at the development of software and peripheral devices with Japanese language input-output capability. Scheduled over the period 1979-83, nearly $200 million was allocated to this effort.[46]

As in microelectronics, R&D is but one of many ways in which Japan's Government assists the computer industry. The Japan Development Bank loans money to the Japan Electronic Computer Corp. (JECC), a jointly held firm which purchases computers from participating manufacturers and leases them to

*An example from the field of artificial intelligence—the area known as expert systems—will illustrate, Research in expert systems aims at computer programs that mimic attributes of people who are "experts" in some realm of knowledge—e. g., medicine, where such programs might help automate diagnosis. The objective would generally be to augment or complement rather than supplant human skills; an expert system would not have the judgement of a physician, but could offer, for example, perfect recall of vast amounts of information. Expert systems typically depend on complex software and large data bases; thus, advances in hardware as well as software maybe needed if they are to be widely implemented.

* * Planning for the fifth-generation program began several years earlier, as outlined in ch. 10. A variety of funding levels for both projects have been reported; spending plans and schedules will no doubt shift as they progress.

[45] "FY82 Government Projects in Electronics Listed, " *Japan Report,* Joint Publications Research Service JPRS L/10676, July 22, 1982, p. 55.

[46] *Computer White Paper: 1981 Edition,* op. cit., pp. 4ff.

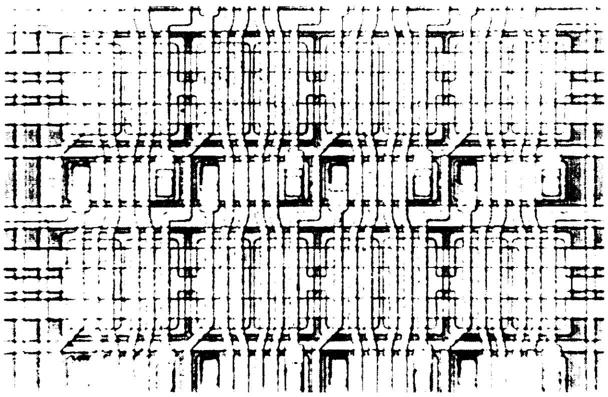


Photo credit IBM Corp

Memory cells in experimental Josephson junction integrated circuit chip

users. Manufacturers can set up tax-free reserves to offset losses incurred when lease contracts with JECC are canceled and equipment must be repurchased. Since 1979, tax-free reserves have been permitted for up to half the income associated with some categories of software. Purchasers of certain types of computers can write off 13 percent of their value, beyond normal depreciation, in the first year. The government has also established special depreciation schedules for high-performance remote data processing equipment.

A panopoly of support measures—of which many more examples could be cited—has thus been designed to help Japanese companies achieve technological superiority and commercial success in the **1990's.** At first glance, the sums of money involved may seem large; in fact, when viewed in the context of the world computer industry, they are modest; as chapter 10 stresses, it is the consistent *support provided by many individual measures acting in concert that gives Japanese industrial policy its impact.*

To place the expenditures of the Japanese Government in perspective, table **46** lists R&D spending by **a** number of [J. S.-based computer firms. On an annualized basis, subsidies provided by Japan's Government for R&D in information processing come to less than the expenditures of any one of these American companies. (Total subsidies for the information in-

Table 46.— Research and Development Expenditures by Several U.S. Computer Manufacturers, 1981

	R&D spending (millions of dollars)
Burroughs	**$220**
Control Data Corp. ., ...	202
Digital Equipment Corp.. ., ...	251
Hewlett-Packard	347
Honeywell	369
IBM ., ...	1,600

SOURCES Annual reports

dustries in Japan—including indirect support through tax preferences—could only be estimated by making a large number of essentially arbitrary assumptions; see ch. 10.) MITI's R&D subsidies are also modest in comparison to the research budgets of Japanese companies. Fujitsu spent **$260** million on R&D in 1981, while Hitachi and NEC spent $610 million and $230 million, respectively .47 The government money does have an important function: helping with the kinds of long-term R&D that individual companies might otherwise have difficulty in justifying. In addition, MITI-sponsored projects—though not cooperative in the usual sense-attempt to stimulate creative thinking, technology interchange, and the complex of synergies so vital to engineering research. The Japanese electronics industry probably benefits more from these factors—which tend to be lacking within the laboratories of individual corporations-than a strict comparison of funding levels would suggest.

Of course, other governments also provide assistance to their computer industries, not excluding the United States. European nations routinely channel direct financial aid to local companies, along with indirect subsidies through procurement and tax benefits. Handsome incentives designed to attract investments and technology have been dangled before the European subsidiaries of U.S. and Japanese companies. In the United States, funding by the Department of Defense through the Very High-Speed Integrated Circuit program and this country's own supercomputer project—still in the planning stages—will have

[47]An n ual reports

commercial spillovers. The lesson is that no industrialized nation has been content to accept a secondary position in technologies and markets considered essential to future economic development. The concern is that the Japanese may be more successful in implementing their policies than other countries.

Marketing Strategies and Multinational Operations

Individual computer manufacturers in Japan have begun to formulate product strategies based on technologies expected to flow from government-supported R&D projects, as well as their internal activities. Marketing computers presents special difficulties because the chief competitors are already well entrenched; only in peripheral equipment such as terminals, printers, and disk drives have Japanese manufacturers made a significant impact outside their home market. In Europe and the United States, where nearly two-thirds of the world's computer systems have been installed, Japanese companies are inconsequential as independent suppliers.

In an industry where sales depend on a thorough grasp of user needs at a technical level—software as well as hardware—late entry is a major handicap. American suppliers-including newer participants like DEC and Hewlett-Packard—have built networks of sales and service centers staffed by engineers and technicians who now have longstanding ties with customers; IBM has such a network within Japan, Even those Japanese firms with strong international positions in microelectronics or telecommunications cannot match the distribution systems of U.S. computer manufacturers. To make much progress, Japanese entrants will have to invest substantial sums over many years without the expectation of immediate returns. The history of fields like consumer electronics indicates that at least some Japanese companies will be willing to make this commitment.

Perhaps surprisingly, given the global perspectives of consumer-oriented firms like Matsushita, the Japanese computer industry as a whole suffers from a pronounced lack of international business experience compared to American firms of even quite modest size, Until recently, most (but not all) Japanese companies have preferred to manufacture at home for export; this could prove a major weakness in computers. While a few Japanese electronics companies—Toshiba is another—have expanded aggressively via overseas investment, most of Japan's past international successes have come in products where integrated manufacturing and marketing in foreign countries has not been essential. The examples include steel, automobiles, and semiconductors; consumer electronics is only a partial exception. In each of these cases, Japanese companies, at least in the beginning, concentrated on export sales. Generally able to take advantage of established distribution systems, they invested overseas only when import restrictions compelled local manufacturing. The competitive pressures that led U.S. semiconductor or computer firms to invest in Europe and elsewhere have only recently begun to impinge on the Japanese. By now, American computer firms not only operate wholly owned sales and service networks in many parts of the world, they have established internationally dispersed and integrated manufacturing operations—partly in response to governmental demands and partly due to the nature of the market. Japanese firms, on the other hand, have been largely unwilling or unable to make the enormous investments required to participate in the world marketplace for computers.

Managers of Japanese firms, along with bureaucrats within the government, recognize their lack of background and experience, and are seeking remedies. The international (as opposed to R&D) strategy appears to be an incremental one, geared to minimizing the resources at risk and taking advantage of existing strengths. As part of this strategy, Japanese electronics firms, with the encouragement of MITI, are beginning to establish manufacturing plants in other industrialized countries, Following investments by Japanese consumer electronics suppliers in the United States and elsewhere, tentative steps have been taken in semiconductors, a market in which the Japanese have already become well entrenched through exports. These same semiconductor manufacturers are of course the major computer firms. Experience gained from investments in semiconductor production will help in structuring multinational computer operations.

As a parallel step, Japanese manufacturers have established marketing links with a number of foreign firms, Fujitsu now furnishes Siemens [West Germany) and IGL (Britain) with large mainframes, while Hitachi has similar arrangements with BASF (West Germany) and Olivetti (Italy). Fujitsu has taken a minority interest in SECOINSA of Spain, while agreeing to a technology transfer tie with a company partially owned by the Brazilian Government. In the United States, Fujitsu holds a minority interest in Amdahl, the PCM pioneer to which it exports large machines; for several years, Fujitsu distributed its smaller systems within the United States through a joint venture with TRW. National Advanced Systems, a subsidiary of National Semiconductor, sells Hitachi computers here.

Such arrangements build from the fact of Japanese parity in hardware for large computers, parity which does not extend to software; both Fujitsu's and Hitachi's systems are IBM-compatible. European firms have been unable to attain the economies of scale that Japanese manufacturers get in their home market, and have chosen to compete with American producers by importing from Japan, From the collective viewpoint of Japanese firms, these ventures—even where the equipment is labeled with some other brand name—increase market exposure and add to production scale. For some time, such relationships will continue to be essential elements in the marketing strategies of at least several of Japan's computer manufacturers, Even so, they link companies none of which has more than a minor share of the global computer market. Siemens, ICL, and the other partners of Japanese firms together do not account for even 5 percent of world computer sales. With the possible exception of ICL, none has a scale of operation and distribution approaching that of the competing local subsidiary of IBM. None is strong in minicomputers or small systems. Moreover, the Japanese participants remain a critical step removed from the customers whose applications their equipment is intended to serve—joint ventures will provide limited help at best in remedying past weaknesses of Japanese firms in software or customer support and service. To become viable international competitors, Japan's computer companies will need to accumulate experience in dealing directly with the requirements of customers in markets where they hope to sell.

Computer manufacturers in Japan do not share these problems in equal measure; the industry is far from monolithic. Fujitsu, at the moment in a clear leadership position (ch. 4), has, along with Hitachi, chosen to stake its international position on supplying IBM-compatible equipment--decisions that will limit both companies' options for many years to come. NEC has taken a different route, developing its own system software (although derivative of U.S. technology). Nor has NEC yet entered into marketing arrangements with foreign concerns. Instead, the company's management appears to be shaping a strategy intended to take advantage of the overlap and merger of computer and communications technologies, areas where the company is already prominent. Despite its relatively small size compared to other Japanese electronics firms, much less IBM or AT&T, Nippon Electric's managers are attempting to position their organization for what they see as an eventual competitive struggle with these two American giants for dominance of the international information industry,

At several points above, the entry barriers created by the well-established sales and service networks of American firms have been described. This aspect of the market for computers effectively turns one of the supposed advantages of the Japanese system on its head. Barriers erected by government to keep out foreign firms have given Japan's manufacturers advantages in a number of industries, partly through scale economies. Closed markets created by import restrictions and foreign investment controls have been reinforced by complex distribution structures and a deeply ingrained "Buy Japanese" attitude. In computers, however, the longstanding customer ties maintained by U.S. firms combine with technological strengths to create formidable entry barriers for Japanese companies—indeed, new entrants from any part of the world. Windows do open because of technological advance; through these windows newcomers have moved into markets for microcomputers, small business systems, and other specialized products. Thus far, most of these entrants have been American firms—in part because the U.S. market is so large, but also because American companies control the distribution apparatus in most parts of the world. The going will be difficult for Japanese manufacturers, although they are beginning to find niche products—desktop computers may be one—suited to their strengths.

In medium and large systems, Japanese companies can choose from a number of alternative (or complementary) courses of action. One is to continue to build joint relationships with foreign enterprises. As noted above, such a strategy will require, first, deeper involvements with end users by the Japanese participants, and, second, movement into markets in more parts of the world. If firms such as Burroughs, Control Data, or Honeywell were to be enticed—each has a relatively small but well-established market share—the prospects for Japanese firms would look a good deal better. The constant pressure of trying to achieve costs comparable to IBM's could well force one or more American companies to accept such ties.

As an adjunct to joint marketing ventures, Japanese manufacturers will probably seek other ways of incrementally expanding sales, while awaiting the fruits of the fifth-generation computer project. If Japan succeeds in pioneering a new generation of hardware and software, companies with multinational production and marketing experience will be able to exploit the new technologies most effectively. In this context, present efforts would not be so important in themselves; rather they would be preparatory steps for rapid growth in the 1990's. Another path, one that some firms will certainly pursue, is to concentrate on selling smaller systems and personal machines. Here the now-traditional Japanese entry strategy is feasible because distribution networks are open to all comers, Thus far, attempts to challenge American companies like Apple or Tandy in personal computers, or the many U.S. entrants in the market for small business systems, have not been notably successful—in the United States or elsewhere. Still, if and when such products become more nearly standardized and interchangeable, Japanese companies could expect an easier time, But even if companies based in Japan were to expand into these markets, it is not at all obvious that this would help them in other types of systems.

Japanese producers of computers are thus taking what seem the only paths available in their attempts to break into the world market: independent technology development coupled with joint marketing relationships. That the marketing ties involve firms that are themselves weak and in need of partners is hardly surprising, but makes the establishment of a viable international presence that much more difficult. At this point, the Japanese have had only marginal impacts on global markets; at home, IBM-Japan remains a formidable competitor. Whether or not technical developments in microelectronics and software will thrust Japan into a position nearer the forefront remains to be seen. If Japan's computer manufacturers do begin to increase their market shares significantly, the most likely victims will be smaller competitors—first in Europe, then perhaps in the United States.

Summary and Conclusions

While international competitiveness—in any industry—depends on many factors, the business strategies pursued by private corporations are central. Costs of labor and capital, technological resources, government policies, human resource endowments—all can, at least in principle, be looked on as forces impinging on management decisions, as features of the landscape for business tactics and strategies.

While a useful perspective, the strategic view of competitiveness is nonetheless an imperfect substitute for more quantitative indicators. Unfortunately, the swiftness of technical change in electronics precludes useful quantitative measures. Productivity trends mean little where the standard products of today—whether semiconductors or mainframe computers--have capabilities that may be orders of magnitude beyond those of a decade past. Comparative manufacturing costs carry weight in some cases, but not where one company can build products exceeding the reach of competitors. Little meaning attaches to patent statistics as surrogates for technical ability when incentives for acquiring patents vary widely among countries and nowhere correlate very closely with qualitative aspects of technology.

If shifts in international competitiveness cannot be extracted from statistical series, careful examination of business activities can yield insights into future prospects as well as past trends. In semiconductors and computers, not to mention consumer electronics, American firms--once undisputed leaders in technology, as in sales in their home markets and virtually around the world-face much stronger competitive pressures. Foreign enterprises, mostly Japanese but also entrants with headquarters in other Far Eastern countries, are selling larger volumes of electronics products within the United States; American corporations are having a more difficult time in foreign markets, The sources of these shifts are many, By-and-large, they are *not* due to mistakes or faulty strategies by American firms or by the U.S. Government. First and foremost, rising foreign competition flows from continued rebuilding of the electronics industries of Europe and Japan in the aftermath of World War II. It is not a new phenomenon. By the mid-1950's, when much of the basic reconstruction of overseas economies was complete, companies in Japan and much of Europe found themselves still well behind the United States in their ability to design, develop, and produce electronics products. But they were in a good position to catch up. The first signs of success came early, when Japanese manufacturers like Sony created new families of transistor radios smaller and lighter than those offered by American firms. The transistor was invented in the United States, the first transistor radios also made here, but Japanese firms pushed their product development efforts vigorously and outstripped their U.S. rivals within a few years. Now that Japan is in the lead with new generations of consumer products it will be difficult for American or European manufacturers to regain the lost ground.

In computers and semiconductors, Western Europe came out of the war well ahead of Japan. The Europeans had good fundamental technology, but were stymied by small and fragmented markets, as well as by managements that had neither the resources nor the vision of their counterparts here. Subsidiaries of U.S. corporations became the backbone of the European computer industry---they still are—and took the lead in microelectronics. In the Japanese market, American firms could not match their accomplishments i n Europe because of the protective policies of Japan Government. Still, if not dominant, the United States was—and remains—a major force in Japanese computer sales, particularly for large machines, as well as in some types of semiconductor devices. *Continued efforts* by *American firms--backed if necessary by the U.S. Government--to participate on equitable terms within Japan, whether by exporting or by direct investment, appear vital for maintaining U.S. competitiveness in electronics. The* Japanese electronics market is large and still expanding rapidly; it is now more important than Europe.

Japanese industrial policy has been a more significant source of support in semiconductors and computers than in consumer electronics. The MITI-sponsored VLSI research program—while not as important as some Americans have claimed--did help Japanese firms master process technologies for very large-scale digital ICs. In standard device families like memory chips--where the path of technological evolution is clear for all to see, and technological success a function more of painstaking development and detail design than highly creative engineering—the Japanese have excelled. While they cannot as yet match the breadth of American product lines, they will certainly continue to improve their capabilities in circuit design as well as processing. If U.S. semiconductor manufacturers can expect intense competition, they too have their advantages—a different set than those of Japanese firms. *If American companies continue to capitalize on these strengths—the best trained engineers in the world, quick recognition and response to market needs, innovations in circuit design, applications of computer-aided techniques, specialized products pursued with entrepreneurial zeal—the United States should be able to maintain a leadership position.* Still, American companies will not be able to monopolize world sales as they did a decade ago.

Competitive pressures, evolving technology, and growing capital intensity—along with the continuing expansion of captive production by integrated firms—are changing the structure of the U.S. semiconductor industry. New structures bring new strategies. Structure is changing in the computer industry as well, driven by the technology of computing, itself depending heavily on microelectronics. As computing power becomes ever cheaper, more and more applications become cost effective. These attract new firms, designing and developing not only peripherals and software, but specialized processors—minicomputers, personal and desktop units, business systems, While the mainframe is hardly a dinosaur, a “computer” can now be a great many things—many never envisioned by the designers of the general-purpose machines sold two decades ago by a small number of companies such as Univac and IBM. Computing power is now cheap and widely dispersed, often invisible to users. As distributed processing and data communications continue to spread, new firms will try to establish themselves, entering through windows of technological or market opportunity. Some of the older firms will find themselves hard-pressed to keep up, even survive; their managers will face hard choices in allocating limited resources. Few companies—even including the largest, here or in Japan—will be able to cover more than a small fraction of product markets.

While no one can foretell competitive outcomes in the world computer industry, it is obvious for all to see that Japan has made a series of explicit decisions—going back as far as the 1960’s and involving both government and industry–aimed at claiming a major share of sales and applications. Based on past performance in other sectors of electronics, the probability of continued expansion by the major Japanese computer manufacturers is high. Because the characteristics of the market for data processing equipment differ from those for semiconductors, the United States remains in a stronger relative position. There is no reason why the United States cannot continue to hold an overall lead in both technology and sales.

As events in all three portions of the electronics industry demonstrate, competitive positions in global markets have shifted more-or-less continually over time. Some firms in some parts of the world rise, others decline. Of those that decline, a few may eventually revive, others disappear. No country can expect all its industries to thrive in international competition; any nation that trades will be more competitive in some industries than others, the leaders in competitiveness shifting over time. That U.S. competitiveness has slackened in consumer electronics does not imply that similar events will follow in other sectors. This could happen, but there is no reason to expect declines in microelectronics or computers paralleling those in color TV—particularly so long as the technology continues its rapid evolution and markets expand at high rates. These are conditions under which American firms have traditionally prospered. When the pace of events slows, other sectors of the Nation’s economy might begin to find themselves faring better than electronics in international competition.