CHAPTER 2

Introduction

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The U.S. electronics industry provides examples that can support almost any perspective on competitive trends in the American economy over the past decade. That portion of the industry manufacturing computers has been a champion of U.S. economic strength both domestically and internationally. Here and abroad, American computer firms—particularly IBM--have been symbols of technological prowess, market power, and multinational marketing and production. In Europe, U.S. computer manufacturers have been models to be emulated—for indigenous companies like ICL in Great Britain, or for joint ventures such as C II-Honeywell Bull in France—and targets to be displaced with the aid of national industrial policies. In Japan, American computer firms have been explicitly depicted as the enemy—IBM as a stateless, global giant, with Japanese firms urged to mount fierce efforts against it. Meanwhile, in the United States, the Department of Justice had in *1969* begun an antitrust suit aimed at dismembering IBM, a suit that was finally dismissed 13 years later.

American consumer electronics firms have been pictured much differently-particularly the old-line manufacturers of televisions and other home entertainment equipment, such as Zenith and RCA, Many firms in this part of the industry have seen themselves as victims of unfair trade practices by overseas rivals, primarily Japanese. Foreign firms selling TVs in this country have been accused of dumping (and found guilty of this), attempted monopolization, and of receiving subsidies from their own governments. To other observers, the U.S. consumer electronics industry has been a victim of management failures, has lacked the will to compete internationally, has ceded some segments of its markets too easily to imports, and has lagged in adopting manufacturing methods that could have cut costs and increased the quality and reliability of its products,

Semiconductor manufacturers in the United States have, over the past several years, pointed to the consumer electronics industry as a possible harbinger of their own fate if the U.S. Government does nothing to support them in their competitive battles with foreign (i. e., Japanese) rivals. At the same time, American semiconductor firms share with our computer manufacturers a deserved reputation as worldwide leaders in technology, innovation, and entrepreneurial zeal—a reputation which the *1980-83* round of new startups in Silicon Valley can only enhance.

These three portions of the electronics industry—computers, consumer electronics, and semiconductors—are the focus of this report. But other parts of the industry could illustrate many of the same themes, Electronic component production—switches, resistors and capacitors, printed circuit boards—has been moved to offshore locations as part of the response to competitive threats from imports. Professional and industrial equipment—instrumentation, industrial process control, medical electronics—is a continuing U.S. strength, but again the technological leads that American firms once held have narrowed. In telecommunications, American firms have lost out in several promising developing country markets. While boundaries between information processing and information transmittal have been blurring for years, and communications is certainly one of the central electronics-related portions of U.S. industry, this report touches on communications only in passing—not because this portion of the industry is unimportant, but only to keep the study to manageable proportions.

The breadth and diversity of the electronics industry contrasts with industries such as steel, which are often pictured as monolithic. Even here, however, specialty steel and nonintegrated "minimills" have proved notable exceptions to the commonly accepted notion of declining U.S. competitiveness.[1] Steel is an old,

[1] *Technology and Steel Industry Competitiveness* (Washington, D. C,: U.S. Congress, Office of Technology Assessment, OTA-M- 122, June 1980); *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),

established industry compared to electronics; yet the electronics industry has roots going back to the early part of the century, in contrast to biotechnology and genetic engineering —for which international competition has hardly begun-though here, too, there are roots in fields like plant breeding and pharmaceuticals. Emerging industries like biotechnology are important for *future* economic growth; *electronics is critical right now*. Moreover, lessons learned from electronics might apply to older, "mature" industries such as steel, as well as to nascent sectors like biotechnology.

What can be learned from electronics, particularly the last 10 or 15 years? That is one of the questions this report attempts to answer. Is the apparent decline of the American consumer electronics industry irreversible? Are the threats to U.S. computer and semiconductor firms real, or are they better considered natural consequences of the growth and maturing of these portions of the industry? How have policies adopted by the Federal Government affected the industry? How do public policies here differ from those of foreign governments, both in their forms and in their effects? To what extent have foreign industrial policies succeeded in strengthening the electronics industries of other countries, in affecting the investment and export strategies of American firms, in replacing tariff and nontariff barriers to international trade with less visible but no less effective constraints? Can governments create comparative advantage? If the United States were to pursue a more consciously developed industrial policy, what should be the objectives in the context of a high-technology industry like electronics? How might the policy tools be formulated and implemented?

Electronics as a High-Technology Industry

The electrical equipment and electronics industries have been known for technical leadership and innovation since their beginnings at the close of the 19th century. While progress in electrical equipment—that which produces or utilizes electric power—is now mostly incremental, electronics—referring to devices and systems that operate on the information content rather than the power transmitted by an electrical signal—remains a technology in rapid flux. Developments in electrical machinery such as practical applications of superconductivity can still promise significant gains in the efficiency of energy conversion and power transmission; advances in electronics will have effects that reach further, and affect the American economy—indeed, society as a whole—more deeply. An obvious case will be the continuing applications of distributed computing. The impacts will be broad as well as deep– manufacturing industries as a whole will be transformed by applications of electronics to automated production equipment. Productivity will rise, the skill mix needed by the work force continue to shift, In service industries, office and workplace automation will also displace people while creating new jobs needing new skills.

Patterns of Development

The portions of the electronics industry where American firms remain preeminent are just those where the pace of technological change continues to be most rapid—e.g., computers and semiconductors. The United States has been a leader in both the technology and the science that underly these sectors: electronic properties of solids and the materials sciences more generally; electrical engineering; computer science and software engineering—and also in the development of new and successful commercial products, Nonetheless, although Americans have been among the leaders in the technology and science of electrical machinery and electronics, many of the impor-

tant prewar developments—e.g., understanding of band gaps in solids and the dynamics of conduction--originated in Europe.

The Second World War pushed electronics to the forefront of engineering science, creating a momentum that still exists. Developments in radar and computing, both analog and digital, proved especially significant.[2] Again, many of the advances came from Europe, particularly the United Kingdom, where considerable strides were made in radar technology, s However, American industry was in a far superior position to capitalize on these new technologies in the aftermath of the war, By the late 1950's, the United States had what appeared to be an unchallengeable lead in fields such as digital computers and semiconductors.

Hindsight shows the more temporary nature of this lead, the result of an infrastructure for technology and science that emerged from the war not only intact, but strengthened, coupled with an industrial base that was likewise far stronger than in countries that had been either allies or enemies a few years earlier, The push created by new technologies, coupled with the pull of war-starved markets in the United States—markets that were eager recipients of the products of these technologies, rather than devastated—created an environment for growth and innovation unmatched in the rest of the world. Meanwhile, trading partners and potential competitors such as Japan, Great Brita in, and West Germany had to rebuild. Nations like Taiwan, South Korea, Brazil, and Mexico —now factors in at least the lower technology segments of the electronics industry—were, before 1960, simply irrelevant,

Rising Competition

Much of the impetus this strong postwar start gave to the U.S. electronics industry has now dissipated. Gloomy predictions for the future competitiveness of even the strongest sectors, such as semiconductors, have been heard. The business press reminds us incessantly that Japanese firms captured 40 percent of the U.S. market for 16 kilobit random access memory circuits (integrated circuits called 16K RAMs), more than 50 percent for 64 kilobit circuits. Market analysts predict that Japanese manufacturers could have 30 percent of the world computer market by the end of the 1980's.[4]

In the past, competitors in countries like Japan relied to considerable extent on electronics technology first developed by U.S. firms; now they have independent capabilities and need not follow paths broken here, As Japanese electronics companies have become less dependent on American technology, their exports of microelectronic devices to the United States have grown faster than their imports of U.S. semiconductors. And, where once they exported mostly discrete semiconductors and the simpler integrated circuits, now firms based in Japan are exporting—or assembling in the United States—large-scale integrated circuits

[2] H. H, Golds tine, The Computer *From Pascal to von Neuma In* (Princeton, N.J.: Princeton University Press, 1972), especially Part Two.

[3] J Kraus, "The Brit ish Electron-Tube and Semiconductor Industry, I935-62," *Technology and Culture*, vol. 9, 1968, p 544.

[4] "No. 1's Awesome Strategy, " *Business Week*, June 8, 1981, p. 84.

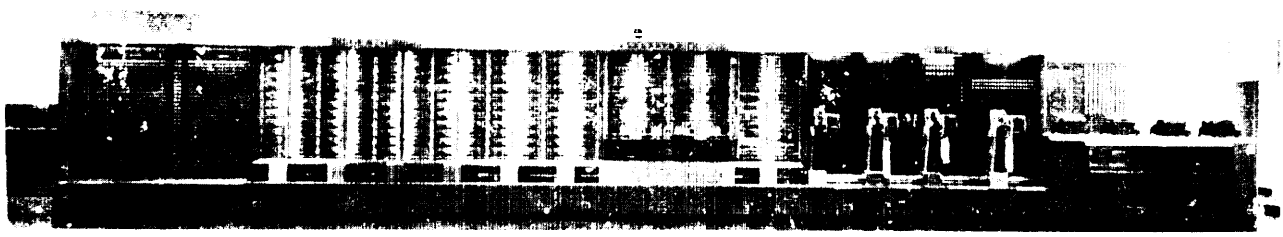

Photo credit Smithsonian *Institution*

Harvard Mark I electromechanical computer, 1939-44

(ICs) at the leading edge of the technology. * Japanese computer firms are not yet exporting large numbers of systems to this country, but clearly intend to try. The government-supported fifth-generation computer project is only one recent signal of the seriousness of Japan's efforts.

Needless to say, this resurgence by America's competitors has not been an overnight phenomenon, nor should it be unexpected. The Japanese presence in consumer electronics began to be felt in the 1950's with the transistor radio; by the late 1970's, firms based in Japan held strong positions worldwide in audio equipment, digital watches, calculators, and TV receivers. Their burgeoning capability in high-technology electronics builds naturally on earlier developments.

Interactions within the industry often stimulate technological and commercial developments; ICs have made possible new families of consumer products, such as hand calculators, as well as cheaper and more powerful computers. Semiconductor devices are becoming indispensable for the products of more and more industries outside electronics; emissions control systems for automobile engines depend heavily on microprocessors and related devices; more than half the cost of an airplane can be electronics. As one result, electronics technology—and particularly microelectronics—has come to be widely regarded as critical to a modern, competitive economy, hence access to this technology a vital strategic weapon of national industrial policies. Government attention to computer industries goes back to the early years of this technology; a number of countries began in the 1970's to subsidize semiconductor research and development; others have felt applications of ICs—rather than capability for designing and manufacturing the circuits themselves—to be more important, and have channeled government funds to this end.

*Small-scale ICs incorporate of the order of hundreds of circuit elements, large-scale ICs of the order of thousands to tens of thousands, very large-scale ICs—e. g., 64K RAMs, 16 bit microprocessors—of the order of a hundred thousand. See ch. 3.

Technological and Structural Change

The rather complex structure of the electronics industry in the United States is described in more detail in chapter 4. The diversity of the industry has already been pointed out; there are more than 6,000 electronics firms in the United States. Only a small fraction could legitimately be called "high-technology" companies. But this smaller fraction—companies building computers, designing and manufacturing large-scale ICs, supplying capital equipment such as microprocessor development systems or plasma etchers, developing software packages for computers—is a driving force for the rest of the industry, as well as for much of the rest of the economy.

By the standards of computers or microelectronics, consumer electronics cannot be considered high technology. Yet the manufacture of cathode ray (picture) tubes is a sophisticated process, and TV receivers are now designed around ICs, some of rather advanced design. Digital TV and digital audio are on their way to commercialization, while consumer products are providing some of the first applications of speech synthesis; the same will be true of voice recognition. Solid-state displays as replacements for picture tubes are a demanding technical challenge. Indeed, the low costs required for practical consumer applications create technological constraints that are, in their own way, more severe than those imposed on designers in portions of the industry more commonly associated with high technology. At the same time, consumer electronics products such as table radios or conventional TV receivers are simple enough that they can be manufactured and marketed competitively by firms in industrializing countries such as South Korea and Taiwan; the same is true of many types of discrete semiconductor devices and small-scale ICs.

As such examples indicate, even consumer electronics is changing more rapidly than industries like steel or automobiles. Despite the pace of technological change, electronics is not only much larger and better established but

more stable and predictable than, for instance, biotechnology. But again, the industry is far from monolithic. Consumer electronics has origins in the 1920's, when radio broadcasting became widespread. The computer and semiconductor sectors are basically post-world War II phenomena, though many of the leading companics-e. g., IBM, Western Electric, Motorola —have prewar origins. Thus, the three portions of the industry on which this report concentrates include examples of both well-established, "mature" sectors, and more volatile, rapidly growing, technology-driven sectors. There are lessons to be learned from each.

One of the lessons that even a superficial look at the computer industry teaches is the importance of marketing, sales, customer support and service, and related nontechnical factors even in a technology-driven industry. IBM has been a dominant force worldwide in computers since the beginning of the 1960's. But IBM's strength has been—not only hardware—but marketing, software, and customer support. In many cases, IBM's competitors have offered considerably more computing power for a given price, but IBM has only slowly lost market share because of its many strengths beyond hardware technology. In some contrast, other U.S. electronics firms have sometimes seemed to rely primarily on advanced technology to win markets. As other countries catch up in technical capability, a technology-based marketing strategy may no longer be enough. In microelectronics, for example, the ability to pack many circuit elements onto a single integrated circuit chip is still important, but competition is more and more a matter of the systems which the ICs comprise or can be integrated into. Moreover, as microelectronics technology continues to evolve, one path to competitive success will be the creation of new end-products incorporating ICs. The skills required for this differ from those needed to establish and maintain leadership in the underlying technology, as shown by the examples of pocket calculators or digital watches—and also by the failure of the West German electronics industry, which has access to excellent fundamental technology, to develop into a strong international competitor,

Although many of the major technological innovations in electronics have originated in the United States—e.g., color TV, computer timesharing, most of the important developments in semiconductor devices—American firms have not always been the leaders when it comes to product innovations that depend, not necessarily on new technology, but on product planning, engineering design, production skills, and marketing. Although transistor radios were developed in the United States, it was Japanese products that reshaped the entire audio market.[5] Analogous strategies—concentrating on product design and engineering, originally perhaps imitative, rather than high technology—have led to success by the Japanese in fields such as cameras and automobiles. Japanese firms, aided by their skills at low-cost manufacturing, have recently done much better at this than companies in the European nations with which the United States also competes.

[5]G. R. White, "Management Criteria for Effective Innovation, " *Technology Review*, February 1978, p. 15.

Photo credit: Be// Laboratories

The first transistor, 1947

Thus, overall, the cushion that greater technical capability once provided U.S. products is eroding. And of course, in some technologies the United States has never had an advantage. In optical communications, for example, Japanese companies have always been near the forefront. Leadership in electronics equipment used for certain types of scientific research has long resided overseas—one example being electron microscopes. That this need not always be a handicap is shown by current developments in electron-beam lithographic equipment. Electron-beam lithography is now essential for making the masks that are, in turn, used to fabricate large-scale ICs (in a few cases electron-beam lithography is applied directly in fabricating the chips). Although the equipment has its roots in technology developed for scanning electron microscopes—virtually all of which are designed and built in Europe or Japan–the United States has not thus far been handicapped. Several U.S. firms are, in fact, leaders in electron-beam lithography,

The Importance of Competitiveness

OTA's earlier comparison of steel, electronics, and automobiles provides background and illustrations for many of the questions concerning competitiveness, economic efficiency, and industrial policy that remain of concern to Congress, to employees of the U.S. electronics industry, and to the public at large.[6] The practical meaning of "competitiveness" in the context of electronics is discussed in chapter 5. In essence, the term refers to the ability of electronics firms located in one country to design, develop, manufacture, and market their products—domestically and by exporting—in competition with foreign enterprises. (For some purposes, subsidiaries of foreign firms that produce and sell electronics products in the United States are considered part of the U.S. industry, but in general the consequences of foreign direct investment must be treated on a case-by-case basis.)

The competitiveness of an industry like electronics is important not only intrinsically, but also because of interactions with other parts of the economy. Still, there is no meaningful way of measuring the competitiveness of an entire economy, Competitiveness must be examined on an industry-specific basis, although it can also be difficult to generalize about an industry as large and diverse as electronics, which for many purposes must be further disaggregated.

Considering the electronics industry itself, competitiveness is one of the factors that determines, among other things: employment patterns within the industry (size of the work force, wage levels, skill mix); balance of trade for electronics products; and the value that purchasers of electronics products receive for their money. Electronics products are used by many industries—whether components such as semiconductors costing a few cents, or capital equipment that sells for hundreds of thousands, even millions, of dollars—and can affect their competitiveness. Computers are the most prominent example, but are far from alone. Nor do they always fill the role of capital equipment; many smaller computers are integrated into more complex electronic systems. Industrial process control, scientific equipment, office machines, and communications apparatus are further examples where electronics or electronics-related products can affect the competitiveness—more generally, the economic performance—of other parts of the economy.

On the broadest levels, then, the competitiveness of the electronics industry affects aggregate employment levels, trade balances (more importantly, the ability to pay for imports), and living standards. How this industry fares in in-

[6] *U. S. Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles,* op. cit.

ternational competition influences the types of jobs available, the country's military strength, and overall rates of economic growth. In turn, the health of the aggregate economy, the quality and quantity of employees available to firms in the industry, the market provided by the military, are among the factors that determine the competitiveness of American electronics firms.

Ultimately, however, the competitiveness of any industry—in the United States or elsewhere—depends on the efforts of individual firms. Policies adopted by the Federal Government influence these efforts in many ways, often indirectly. Foreign industrial policies are part of the same context. Among the more important domestic measures are those dealing with taxes, Government spending, and monetary policy, as well as research and development (both basic and applied), international trade, and many types of regulatory policies. Sometimes Federal policies affect only one or a few industries—e.g., regulation of TV broadcasting. others are broader. Tax treatment of income from overseas investments affects firms with multinational operations regardless of industry. Some policies affect the entire economy—macroeconomic policies or those dealing with education.

Generally within the province of individual firms are factors associated with manufacturing—including costs, the quality and reliability of finished products, and decisions to manufacture domestically or overseas (offshore assembly, wherein some but not all manufacturing operations are carried out in other countries to take advantage of low labor costs, is common in electronics). The ability to raise external capital—whether equity or debt—and to generate capital for reinvestment through sales, is crucial to firms in any industry, but particularly when markets grow as fast as those for semiconductors and computers. As with offshore manufacturing, which is favored by U.S. tariff laws, sources and costs of capital for electronics firms are affected by public policies—tax policies and many others, including those aimed at controlling inflation.

With respect to *consequences* of shifts in competitiveness, employment receives the most attention in this report—both in terms of job opportunities and in terms of the skills needed. This and many other topics are discussed, where possible, in the context of international comparisons drawn between the United States and its trading partners and rivals—usually one and the same. Japan, at present, is the home of the strongest competitors, in electronics as in many other industries. Japanese firms are likely to continue to be the chief rivals for U.S. electronics manufacturers over the remainder of the century, But several European nations have strong technological bases in electronics, as well as supportive governmental policies. And rapidly industrializing countries will rise in competitive strength in the future; TVs from Taiwan and South Korea are growing factors in the U.S. market,

Industrial Policy

Public policies that affect competitiveness can be considered elements of "industrial policy. "[7] The term is intended to embrace Federal Government policies of whatever origin that affect the activities of private industry, particularly its competitiveness, productivity, and economic efficiency,

The United States does not at present have a coherent or consciously developed industrial policy, in contrast to nations such as Japan or France, This is not to imply that industrial policies like those of the Japanese are necessarily effective in promoting international competitiveness, but simply that the United States has not *attempted* to develop a coherent industrial policy. Instead, policies affecting industries—

[7] Ibid,, ch. 8.

and their competitiveness-have been formulated and implemented on an ad hoc basis. As a result, industrial policy in this country has been fragmented, sometimes contradictory, often inconsistent and lacking in continuity.

These characteristics of U.S. industrial policy—reflecting our pluralistic political traditions—have sometimes served the American economy well, lending flexibility and the potential for innovative response to changing circumstance. But the OTA report cited above concluded that this approach to industrial policy—while it might have been well-suited to an earlier period when U.S. industries were relatively isolated from foreign competition, and possessed advantages in technology—in more recent years has too often contributed to declines rather than improvements in competitiveness.

Foreign industrial policies often include direct subsidies to industries—perhaps to maintain employment, or for reasons of national security. Export incentives and protection for domestic industries are common. Foreign investors may face a complex set of carrots and sticks. Cooperation among nominally competing firms may be encouraged. Governments in some countries have engineered "national champions" in attempts to increase competitiveness. Restrictive business regulations may be relaxed, government procurements channeled to favored companies, which in some cases may be publicly owned. Nationalized enterprises-an increasing presence in sectors like banking or energy production although not a major factor in electronics—couple industry and government even more tightly.[8] American businessmen increasingly complain of the difficulties involved in trying to compete with such ventures, which need not make profits, or may have unusually long profit horizons.

The variety and complexity exhibited by present-day national industrial policies—particularly the difficult questions of when government support measures should be judged subsidies that distort international trade—have hampered efforts by international organizations such as the General Agreement on Tariffs and Trade (GATT) to fit remedies for many of the possible means of "unfair" competition into the body of international trade agreements. As one result, bilateral agreements are becoming more common—exemplified by the Orderly Marketing Agreements negotiated by the U.S. Government to control imports of TV receivers from several Far Eastern nations.

[8] For a survey, see R. P. Nielsen, "Government-Owned Businesses: Market Presence, Competitive Advantages and Rationales for Their Support by the State, " *American Journal of Economics and Sociology, vol. 41, 1982,* p. 17.

Issues

As emphasized above, a vast number of Federal Government policies in some way affect the international competitiveness of the U.S. electronics industry. Among the more important are:

- Government support for commercial (as opposed to military) R&D, ranging from tax policies intended to increase levels of research spending or encourage commercialization to direct support;
- trade policies dealing with exports as well as imports—e.g., the ways in which measures that affect the the electronics industry fit within the overall framework of U.S. foreign economic policy, the meaning of "reciprocity" for an industry like electronics, barriers to investment in foreign electronics industries;
- Government policies affecting capital formation for the economy as a whole, and, more directly, the ability of firms in the electronics industry to generate and attract capital for expansion;
- regulatory policies that may affect the competitiveness of the U.S. electronics industry—e.g., antitrust enforcement;

- the availability of enough people with adequate levels of education and training, particularly engineers and skilled workers such as technicians, as well as the Government role in supporting technical education;
- economic adjustment policies intended to encourage shifts of resources from declining industries to those with better prospects for future competitiveness, and to aid workers, communities, and regions that have suffered because of shifts in international competitiveness—e.g., in consumer electronics.

These examples all involve complex issues, with effects that may differ among various parts of the electronics industry, and from firm to firm. The remainder of this report attempts to deal with such complexities; at the same time, of course, public policies continue to evolve and change—witness the 1981 tax act, or the expiration in July 1982 of the Orderly Marketing Agreements covering imports of color TVs from Korea and Taiwan. The objective is not to be exhaustive but selective—to try to differentiate the factors influencing competitiveness in electronics that are primarily under the control of managements of individual firms from those that are strongly affected by the Federal Government, and to examine the latter in the context of a high-technology industry that has been one of the mainstays of U.S. competitiveness during the postwar period.