Employment lessons from the electronics industry

Semiskilled and 'unskilled' workers in semiconductors, computer manufacturing, and consumer electronics industries are more likely than other workers to lose jobs because of technology, imports, and offshore production; advances in technology create jobs for skilled workers

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In the U.S. electronics industry, competition—domestic as well as international—has led to increases in labor productivity through changes in product design and automation and to transfers of manufacturing operations to low-wage developing countries. For example, in the consumer electronics industry, annual output of color television sets per production worker in the United States increased from 150 in 1971 to 560 in 1981. Total output nearly doubled, from 5.4 million sets to 10.5 million. At the same time, domestic employment in color television manufacture dropped by half—a result of greater foreign value-added, redesigned televisions with fewer parts and less need for assembly labor, and automation. The example is not atypical, the implications are clear: new technology can cut into job opportunities even though output rises substantially.

In two other sectors of the electronics industry—microelectronics (which includes semiconductors) and computers—employment has grown rapidly. (The 1985 layoffs will, as in earlier business slumps, prove temporary.) Microelectronics technology made redesigned color television sets possible, and far more Americans now work for semiconductor manufacturers than were ever employed in consumer electronics. Skilled and professional jobs predominate in microelectronics, accounting for nearly 60 percent of employment, compared with about 30 percent in consumer electronics. Similar patterns exist elsewhere in high technology electronics: continuing advances in both products and processes leave relatively fewer openings for unskilled and semiskilled workers. Indeed, jobs for production workers in U.S. computer firms declined slightly during 1984, although overall employment in the computer sector rose.

American consumer electronics firms have faced stiff foreign competition since the latter part of the 1960's. But only in the last few years have U.S.-based microelectronics and computer manufacturers found competitors from Japan able to match their product offerings. Given declining advantages in product technology, and Japan's proven capabilities in process technology, American manufacturing companies have been forced to change their priorities. Within any manufacturing organization, quality and productivity, hence costs and competitiveness, depend on the integration of workers and machines into an efficient and effective production system. Highly automated plants will demand new ways of using skills, resolving conflicts, and making decisions. The emphasis on shared responsibility and decision-making in Japanese organizations appears to give them a head start in integrated production systems. Japan's manufacturers are more adept at utilizing the skills and capabilities of their work force, and are further along at integrating workers and machines—an important source of competitive advantage.

In a given industry, job opportunities change with demand for the industry's products, with shifting patterns of international competition, and with increases in labor

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productivity. The latter stem not only from automation and work reorganization, but from products redesigned for easier, cheaper manufacture. Rising worldwide demand for the output of a given industry will create new jobs only if demand rises more rapidly than productivity. From the perspective of a national economy, net job creation also depends on trends in imports and exports and on foreign and domestic investments. Imports may displace domestic production; overseas investment by domestic companies may do the same.

In any economy, new jobs are continually being created, old jobs eliminated. At the level of the firms, jobs are created as companies are established or expand, and jobs disappear as companies atrophy and die or move production overseas. Over time, automation, work redesign, and organizational change help fewer workers produce more. If a firm cannot sell enough of the additional output, it may have to reduce its labor force. Even if it can increase sales, improvements in efficiency necessarily cut into future job opportunities. Aggregate economic growth provides the gross context for job creation and job destruction; the organization of work within the enterprise creates the fine structure.

This article discusses factors which affect employment in two components of the U.S. electronics industry[1]—consumer electronics (SIC 3651) and microelectronics (SIC 3674), touching briefly on computer manufacturing (SIC 3573).[2]

Employment trends in electronics

Employment in U.S. manufacturing has been essentially static since the late 1960's, but declined relatively over the 1974–84 period from 26 to 21 percent of the nonagricultural work force. However, in electronics, employment expanded rapidly over the period—although not in all parts of the industry. Employment has nearly doubled in microelectronics and has increased even faster in computers, while the consumer electronics category (which includes many types of products other than television sets) has shrunk. The following tabulation shows the number of employees and the percent of production workers in consumer electronics, microelectronics, and computer and peripherals industries, 1974, 1984, and the first 6 months of 1985:

Industry	*Number of employees*		
	1974	*1984*	*1985, first half*
Consumer electronics	113,600	71,800	68,400
Microelectronics	148,300	273,000	283,300
Computers and peripherals	217,000	460,900	456,900
	Percent production workers		
	1974	*1984*	*1985, first half*
Consumer electronics	74	68	66
Microelectronics	51	43	41
Computers and peripherals	39	37	35

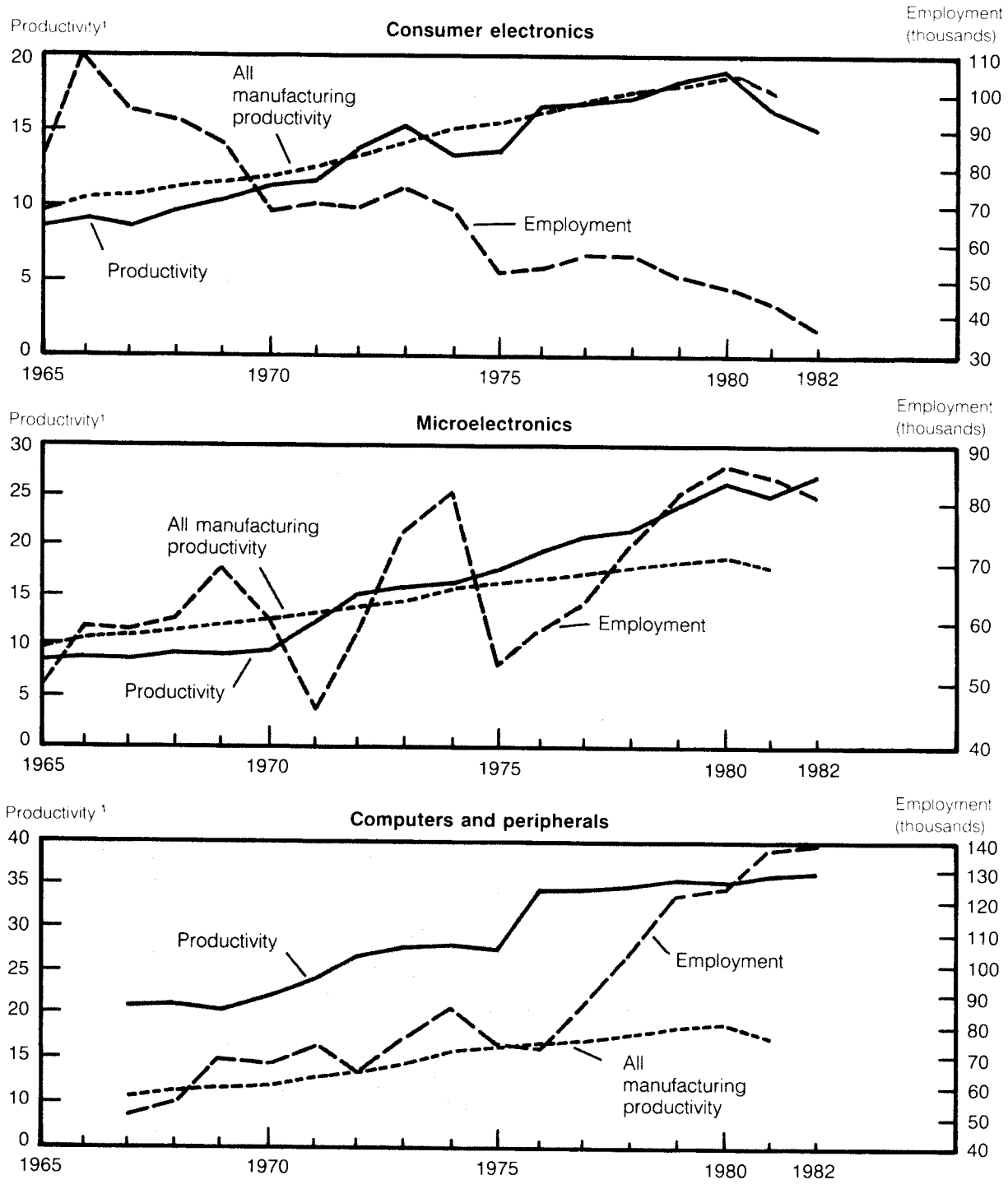
By mid-1985, the 808,600 workers in consumer electronics, microelectronics, and computer firms accounted for more than 4 percent of the U.S. manufacturing labor force. Although these firms make up only a portion of the electronics industry, they employ more than twice as many workers as the steel industry.[3]

Chart 1 compares trends in labor productivity and production employment over the past decade for each of the three categories discussed in this article. (Productivity is plotted as value-added per production worker hour in inflation-adjusted terms.) Value-added productivity growth in consumer electronics—where employment declined—has roughly paralleled the all-manufacturing average. In contrast, computer manufacture shows a rapid rise in employment, with productivity rising almost as fast until the mid-1970's. Many jobs have also been created in microelectronics, where productivity gains were again substantially above the all-manufacturing average. With both computers and microelectronics suffering from business slowdowns during 1985, layoffs have been common and total employment has dropped.[4] No doubt these declines will prove temporary, with employment levels rebounding once the slump has passed, as occurred twice during the 1970's for both the microelectronics and computer sectors. Over the long term, however, employment prospects in the U.S. computer industry appear far better than those in microelectronics.

Productivity trends are seldom unambiguous. Their significance can be questioned when technological change is as rapid as it has been in computers and peripherals and in microelectronics. In these sectors, product performance has advanced rapidly; today's dollar buys far more capability than it did a few years ago.[5] In color television manufacture, technical change has been much slower, with intense price competition depressing value-added productivity measures compared with other U.S. industries over the 1965–82 period; the retail price index for color television sets increased by less than 5 percent, while that for all consumer durables more than doubled. Productivity on a unit output basis for color television manufacture has, however, risen far more rapidly than on a value-added basis.

As chart 1 demonstrates, the portions of the electronics industry with the highest rates of value-added productivity growth (microelectronics and computers) also experienced the highest rates of employment growth. Rapid increases in productivity were associated with the creation of jobs, not their elimination. The reasons are straightforward: spurred by technological changes opening vast new markets, export as well as domestic, output in microelectronics and computers has for many years grown at rates in the vicinity of 15 percent annually, far higher than the rate for all manufacturing. In contrast, the domestic market for consumer electronics grew less than half as fast, exports were small, and import penetration was severe; the value-added productivity measures for consumer electronics reflect the plight of an

Chart 1. Trends in productivity and production worker employment in consumer electronics, microelectronics, and computers, 1965–82



[1]Value-added productivity per production worker hour (in 1972 dollars).

SOURCE: 1977 and 1982 Census of Manufactures.

industry hard pressed by foreign competition and striving to make relatively standard products more cheaply.

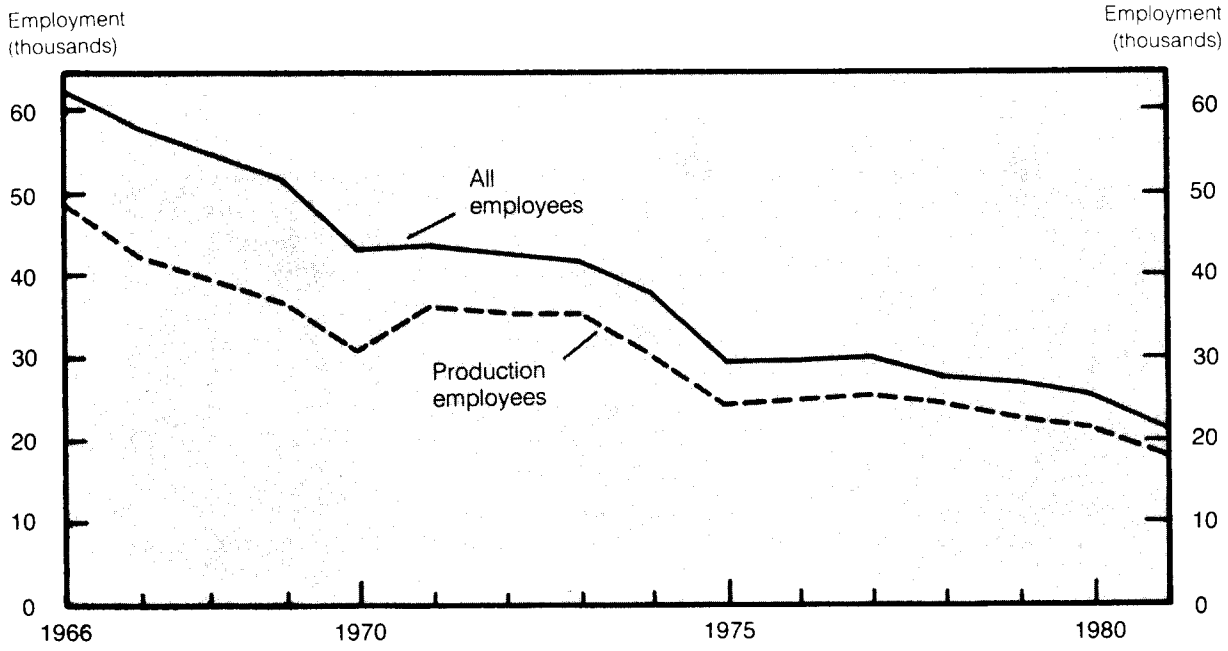
The examples of microelectronics and computers show that when technological change is rapid, rates of productivity increase may be high while employment nonetheless rises. Similar correlations sometimes follow at the aggregate level; rates of unemployment may drop nationwide while productivity climbs, particularly if coupled with high investment and the introduction of new technology.

Consumer electronics

In many respects, the manufacture of television sets, accounting for about half of U.S. consumer electronics employment, can stand for the sector as a whole. Domestic employment in television manufacturing has been falling since the mid-1960's. (See chart 2.) Jobs for production workers dropped by half between 1971 and 1981, despite a near doubling of output, from 5.4 million to 10.5 million television sets. During this period, a dozen U.S. manufacturers either merged with Japanese or European producers or left the business; General Electric's departure, announced late in 1985, will leave only two major U.S. firms. The U.S. industry now includes more than 10 foreign-owned companies. While contributing to the employment totals in the chart, U.S. production by foreign-owned companies such as Sony or Gold Star tends to reflect higher fractions of foreign value-added than the output of American-owned firms such as Zenith or RCA.

As television sales grew, apparent productivity on a unit output basis (measured as annual output divided by the number of production workers) jumped from 150 sets per worker in 1971 to 560 in 1981. In terms of value-added per production worker, productivity was up by about 40 percent—a trend similar to that for consumer electronics as a whole.[6] The productivity improvements came from multiple sources. As color television sets replaced black-and-white receivers, manufacturers introduced more highly automated production processes. Somewhat later, reductions in the number of parts—resulting from solid-state chassis designs—meant reduced labor content. Only 6 percent of the color television sets made in the United States were solid-state models in 1970, but by 1976 essentially all had been redesigned around transistors. The number of parts dropped by half or more—for example, from 1,023 components for a Panasonic color model in 1972 to 488 in 1976.[7] Often, component insertion was mechanized at the same time. A good deal of the productivity growth during the 1970's resulted from these interrelated changes in chassis design and manufacturing methods. Clearly, the causes of the employment declines in television manufacturing extend well beyond import penetration or offshore assembly; the spread

Chart 2. U.S. employment in television manufacturing, 1966–81



NOTE: Data for the 1966–75 period are for all television employment; data for 1976–81 are for color television only.

SOURCE: *International Competitiveness in Electronics* (Washington, DC. Office of Technology Assessment, November 1983), p. 354

of solid-state chassis designs and automated manufacturing dramatically reduced labor requirements in this sector of the electronics industry. Import competition did have the effect of speeding the changes.

Over the same period, American consumer electronics firms relocated many of their manufacturing operations to low-wage developing countries. While there are no precise numbers on foreign workers employed in these plants, the U.S. Department of Labor believes there may be more than 30,000—a greater number than now employed in domestic television manufacture. As a result, the proportion of domestic value-added dropped during the 1970's; more parts and subassemblies were produced overseas for final assembly in the United States, whether by American- or foreign-owned companies. Given these trends, simply dividing the total output of television sets by the number of employees overstates productivity gains (although value-added productivity adjusts for this). By 1980, the United States imported more than $1 billion worth of circuit boards and picture tubes for color television sets, about one-third of the total value of domestic output. Two basic causes, then, account for the employment decline in television manufacture: greater labor productivity, achieved through product redesigns as well as automation; and transfers of labor-intensive operations overseas. Intense competitive pressures, centered on manufacturing costs, drove both trends.

Improvements in productivity and manufacturing efficiency may eliminate jobs in the short term, but help to slow down job losses over the longer term. In 1974, for example, Matsushita, a Japanese company, bought Motorola's money-losing Quasar television operations. Matsushita invested heavily in automated manufacturing (some of it in Mexico); redesigned Quasar's product line; and reorganized shopfloor operations, with particular emphasis on quality control and employee participation programs. Greater labor productivity and higher quality—stemming from new capital equipment and redesigned products as well as work reorganization—helped save the jobs of several thousand American workers. At the same time, the production process was more automated, cutting into job opportunities. Quasar's investments in Mexico also came at the expense of job opportunities for Americans. But without these steps, Quasar's U.S. plants might have closed—at the cost of many more jobs.

In the Quasar example, impacts on manufacturing efficiency had many sources; it is impossible to isolate and account with any precision for each. As chart 2 and the Quasar example illustrate, rationalization of production may improve manufacturing efficiency and keep some people at work while making others redundant. Prospects for avoiding displacement are far better in U.S. industries that are more technologically dynamic and are expanding more rapidly than consumer electronics. But nowhere can the tradeoffs between productivity and job opportunities be avoided. In general, productivity must rise to improve competitiveness. Unless output expands at least as fast, some jobs will vanish.

Import and offshore production: How important? The U.S. consumer electronics industry has faced strong external competition since the late 1960's, largely from producers in the Far East. Half the U.S. consumer electronics market has been taken by imports; most products still assembled in the United States contain many imported components. Penetration of consumer electronics markets coincided with employment decline. For example, imports of black-and-white television sets rose from one-quarter to three-quarters of U.S. sales over the 1967–77 period. Imports of color television sets peaked in 1976 at a level nearly 10 times greater than in 1967, then dropped because of quotas termed Orderly Marketing Agreements negotiated with Japan, South Korea, and Taiwan.[8] The quotas cut imports roughly in half.

To what extent have imports cost U.S. jobs? First, we must determine the causes of import penetration. Imports may rise because demand exceeds domestic capacity or because consumer preference shifts to foreign-made goods (perhaps they are judged better values). In the first case—exemplified by video cassette recorders, where U.S. capacity is zero—jobs may not be lost directly but the rate of increase in job opportunities may slow. In the second case, typified by imports of Japanese cars and to a lesser extent by sales of television sets, immediate decreases in employment are likely.

Nor are the consequences of offshore production straightforward. Today, the remaining American-owned television manufacturers all operate overseas production facilities. In addition to the attraction of low-wage labor, the U.S. tariff schedules serve to encourage offshore assembly. (Items 806.30 and 807 permit re-imports with duties computed only on foreign value-added.) All wages and salaries paid overseas could be viewed as a loss to American labor and the U.S. gross domestic product. But what if American firms can only lower their costs and maintain or expand their markets by moving abroad? In some cases, American firms may seek offshore production to take advantage of low-cost labor. In other cases (computer plants in Western Europe, for example), U.S. manufacturers may wish to manufacture near their overseas customers.

It is oversimple to argue that the total number of foreign workers engaged in production for shipment to the United States—whether employed by U.S. or foreign firms—represents domestic employment loss. In most cases, U.S. consumer electronics firms had little choice concerning offshore production. Movement abroad was a defensive reaction, not a strategy aimed at expanding markets and improving profitability. To assume that jobs overseas substitute directly for U.S. employment is tantamount to assuming a stable competitive environment—not at all the case. Rather, employment declines followed losses in competitiveness. American firms had higher costs than their rivals. They pursued the

obvious route: increases in automation to raise productivity at home, combined with transfers of labor-intensive operations offshore. Only some companies survived; the others left the industry or were purchased by more successful manufacturers. In this complex chain of events, then, import competition must be counted as the primary cause of job losses in the U.S. consumer electronics industry.

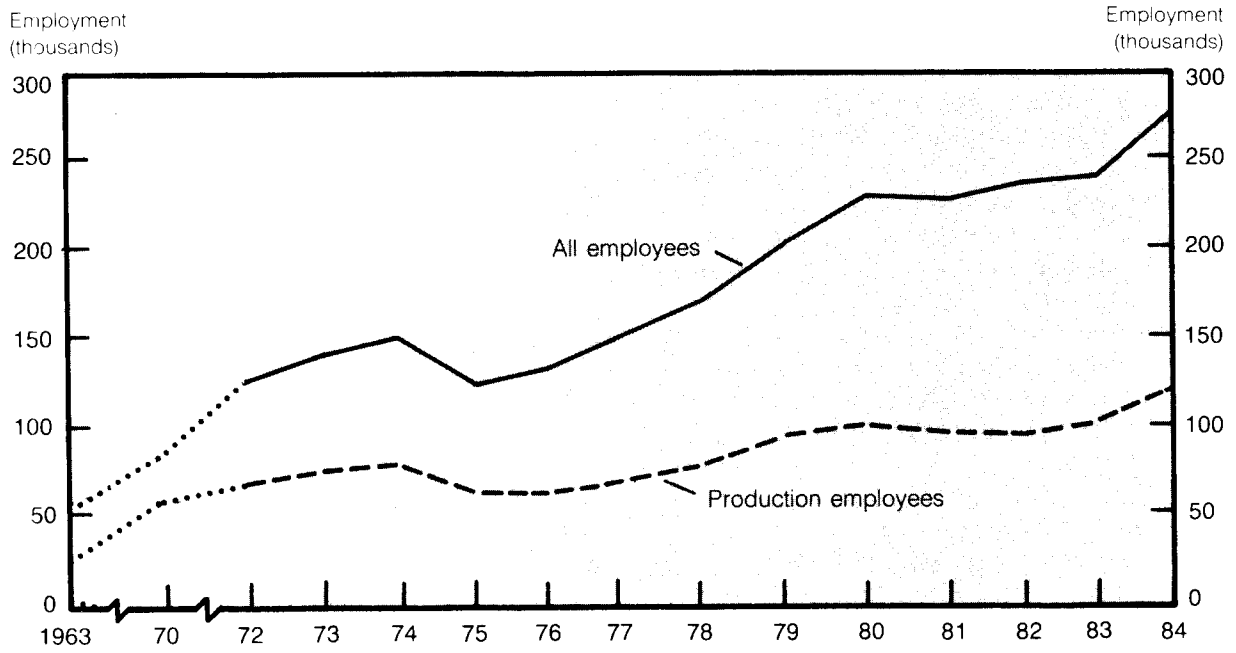
Microelectronics

Since the mid-1950's, U.S. employment in semiconductor manufacture has increased rapidly, from a few thousand when production of transistors was just beginning, to more than 280,000 by the first half of 1985. (See chart 3.) In addition to merchant firms selling on the open market, the totals in the chart include captive production by vertically integrated manufacturers such as IBM and AT&T. During two periods, 1969–71 and 1974–75, employment dropped sharply as a result of recession. Since late 1984, total employment in semiconductors has again been dropping, with the number of production workers falling more sharply. These recent declines come when the economy is not in recession; given the new strength of Japanese competition, it appears that the microelectronics sector has entered a new phase in its evolution.

The proportion of production workers in the U.S. microelectronics industry dropped from 66 percent of the total work force in 1963 to slightly more than 40 percent in 1985. American semiconductor manufacturers, particularly the merchant firms, have been moving labor-intensive assembly operations offshore for years; technological advance has contributed to the shift toward skilled and professional jobs in the United States. Demand for technicians and other nonproduction workers has risen with each succeeding generation of more sophisticated (and expensive) fabrication equipment. With movement through large-scale and now very large-scale integration, design and development of new circuits has become far more complex and time consuming; the ranks of engineering and R&D personnel have grown much faster than those of unskilled and semiskilled production employees.

Imports and offshore manufacturing. In comparing current layoffs, particularly for production workers, with those in previous downturns, one major difference is this: Japanese competition was not a factor during the 1970's. Today, Japanese firms account for substantial fractions of world market share for some types of devices, holding 85–90 percent of the burgeoning worldwide merchant market for 256K RAM memory chips. (Note, however, that this percentage excludes devices produced by such companies as AT&T for internal use.) Furthermore, huge investments by Japanese semiconductor manufacturers over the last few years have created a great deal of overcapacity. This excess

Chart 3. U.S. employment in semiconductors and related devices, 1963–84



SOURCES: *International Competitiveness in Electronics* (Washington, DC. Office of Technology Assessment, November 1983), p. 356; Bureau of Labor Statistics.

capacity, as much as 30 or 40 percent for some types of chips, aggravated the price cutting that has been endemic in the industry. After informal complaints against the Japanese going back a number of years, U.S. semiconductor manufacturers filed three major trade-related complaints with the Federal Government over a 4-month period in 1985. Partly in consequence, Japanese firms have been cutting back on shipments to the United States, while also accelerating their investments here—paralleling their earlier investments in consumer electronics.

Imports are not new to this sector. In 1971, the United States exported twice as many semiconductors as it imported, but by 1982 imports exceeded exports. Do the trends now visible portend job losses? Will employment suffer here as in consumer electronics? The answer is no, at least not over the next decade. There are two reasons. First, despite the current sales slump, worldwide demand for microelectronic devices will continue to grow over the longer term. Although the Japanese have made substantial inroads, American firms retain more than half of worldwide sales, and are still in a position of technical leadership in some if not all varieties of integrated circuits. Second, U.S. semiconductor firms have exported much more agressively than consumer electronics manufacturers. Moreover, about three-quarters of all U.S. imports of microelectronic devices consist of intra-corporate transfers by American-owned firms—that is, re-imports after offshore processing. Offshore employment may continue to rise, and perhaps continue to increase faster than domestic employment, but U.S. jobs in microelectronics should rise as well. Nonetheless, total employment in the sector could continue to grow while the number of production jobs declines.

American semiconductor firms transferred labor-intensive "back-end" operations overseas—primarily assembly steps such as wire bonding and encapsulation—at a rapid pace beginning in the 1960's. During that decade alone, U.S. companies established more than 50 foreign manufacturing plants.[9] Wafers, fabricated domestically, were shipped to low-wage sites, mostly in Asia, for the final stages in processing, then returned to the United States or sent on to other markets. In recent years, U.S. merchant manufacturers have carried out perhaps 90 percent of all assembly work overseas.[10]

The reason is simple. Typical estimates for the 1970's indicated that production costs could be cut in half through offshore assembly.[11] Given these potential savings, cost/price competition became the primary motive for such investments; American semiconductor firms moved offshore to reduce costs and expand markets. Once the first U.S. manufacturer invested in low-wage countries, others followed. With questionable prospects for automation during the 1960's and early 1970's, and a rate of technological advance that threatened to render investments in automated equipment obsolete, the choice was plain: move offshore or be undersold. In contrast to consumer electronics, the competitors in microelectronics were American firms almost exclusively; large-scale foreign investments by U.S. manufacturers predated Japanese thrusts in microelectronics by more than a decade. If in the case of consumer electronics, offshore manufacturing was a reaction to import competition, in microelectronics the motives were offensive.

Because most offshore jobs are filled by assembly workers, overseas manufacturing has contributed to the declining fraction of production employees in the United States. U.S. firms employ perhaps three-quarters as many people in their foreign operations as they do here; but, while only 40 percent of the domestic jobs are in production, the figure is more than 80 percent for offshore plants.[12] As a result, American companies employ many more production workers overseas than at home—roughly 150,000, compared with about 115,000. Although domestic jobs more than doubled during the 1970's, offshore employment grew even faster.

To what extent do foreign workers employed in the overseas operations of U.S. firms, or the employees of foreign-owned companies which export to the United States, stand for job opportunities lost to Americans? In contrast to offshore facilities, most of which are in Asia, point-of-sale plants in industrialized countries have been established largely for strategic reasons: market access, customer liaison, and, sometimes, the avoidance of import barriers. While these point-of-sale plants have arguably small consequences for U.S. employment, offshore investments driven by lower wages directly displace American workers, just as in consumer electronics. Periodically, speculation arises that advances in automated production equipment will mean that American firms can return back-end processing to the United States. With more automation, the labor cost advantages of offshore sites diminish, although they may not vanish. But even when costs remain lower overseas, strategic advantages—similar to those for point-of-sale plants in other industrialized countries—may mean that American companies will bring some of their production back home.[13] If they do (keeping in mind that it is automation that would make this possible), the result is not likely to be an increase in jobs for production workers. Employment is far more likely to increase for engineers, technicians, and supervisors.

The production system. The picture outlined above is not quite so simple as it might seem. Generalizations about the microelectronics industry conceal a good deal of diversity within. Low production costs are far more important for some firms than for others. Companies that depend on product leadership must develop manufacturing systems geared to device technologies pushing the state of the art. Those with broad product lines will place greater stress on costs and quality. Needless to say, no microelectronics manufacturer can neglect costs or quality; the question is one of priorities. Still, unique product designs—for example, a

microprocessor with capabilities outstripping those of the rest of the industry—will generate competitive advantages almost irrespective of manufacturing costs.

Nonetheless, in microelectronics as in any industry, unique products remain the exception; generally, manufacturing capabilities are critical for competitive success. Microelectronics, first of all, is an industry where product and process knowhow interact more closely than in perhaps any other. As an example, in mid-1984, Trilogy Systems abandoned its attempts to achieve wafer-scale integration, which would have increased scale and complexity by factors of 100 or more—companies must be able not only to design but to build new types of devices. More than this, quality has become, since the end of the 1970's, central to competitive dynamics. As in many other industries, Japanese manufacturers made quality and reliability a major element in their export strategies. This helped Japanese semiconductor firms penetrate U.S. markets. They concentrated on standard devices such as memory chips, meeting or undercutting the prices of American manufacturers while offering better quality, hence better value.

What does it take to achieve high quality in the production of integrated circuits? Certainly it takes good manufacturing equipment. Japanese semiconductor firms purchased most of their equipment from the same vendors that supplied the U.S. industry; hence they had no advantage on the factory floor as far as equipment was concerned. Integrated circuits from different manufacturers do differ in design, even when functionally identical. Design details influence costs and quality; Japanese firms made design choices aimed at quality and reliability, sometimes at the expense of cost or performance. But more than this, Japan's factory system as a whole—plant layout, integration of people into the production process, task allocations, management style, and internal training and retraining programs—leads to high quality as well as low costs. From a systems perspective, their production processes helped Japan's semiconductor manufacturers to penetrate world markets, competing successfully with American firms that had the lead—and still do—in many functional aspects of circuit design.

Do imports, technology cost U.S. jobs?

Import competition, automation, and offshore investment take place in a context of global shifts in market structure, with long-term consequences for jobs and job opportunities in a national economy, as well as immediate impacts on workers, firms, and industries. In expanding markets, a firm that can respond quickly to new opportunities anywhere in the world may be able to increase exports and consolidate its position. During the 1970's, for example, American semiconductor manufacturers capitalized on the shift toward metal-oxide-semiconductor integrated circuits ahead of their foreign rivals. In doing so, they created many new job opportunities for Americans, unskilled as well as skilled.

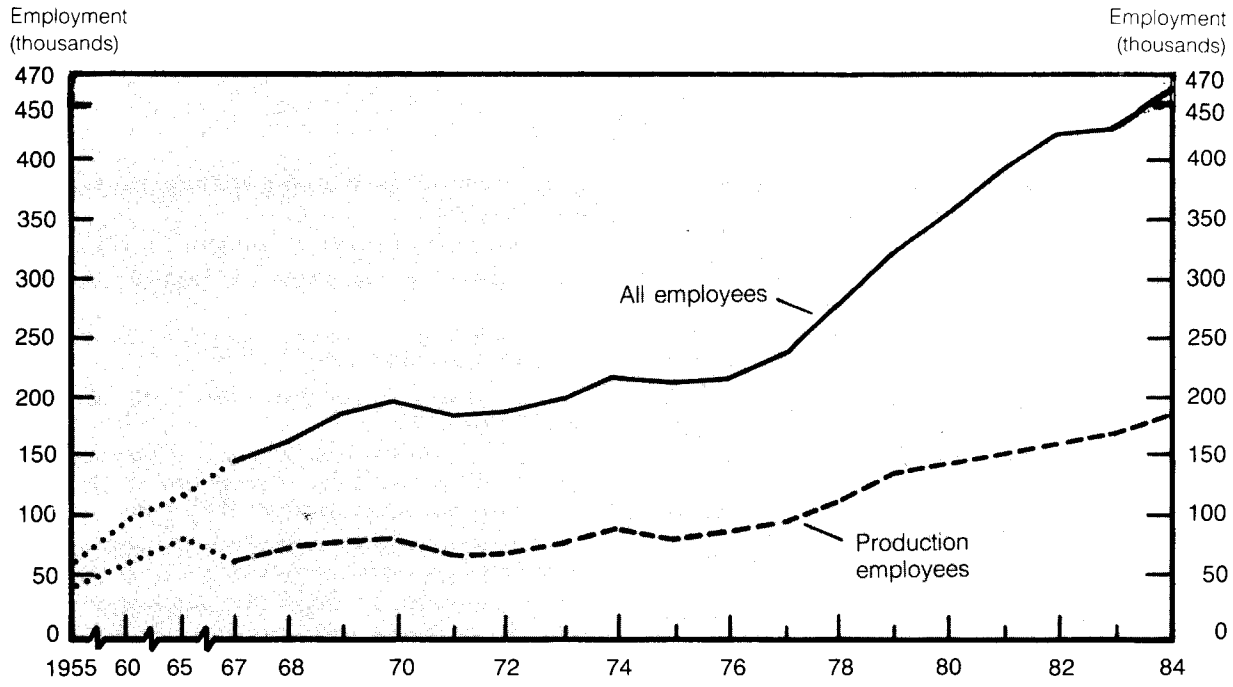
In consumer electronics, particularly television manufacture, the dynamic has been far different. Much of the technology is conventional, accessible to firms in many parts of the world. Markets grow more slowly. In the United States, competition at the retail level has been fierce, with prices declining relative to other consumer durables. As productivity increased, employment declined. Overall, then, while employment in the U.S. electronics industry has grown, the increases have been far from uniform. Few of the workers who once made vacuum tubes found work in microelectronics.

Of course, growth and technological change in electronics also exert influences far beyond this industry. Computer manufacturing, where U.S. competitiveness remains high, has seen rapid employment increase with simultaneous productivity improvements. At the same time, advances in computer systems have created and destroyed vast numbers of jobs in other industries.

Chart 4 illustrates employment growth in computer manufacture, including peripherals. Even more than in microelectronics, the trend has been away from production employees and toward more skilled workers and professionals. Unlike either semiconductors or consumer electronics, neither imports nor offshore production has as yet affected employment greatly. American computer firms have invested heavily overseas, but foreign plants generally serve foreign markets. As in microelectronics, some foreign production may substitute for exports from the United States. But in industrialized (and some developing) countries, American firms often must invest in manufacturing facilities if they expect to sell in volume, limiting the extent to which point-of-sale plants can be viewed as displacing domestic workers. Imports of peripherals and components have been more important; many disc drives and terminals now come from overseas.

In computers, competitive threats lie well in the future.[14] But in consumer electronics, U.S. competitiveness began to slip 20 years ago. Employment typically falls when industries lose ground in either domestic or international markets. Even if aggregate economic growth brings greater demand, only the more efficient companies can take full advantage; firms seldom have any choice but to adopt new technologies, process as well as product, if they wish to remain competitive. Those that move quickly (but not too quickly) may be able to gain an edge over their rivals through efficiency improvements or differentiated product designs. Companies may be forced to automate or pursue alternative routes to lower costs and greater productivity simply to survive. Such strategies have enabled Zenith and RCA, the two largest American color television manufacturers, to maintain their approximate market shares, but to do so, they had to cut their payrolls. If modernizing production facilities and moving offshore costs U.S. jobs in the short term, such strategies may help maintain the total market for American-made products over the longer term.

Chart 4. U.S. employment in computer and peripheral equipment manufacturing, 1955–84



SOURCES: *International Competitiveness in Electronics* (Washington, DC: Office of Technology Assessment, November 1983), p. 359; Bureau of Labor Statistics.

Like all technical change, then, advances in electronics will continue to bring a mix of positive and negative outcomes. Firms manufacturing electronics products will, for some years, continue to create substantial numbers of new jobs. In U.S. manufacturing as a whole, however, jobs—at least for production workers—may go down in absolute terms. A major source of decline in employment opportunities will be redesigned production systems utilizing computers and computer networks along with other tools for improving organizational efficiency.

For firms determined to maintain their competitiveness in world markets while retaining a production base in high-wage economies, computer-assisted automation will be necessary but not, by itself, sufficient. To be successful, these companies will have to redesign their product lines with greater manufacturing efficiency as a primary goal. Product engineers will have to work more closely with manufacturing engineers. Technical staffs will have to work effectively with shopfloor employees—learning from them during the design stage and, at later stages, helping production employees operate the system in something approximating optimal fashion. In the recent past, Japanese companies have done a better job at this than American (or European) firms. Some Japanese firms have nearly erased the interface between design and manufacturing, while building corporate organizations that effectively utilize available human resources, including the capabilities of "unskilled" workers. This has been a major source of Japanese competitiveness in consumer electronics and microelectronics.[15] While we prefer to stress similarities rather than differences between Japanese and Western management styles, it seems clear that the Japanese are well ahead in introducing more highly integrated production systems. A major reason is decision-making processes that lend themselves to conflict resolution and the development of shared values, necessary attributes of integrated systems. Designing products for manufacturing efficiency will be one of the keys to competitive success for American firms over the next few decades. So will integration of workers—at all levels, but particularly on the shop floor—into the production process.

Only by using labor effectively and efficiently—which often means changes both in product design and in the production system—can firms in high-wage economies maintain their international competitiveness. Not all firms will be successful. Some workers, companies, industries, and regions will lose out. Unskilled and semiskilled manufacturing workers are in the greatest jeopardy.

How can the negative impacts be minimized, while capitalizing on the potentials of new technology? The relationships between technical change, employment, and international competition may be complex, but from the standpoint of public policy, many of the negative effects are quite

predictable. Adjustment problems cannot be avoided, but governments can prepare for them, both to ease the inevitable shifts and to help maintain the competitive ability of domestic industries. Because shifts in industrial structure bring new jobs with new skill requirements, it may be time to rethink both public and private programs of training, retraining, and education. With jobs and job opportunities for production workers declining, it may be time to rethink the meaning of work in advanced industrial societie □

——*FOOTNOTES*——

[1] This article is based in part on *International Competitiveness in Electronics* (Washington, DC, Office of Technology Assessment, U.S. Congress, November 1983), Chapter 9. An earlier version was presented at the 2nd International Conference on Human Factors in Manufacturing, Stuttgart, Federal Republic of Germany, June 11–13, 1985. The authors thank Philip A. Mundo for assistance with the statistical data.

[2] These industries are categorized under the following Standard Industrial Classification (SIC) codes as published in the Office of Management and Budget's *Standard Industrial Classification Manual, 1972:* consumer electronics—SIC 3651, "Radio and Television Receiving Sets, Except Communication Types;" microelectronics—SIC 3674, "Semiconductors and Related Devices;" and computer manufacturing—SIC 3573, "Electronic Computing Equipment."

[3] Including communications equipment and components other than semiconductors would double the total, to more than 1.7 million workers, while employment in the American steel industry fell to about 330,000 during 1984.

[4] Both sectors' troubles have been widely reported. See, for example, "Those Vanishing High-Tech Jobs," *Business Week*, July 15, 1985, p. 30. Although the averages for 1984 and the first half of 1985 do not yet show the decline in microelectronics, employment fell each month during 1985 through June in both microelectronics and computers.

[5] See *International Competitiveness in Electronics*, p. 89.

[6] *1977 Census of Manufactures: Communication Equipment, Including Radio and TV, MC77–I–36D* (Department of Commerce, June 1980), p. 36D–5; *1982 U.S. Industrial Outlook* (Department of Commerce, January 1982), p. 343.

[7] *International Competitiveness in Electronics*, p. 223.

[8] See *International Competitiveness in Electronics*, pp. 112–13 and 446–49.

[9] *A Report on the U.S. Semiconductor Industry* (Department of Commerce, September 1979), p. 84.

[10] J.R. Lineback, "Automation May Erase Offshore Edge," *Electronics*, Apr. 21, 1982, p. 94.

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