Chapter 1

Summary

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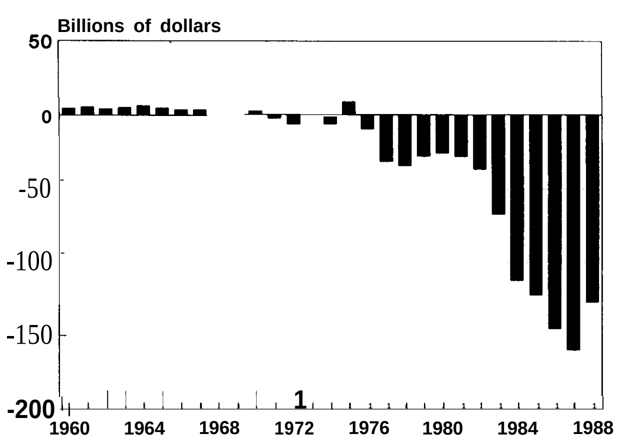
Chapter 1
Summary

American manufacturing has never been in more trouble than it is now. Its biggest challenge is from Japan, where, more than in any other nation, well-designed products are manufactured with great reliability, while costs are rigorously controlled. Other nations, developed and developing, are rising to the Japanese challenge in creative ways. The important difference is that many of those nations are responding *as nations,* with the support and participation of government. While some American companies and institutions have redoubled efforts to improve manufacturing, the government is dozing at the switch. Certainly, there are many problems that manufacturers must solve themselves. But some of the problems are generated by the American people and government. As a nation, we owe it to ourselves to help with their solution.

Symptoms of America's problems are clearly visible: the merchandise trade deficit remains stubbornly high, despite significant downward adjustment of the dollar against major currencies (figure l-l). Productivity growth is sluggish compared with that of many other advanced and developing nations, including our ablest competitors (figure 1-2). U.S. manufacturers are increasingly dependent on foreign producers for a wide range of machinery and tools of production. Even the microelectronics industry, once the standard bearer for American competence and inventiveness, is losing sales and market share to Japanese, Korean, and Taiwanese producers.

Figure 1-1--Merchandise Trade Balance



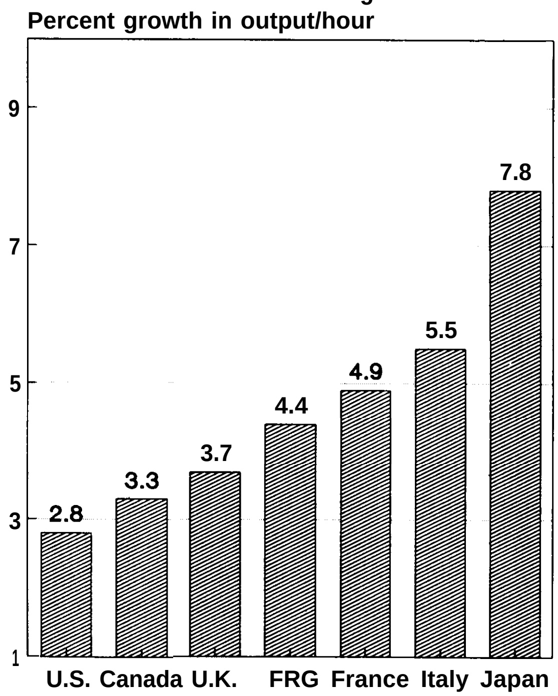
SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, *Business Conditions Digest, September 1939* (Washington, DC: U.S. Government Printing Office, September 1989), table 822.

The weaknesses in U.S. manufacturing technology must be cured if the Nation is to enjoy rising living standards together with a strong, stable position in international trade. Most of the U.S. trade deficit is in manufactured goods (figure 1-3). The most constructive way to right the deficit is to manufacture products that the world will buy because the products are well-made and reasonably priced (not just because a low dollar makes them cheap). More fundamentally, manufacturing is valuable to the Nation as a direct source of productive, well-paid jobs and the indirect source of many better-than-average jobs in the service sector (table l-l). Manufacturing also supports most of this country's commercial research and development.[1]

There is no single solution, but all the signs point in one direction: U.S. manufacturing technology must improve—in everything from product design to manufacturing process development and refinement. For industrial nations, technology is the key to competitive success. Nations that rely on low wages to sell their goods in the world market are, by definition, poor, whereas superior technology raises productivity and thus supports rising standards of living. Moreover, technology is a steady, predictable source of advantage, while others may shift with political currents. For example, a nation's fiscal and monetary policies affect the

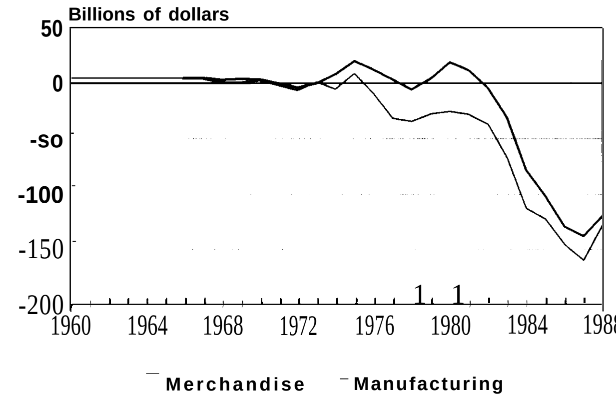
[1] For more detailed discussion of the place of manufacturing in international trade and the national economy, see Office of Technology Assessment, *Paying the Bill: Manufacturing and Americans Trade Deficit,* OTA-ITE-390 (Springfield, VA: National Technical Information Service, 1988).

Figure 1-2—Average Annual Productivity Growth in Manufacturing



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics,"International Comparisons of Manufacturing Productivity and Labor Trends, 1986," June 1989, table 1.

Figure I-3-Merchandise and Manufacturing Trade Balances, 1960-88



SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, *Business Conditions* Digest, *September 1989* (Washington, DC: U.S. Government Printing Office, September 1969), table 622; U.S. Department of Commerce, International Trade Administration, Office of Trade and Information Analysis, unpublished data, 1989; and President of the United States and the Council of Economic Advisers, *Economic Report of the President* (Washington, DC: U.S. Government Printing Office, January 1987), table B-102.

value of its currency, which in turn affects the salability of its manufactured goods in the world market. But macroeconomic policies are changeable, and are far beyond the control of private fins.

Americans are used to thinking of their nation as leading the world in technology—with the select company perhaps of a few other developed countries or a few foreign industries. But the realization has dawned that we are no longer at the forefront.[2] Several major U.S. industries have not only fallen behind in technology, but will be hard put to catch up even if they adopt a whole catalog of changes needed to reverse the slide. Not all American industries are lagging, but trends in many sectors, from computers to aircraft, indicate that our ablest competitors can now or soon will match our technology, and are accelerating faster.

Is this a problem? We have long accepted (in principle, if not in fact) that our technological lead across a wide range of industries was fated to narrow or disappear as developed countries recovered from war damage and poorer countries advanced. But we did not expect the gap to close so rapidly, and we certainly never expected to fall behind.

The toughest challenge is coming from the Far East. At the close of the 1980s, Japan has emerged as the world's premier industrial competitor. The United States is still the richest of nations, with gross domestic product per capita considerably higher than most others (only Canada is close; see figure 1-4). Several European countries are strong performers in one or another manufacturing sector or product—especially Germany, which excels in metalworking and machinery, and consistently runs large trade surpluses. But Japan's record is unique. It has led all major industrial countries in productivity growth for decades—not just in the early postwar years when it was rising from the ashes, but also right through the 1970s and

[2]For aggregate indicators of America's relative technological performance, ibid., pp. 26-35.

Table I-I—Work Force Involved in Manufacturing and Average Full-Time Equivalent Compensation, 1984

	Wage and salary workers involved in manufacturing	Percent of sector employment involved in manufacturing	Average annual full-time equivalent compensation (thousands of dollars)
Agriculture	792	50.4%	$11.3
Mining	443	45.5	37.0
Construction	575	13.3	26.8
Manufacturing	19,396	100.0	28.7
All public and private services	6,492	9.4	246
Ail private services	6,343	11.9	24,4
Wholesale trade	1,501	26.3	27.6
Transportation and warehousing	704	24.2	30.3
Business services	1,276	22.8	24.7
Radio and TV broadcasting	50	21,8	29.6
Electric, gas, water and sanitary services	171	21.4	37.5
Communications, except radio and television	129	11.6	39.7
Automobile repair and services	79	11.6	17.8
Retail, except eating and drinking	1,176	10.3	17.1
Finance and insurance	413	9.0	27.4
Hotels, personal and repair services (exe. auto)	207	8.5	15.7
Eating and drinking places	428	7.9	11,0
Real estate and rental*	72	6.7	21.1
Amusements	46	4,5	19.9
Health, educ. & social sew. and nonprofit org.....,	89	0.9	20.2
Government	149	0.9	31.1
Total	27,697	29.0%	$27.4

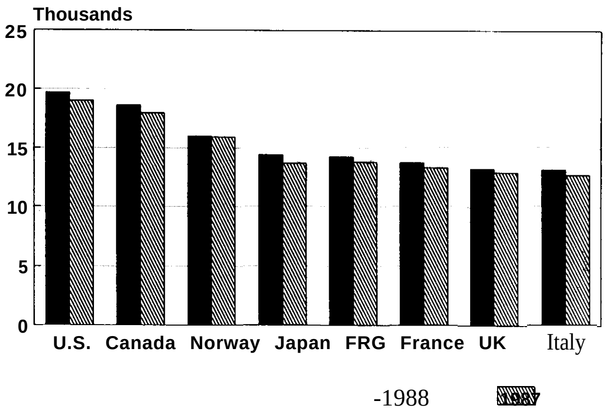
SOURCE: Workers involved in manufacturing data is derived from OTA Input-Output Model (1980 technical coefficients, 1984 estimated demand, 1984 BLS employment, adjusted for capital flows, imports andduties). Compensation data derived from Bureau of Economic Analysis, National Income and Product Accounts, electronic data, mapped to input-output industry classifications.

1980s, despite the oil shocks and two periods of a steeply rising yen. Alone among advanced industrial countries, Japan managed in the 1980s to combine great productivity growth in manufacturing with rising manufacturing employment, rising wages and benefits, and greatly rising output.

These singular achievements suggest some systematic advantages in Japan that are well worth examining. There are of course elements of superiority in other countries too (including the United States) and things to be learned from them. But Japan's sustained improvement in productivity and its pre-eminence in several industries that were once nearly an American preserve (e.g., computers, semiconductors) make Japanese manufacturing a subject of special interest. Thus this assessment on the contribution technology makes to competitiveness in manufacturing concentrates quite heavily—though not exclusively--on Japan.

The Japanese accomplishment rests to a great extent on technology. Broadly defined, manufacturing technology covers not only the generation of new products but also know-how in using equipment, organizing work, and managing people to make the products. Where U.S. firms have fallen down in recent years is in the manufacturing process. The American system, including our great universities as well as industrial labs, still excels at making technical discoveries and inventing new products. But foreign companies (especially Japanese companies) have repeatedly beaten U.S. firms in getting new, improved versions of a great many products to market while keeping costs competitive and quality high.

Figure 14-GDP Per Capita in 1988 U.S. Dollars
(Purchasing Pourer Parity Exchange Rates)



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, unpublished data, August 1989.

Over the past decade or so, we have learned much about the sources of the Japanese manufacturing superiority. We have become familiar with features such as *kaizen,* or continual improvement in every detail of manufacturing; the training of workers to participate in */wizen,* learn multiple skills, and work in teams; and ***kanban, the*** just-in-time delivery system for parts that depends on reliable high quality and reveals failures to achieve it. These features are all part of the "lean" production system that is practiced by the leading Japanese manufacturers and is widely credited with keeping costs low and quality high. The "buffered" system, common in U.S. plants, depends on having large stocks of parts and work in progress, so that faulty items can be replaced, and sizable repair areas for fining up defects in the finished product.[3] The lean system, by contrast, is designed to expose problems while the work is in process, solve the problems, and from there on do it right the first time. If this report gives only passing attention to some of these aspects of Japanese manufacturing, that is not because they lack importance, but because they are very well-known.

Greater investment in advanced equipment is another advantage of leading Japanese industries. From 1976 through 1987, Japanese investment in machinery and equipment consistently ran from 14.9 to 20.6 percent of GNP; in America, it ranged from 7.5 to 9.0 percent of GNP[4] (figure 1-5). Japanese capital investment in the late 1980s was especially high, posting double-digit increases in both 1988 and 1989. In manufacturing, the rate of increase was even greater--over 25 percent for both years. An important reason for these whopping investment increases was a shift in production to higher value added goods.[5] Capital investment in American manufacturing rose only 9 percent from 1988 to 1989 (less in real terms).

It is not simply advanced hardware that gives Japanese manufacturers the edge, however. Their genius lies at least as much in the employment of people in relation to the hardware. This effective use of people is also a factor in the Japanese ability to shorten the product development cycle—to repeatedly incorporate state-of-the-art improvements in their products and bring them to market quickly. For example, it takes Japanese auto companies about 3 1/2 years to get a new model from design to full-scale production, compared to over 5 years for American and European auto makers.[6] A key difference is the Japanese emphasis on simultaneous rather than sequential engineering. The people doing research, development and design of the new model are in constant communication with the people responsible for manufacture. Other factors are involved too, such as the reliance of the major manufacturers on a trusted group of suppliers to do part of the product development work. The result is a headstart over

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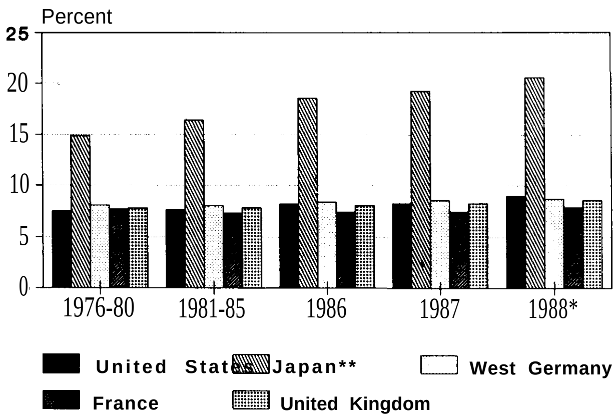
[3] These terms were coined by John F. Krafcik, "A New Diet for U.S. Manufacturing,' *Technology Review,* Jan. 28, 1989.

[4] International Monetary Fund, *World Economic Outlook,* April 1989. The Japanese figures exclude public investment, while those for the United States do not.

[5] The Japan Development Bank, "The Japan Development Bank Reports on Capital Spending: Survey for Fiscal Year 1988 to 1990," Economic and Industrial Research Department, September 1989.

[6] Kim B. Clark and Takahiro Fujimoto, "Overlapping Problem Solving in Product Development" working paper 87-048, Harvard Business School, revised April 1988.

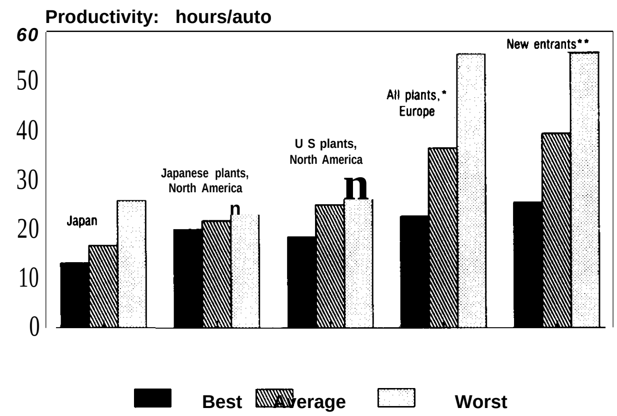
Figure 1-5-Fixed investment in Machinery and Equipment as a Percentage of GNP/GDP



•January to June
** Figures for Japan exclude public investment.

SOURCE: International Monetary Fund (IMF), *World Economic Outlook* (Washington, DC: April 1989), table 17.

Figure 1-6-Productivity Performance, World Auto Manufacturers



•Includes foreign owned.
•* Includes East Asia, Mexico, and Brazil.

SOURCE: John F. Krafcik and John Paul MacDuffie, "Explaining High Performance Manufacturing: The International Automotive Assembly Plant Study," paper prepared for the International Motor Vehicles Program International Policy Forum, May 1989.

slower competitors in responding to consumer preferences and, perhaps even more important, in incorporating the latest technologies.

Some American managers are now adopting Japanese-style approaches, or versions of them, to turn out better goods at lower cost. For example, in the early 1980s, it took twice as many hours to assemble a standard car in an average American auto plant as in the average Japanese plant. By 1988, U.S. assembly plants had improved enough that the Japanese advantage was down from 100 percent to about 50 percent (25.1 hours for assembly in the average U.S.-owned and managed plant v. 16.8 hours in the Japanese). The best Japanese plant had an advantage of 5.4 hours over the best American plant[7] (figure 1-6).

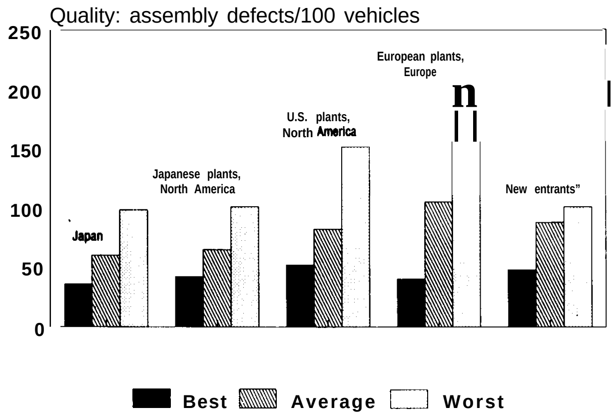
In quite a few other industries (e.g., textiles and steel), well-managed U.S. firms have shown that they are able to turn some of the Japanese-style approaches to good account. But that is no reason for complacency. For one thing, the target is moving. Faced with the high yen, which raises the prices of goods they export, the Japanese Government and Japanese manufacturers redoubled their own efforts to improve technology and competitiveness. For example, the best Japanese plant shaved assembly time for a standard model car from 16 to 13.2 hours in just one year, 1987 to 1988, and the average plant improved from 19.1 hours to 16.8.[8] The Japanese were also holding onto a lead in better quality. In 1988, the average Japanese assembly plant was turning out cars with less than three-quarters of the defects of cars produced in American plants. U.S. plants stacked up very well against the Europeans, however, as shown in figures 1-6 and 1-7.

The reasons for Japanese success are broad and complex. Public as well as private actions, and the interrelation between them, are very much involved. The issues selected for analysis in this assessment include both, and may be grouped into a few broad areas: 1) the cost and availability of capital, and its influence on business decisions to invest for the long pull in product and process improvements; 2) the use of

[7] John F. Krafcik and John Paul Mac Duffie, ''Explaining High performance Manufacturing: The International Automotive Assembly Plant Study,'' working paper of the International Motor Vehicles program of the Massachusetts Institute of Technology, May 1989.

'Ibid., p. 5.

Figure 1-7--Quallty Performance, World Auto Manufacturers



•Includes East Asia, Mexico, and Brazil

NOTE: Data are derived from 1988 J.D. Powers International Quality Survey and corporate data.

SOURCE: John F. Krafcik and John Paul MacDuffie, "Explaining High Performance Manufacturing: The International Automotive Assembly Plant Study," paper prepared for the International Motor Vehicles Program International Policy Forum, May 1989.

human resources to contribute to manufacturing excellence, with special emphasis on engineers; 3) relations between supplier and customer firms within an industry complex, in particular the benefits of close, cooperative links; 4) ways to diffuse new technologies from outside sources to private companies, and especially to smaller manufacturers; and 5) existing government programs-Federal, State, regional and local—that help (or in some cases hinder) U.S. manufacturing firms in using technology to improve their competitive performance.

Lessons from the successes of other countries are not always easy to apply. Some elements in the Japanese system may be quite adaptable to U.S. companies that are enterprising enough to try them-for example, close relations between different segments of an industry complex (e.g., chemical companies that make textile fibers, textile producers, apparel makers, designers, and retailers) in which suppliers are attuned and responsive to the needs of their customer firms, and purchasers are willing to form stable, cooperative relations with their suppliers. Other practices and policies of foreign nations would be much harder to translate into American terms-for example, the century-old system of vocational education that trains half the young people of West Germany in good work habits and a variety of skills. And some policies of other nations are quite foreign to our traditions and outlook-for example, centralized direction of trade and industrial policy as practiced in Korea (until recently, when controls have loosened somewhat).

One way or another, however, the United States must regain excellence in the manufacturing process. That is key to raising income for the Nation. No longer can U.S. industries count on profiting from new inventions for years before competitors begin to produce them. Many technical inventions cannot be protected from skillful imitators-and the world is now full of manufacturers who can quickly and ably produce things that were invented elsewhere (just as U.S. manufacturers themselves have often done with foreign inventions). Over the long run, a country and its citizens cannot control or profit from what they cannot produce competently.

Restoring or creating excellence is no easy task. U.S. manufacturers who once were the masters of mass-production grew complacent in the years of American domination. Many still cling to wasteful production systems that take a narrow view of cost reduction, and do it at the expense of reliability, flexibility, and customer service. Many smaller manufacturers are far behind the times technologically. Federal technology policy is still aimed much more at research and the generation of new inventions than at quickly diffusing new technologies (whatever their source) and putting them into practice. Some government policies run counter to manufacturers' efforts to improve their performance, although that is not their intention. Most important is the government's inability to eliminate the budget deficit, which increases pressure to raise interest rates and the value of the dollar, and directly diminishes manufacturers' ability to sustain long-term, risky investments. The Federal Government, along with many State and local governments, has initiated some new programs to help manufacturers improve competitiveness and technology, but these are modest at best. The dampening effects of macroeconomic and foreign policies can easily overwhelm them.

With will and effort, a nation's industries can change. Forty years ago, Japan was a poor nation, backward in manufacturing technology, lacking engineers and scientists, relying mostly on low labor costs to make products attractive enough for export. Between that Japan and the Japan we know today are years of heavy investment in people, technology, and machinery, and a great deal of sacrifice on the part of consumers. The United States today is in a far stronger position than Japan was then but, ironically, this may make it harder to undertake the sacrifices and changes needed to rebuild our competitiveness. We are still a wealthy nation, and there is no widespread feeling that we are in or approaching a crisis. Under such circumstances, it would take extraordinary leadership to summon the energies to make significant changes. One hopeful sign is that the nations of the European Community—also wealthy and with no apparent crisis—have pulled together to create a new economic order, with the Single Market Act.

The European Community's efforts to harmonize internal markets beginning in 1992 have several things in common with the measures Japan took to industrialize two decades ago. They also have much in common with measures the United States needs to consider to improve our competitive performance. Broadly speaking, they are measures to promote investment in people, technology, and equipment; to disseminate information and know-how; and to encourage cooperative efforts to solve common problems.

INVESTMENT

Investments in technology require patience. Researchers, inventors, and designers often must wait years—sometimes decades—for their efforts to pay off. Although investments in equipment are more predictable and less risky, even these may not break even for years.

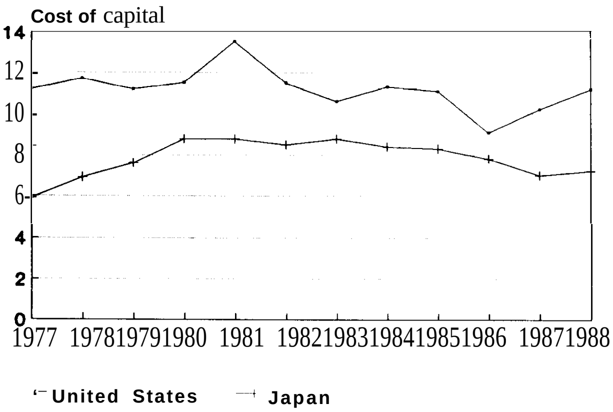
America's financial climate is not conducive to long-term investments in technology and equipment, compared with Japan, Germany, and the most rapidly developing Asian nations. Several things contribute to this relatively unfriendly environment. High U.S. capital costs shorten the time horizons of investors, so do the pressures exerted on companies by the stock market, particularly by institutional investors and takeover specialists. In sum, both government policies and business practices reinforce an excessive concern with short-term profit in America. If these conditions persist, it will be increasingly difficult to keep up with technological advances made elsewhere.

U.S. capital costs have been and remain high compared with those in Japan, the nation that provides the greatest contrast with U.S. short-term thinking. There is some disagreement over just how large (or small) the differences are, but most recent studies estimate significantly higher capital costs in the United States[9] (figures 1-8, 1-9, and 1-10). On the high side, the estimates range up to 13 percentage points difference, while the difference at the low end is on the order of 1 or 2 percentage points. Even relatively modest differences of a few percentage points in capital costs can be a significant disadvantage in making investments that take many years to pay off.

U.S. capital costs are high for many reasons. Interest rates rose in the 1980s and remain high principally because of the enormous pressure of the budget deficit, which is a large drain on savings, and the fall in other savings rates. But there is a great deal more to capital costs than interest rates. The price a firm pays for capital is also a function of its relationships with creditors and equity holders, and the taxes it pays. During Japan's high growth period, which lasted until 1973-74, heavy reliance on debt financing from main banks kept capital costs down for Japanese

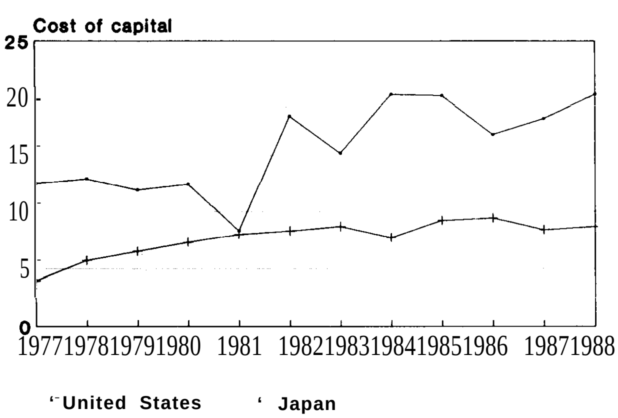
[9] Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, Made *in America: Regaining the Productive Edge* (Cambridge, MA: The MIT Press, 1989).

Figure 1-8--Cost of Capital for Equipment and Machinery With %)-Year Physical Life



SOURCE: Robert N. McCauley and Steven A. Zimmer, "Explaining International Differences in the Cost of Capital," *Federal Reserve Bank of New York Quarterly Review*, Summer 1969, table 2.

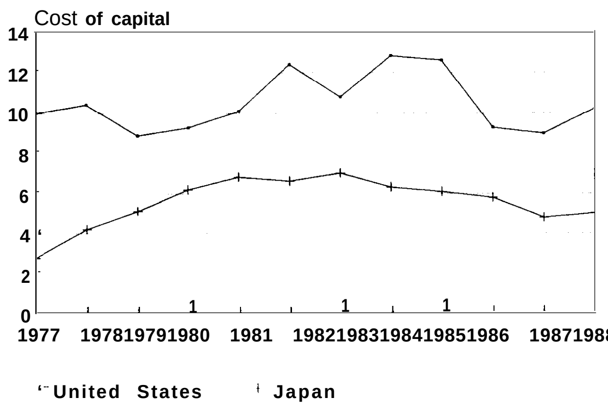
Figure I-9-Cost of Capital for R&D Project With 10-Year Payoff Lag



SOURCE: Robert N. McCauley and Steven A. Zimmer, "Explaining International Differences in the Cost of Capital," *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, table 2.

manufacturing firms (particularly in favored industries). A variety of Japanese Government policies encouraged the banks to lend heavily at low rates to large corporations. These policies included direct government lending through the Japan Development Bank (which is a signal to private banks), administrative guidance from the Ministry of Finance, and close regulation of

Figure I-l O-Cost of Capital for Factory With 40-Year Physical Life



SOURCE: Robert N. McCauley and Steven A. Zimmer, "Explaining International Differences in the Cost of Capital," *Federal Reserve Bank of New York Quarterly Review*, Summer 1989, table 2.

every aspect of banking and finance, including the disposition of household savings.

Today, Japan has enormous capital reserves, and most major corporations finance all their investment with retained earnings and depreciation. Moreover, Japan is deregulating its financial markets, and large Japanese companies are getting more of their external capital in foreign markets. Most estimates of U.S. and Japanese capital costs still show American firms at a substantial disadvantage-one study, for instance, reports U.S. cost of capital at 20.3 percent, compared with 8.7 percent in Japan.[10] But even if nominal costs were the same, differences in the financial environments in the two countries would still favor Japanese firms. Most of the stock of large Japanese corporations is held by other corporations, often in the same *keiretsu* (industry group), who agree to hold the stock for long periods with few demands in return. This system, known variously as cross shareholding, mutual shareholding, or stable shareholding, is in marked contrast with U.S. practice. Here, shareholders must be given far more attention; corporations pay larger dividends, and corporate managers are under heavy

[10] Robert N. McCauley and Steven A. Zimmer, "Explaining International Differences in the Cost of Capital,' *Federal Reserve Bank of New York Quarterly Review*, *summer 1989*, pp. 7-28. These figures apply to investments in research and development. Other investments, such as equipment and machinery and factories, are also shown to be more expensive in America than in Japan and West Germany.

pressure to show a profit each quarter. In the 1980s, new financial instruments have made it much easier for outsiders to mount takeover bids, and managers in U.S. companies feel that they must show profits or become vulnerable to takeover attempts. American managers' increasing preoccupation with the short-term bottom line in the 1980s is in part due to that vulnerability.

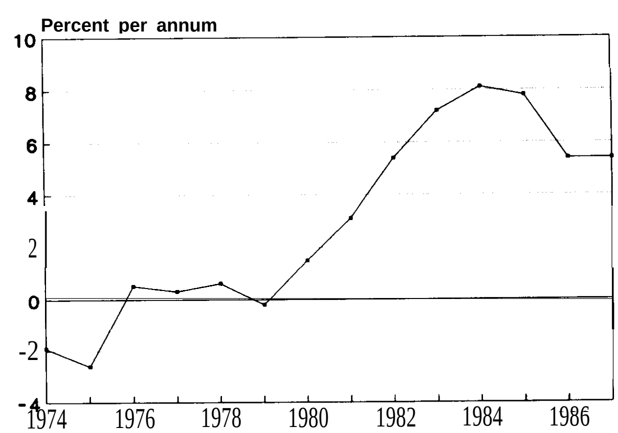
Several other factors tend to reinforce short-term bias in America. None by itself is conclusively important, but together they have a considerable effect. Company size and structure may account for some of the short term focus of the semiconductor industry, in particular. The leading Japanese semiconductor producers are large, integrated, stable companies making a variety of products, from semiconductors to computers and consumer goods. The U.S. industry has a few large, integrated producers, making chips mostly for their own use, but the merchant firms that sell semiconductors to systems makers are mostly smaller, entrepreneurial companies. Such companies have been highly innovative, but also highly unstable. Personnel turnover (especially defections to start new firms) is high, as are rates of entry and exit. Their relatively small size, instability, and irregular cash flow make it especially hard for them to raise the large amounts of capital required for semiconductor production. These factors exaggerate the short-term focus that is endemic in U.S. financial markets.[11]

Government policies that increase uncertainty also aggravate the problem. For example, in the 1980s, American business managers were faced with a very high dollar, which made it harder to sell goods abroad and to compete against foreign goods at home. The dollar finally began falling in 1985. But throughout the high dollar period of the early 1980s, the U.S. Government made no provision for firms working under that disadvantage. In contrast, the Japanese Government put in place special loan and loan guarantee programs to help Japanese firms cope with ***endaka*** (high yen) after the international accords that brought the dollar down in 1985.

The single most important step the government could take to improve the financial environment is to greatly reduce the Federal budget deficit, and eventually eliminate it. That would help to lower interest rates and allow the dollar to find a level that more accurately reflects the competitiveness of American industry (Figure 1-11 shows real long-term interest rates in the 1970s and 1980s.) It would also be a powerful signal to the business community that government could be relied on to provide some stability.

None of this means that American manufacturing is entirely a victim of circumstances beyond its control. U.S. companies are hobbled, but not crippled, by a financial environment that undervalues long-term investment. Some of the myopia of U.S. firms could be overcome through the will of top management. Against the general background of short-term decisionmaking, a few firms standout as long-term investors. Many of these firms have done well. But the power of finance and accounting in American corporations has lifted financial specialists to

Figure 1-1 l—Real Long-Term Interest Rates



SOURCE: Organization for Economic Cooperation and Development (OECD), *Historical Statistics* 1960- 1967 (Paris, France: OECD, 1989), table 10.10.

[11]Dertouzos, et al., 1989, op. cit.

many top decisionmaking spots, and their biases could be difficult to overcome, especially if the rewards for managing for the short-term bottom line do not start to dwindle.

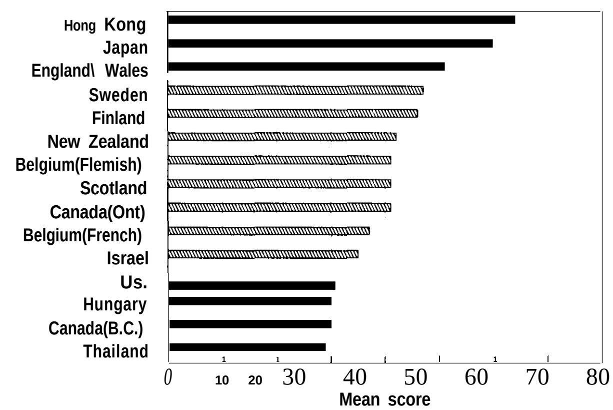
In the discussion so far, investment in technology has been defined as investment in capital equipment, research, and development. The United States also needs well-educated and trained people to make the best use of sophisticated technology. Currently, the investments we make in human resources have disappointing results.

Success in manufacturing depends on the competence and inventiveness of people at all levels. Increasingly, workers from the production line to the executive suite must be comfortable with advanced technology. Production workers are responsible for implementing statistical process control procedures; designers, line managers, and workers must interact frequently and productively; and everyone must assume broader responsibility for making high-quality products effectively. The skills demanded for these tasks are those of analysis and problem-solving. The days when most factory workers used their hands more than their heads are disappearing.

American workers are poorly equipped to cope with these changes, in part because our public schools do not educate many of our children adequately, and in part because firms have been slow to adopt production systems that demand higher order skills, and to train workers to use them. Firms, in turn, are often reluctant to invest heavily in training for fear that they will not be able to recoup their investments.

U.S. educational deficiencies are great in science and mathematics. In the mid-1980s, American junior high school students ranked 10th in arithmetic, 12th in algebra, and 16th in geometry in tests of mathematics competence in 20 countries. In a another comparison of students in 14 nations, American 12th graders ranked 12th in geometry and 13th in advanced algebra (figures 1-12 and 1-13). In the 1960s, American students performed as well as students anywhere in the world. Further evidence of deterioration is the decline in Scholastic Aptitude Test scores over the last quarter of a century.

Figure l-12—Twelfth Grade Achievement Scores in Geometry



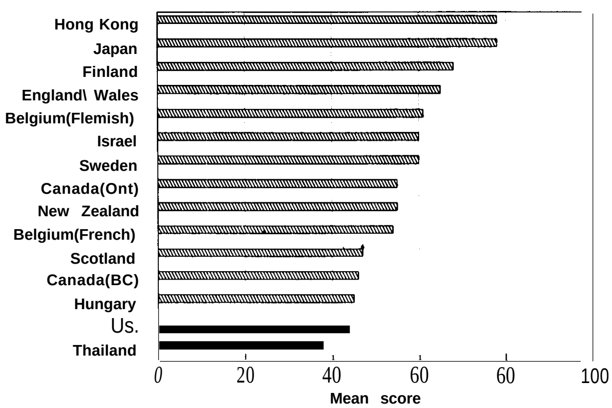
SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics From an International Perspective* (Champaign, IL: Stipes Publishing Co., 1987).

Workers who cannot cope with mathematics or problem-solving are a liability in advanced manufacturing. For example, Motorola determined that workers in its Factories of the Future needed math skills equivalent to seventh grade proficiency to get by. Even this modest requirement has obliged Motorola to invest tens of millions of dollars in training.

Not only is our general public education inadequate, our vocational education system falls far short of the standards set by other countries. It certainly does not match the apprenticeship training taken by more than half the young people of West Germany. This system gets much of the credit for the broad diffusion of technical competence throughout German manufacturing.

While there are small indications of improvement—a recent turnup in SAT scores, for example-there is need for a great deal more. The fact that American students are behind those

Figure I-13-Twelfth Grade Achievement Scores in Advanced Algebra



SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics From an International Perspective* (Champaign, IL: Stipes Publishing Co., 1987).

of other advanced nations—and of several developing nations as well—makes it harder for the United States to keep up in manufacturing. Another worrisome trend is demographic. In the past, most engineers and scientists were white males; they now comprise a shrinking portion of the population of school-age children. Minorities and women have historically performed much less well than white males in math and science, for reasons that are only partly understood. To avoid a future scarcity of technologists, the Nation must devote particular efforts to improving math and science proficiencies—of students of both sexes and all races—all the way from grammar school to employer-provided training.

Do we need to invest more money? It is a widely held belief that the United States invests more in educating its children than other nations, both per capita and as a share of gross domestic product.[12] This is clearly true only if post-secondary education is included. A recent study that separated out education past high school found that U.S. public and private spending on schooling from kindergarten through 12th grade, as a share of GDP, is lower than in most industrialized countries-tied for 12th among 16 (figure 1-14). In spending per student in grades K-12, the United States ranks higher—5th of the 16 (figure 1-15).[13] The United States has some special educational problems: our population is much more diverse in culture and language than that of most of our competitors. It could well take heavier investments in human resources to solve our unique problems.

PROMOTING COOPERATION

Partly because of American traditions—the emphasis on individual initiative, for example—and partly because of public policies that limit cooperation, U.S. firms tend to be isolated from customers, suppliers, and competitors compared with Japanese and many European firms. Japanese firms, in particular, are knitted into a network of mutual obligation and cooperation. This is not to say they don't compete; competition is fierce, but is often greater in product quality and features than in price.[14] The bonds of cooperation and obligation, together with relatively limited price competition in the Japanese market, provide Japanese firms with two advantages: access to a wider array of information and support than they would have alone, and enough stability to encourage investment in equipment, knowledge, and people.

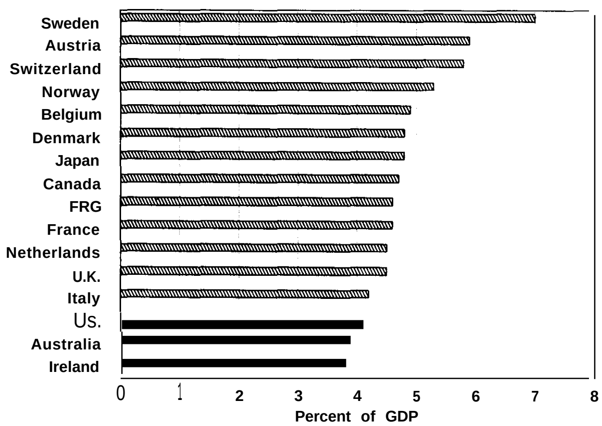
U.S. companies, on the whole, do not form strong collaborative links. The typical relationship between supplier and customer is distant, even adversarial. Price has been the major basis for dealings with both suppliers and competi-

[12] For example, President Bush told the "Education Summit' in September that the United States "lavishes unsurpassed resources [our children's] schooling."

[13] M. Edith Rasell and Lawrence Mishel, "Shortchanging Education,'' Economic Policy Institute briefing paper, Washington, DC, January 1990.

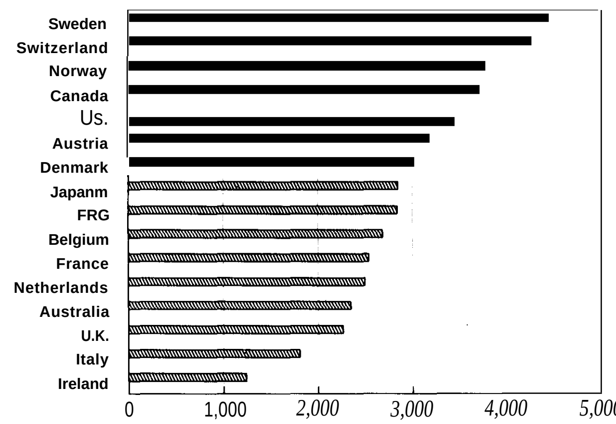
[14] The fact that prices of many consumer goods made in Japan are lower in the United Stare and other foreign countries than in Japan indicates that Japanese manufacturers do not always compete vigorously on price, Japan's complex distribution system amounts for some but not all of the higher retail price for many goods.

Figure 1-14--Spending for Education Grades K-12. percent of GDP, 1085



SOURCE: Lawrence Mishel and M. Edith Rasell, "Shortchanging Education," Economic Policy Institute briefing paper, Washington, DC, January 1980.

Figure 1-15--Spending for Education Grades K-12, Per Pupil, 1985



SOURCE: Lawrence Mishel and M. Edith Rasell, "Shortchanging Education," Economic Policy Institute briefing paper, Washington, DC, January 1990; arrd U.S. Department of Labor, Bureau of Labor Statistics, unpublished data, August 1989.

tors. This is not invariable, nor is it without advantages. In some industries-notably, the airline and aircraft industries-relationships between suppliers and customers are traditionally strong; and in some where relations used to be distant or hostile--such as textiles and apparel—they are becoming stronger. Moreover, price competition among suppliers or between competitors, is desirable and healthy. But taken too far, narrow reliance on price competition can sever close links between customer and supplier, and reduce incentives to improve quality and timeliness, Close and stable relationships with customer firms are incentives for supplier firms to invest in human resources and in equipment that may take several years to pay off. To illustrate the point, in a recent study of metalworking companies, about half the firms that had not bought numerically controlled (NC) or computer numerically controlled (CNC) machine tools cited lack of stable demand for their product as the reason.[15]

Both parent and supplier companies in Japan benefit from close, cooperative relationships. Without having to manage every detail, the parent company is able to demand favorable terms for costs, quality, and delivery times. The supplier has the advantage of a reliable customer who can provide assistance with technical problems and occasionally with finance if needed. While these relationships are often quite stressful for the supplier companies, they have promoted the diffusion of technology and know-how to Japan's myriad of small companies with remarkable effectiveness, aided by an abundance of Japanese Government technology diffusion programs. (See the following section in this chapter on ***Transferring Knowledge*** and ch. 6).

In contrast, American companies have traditionally opted for one of two strategies: vertical integration, or arms' -length dealing with competing suppliers. While vertical integration could be thought of as the ultimate in close relationships, the control over cost that a company can exercise with an outside supplier may be sacrificed. And pitting suppliers against each other—making them compete for every contract on price with no assurance of ever getting another one—makes it more difficult to transfer technology and design responsibilities. The Japanese system has been a remarkably effective compromise. A measure of its effectiveness is that

[15] Maryellen R. Kelley and Harvey Brooks, ''The State of Computerized Automation in U.S. Manufacturing," John F. Kennedy School of Government, Harvard University, 1988.

many American industries-the motor vehicle industry, as well as the textile and apparel industries-are making similar arrangements with their own suppliers.

Close relations between capital equipment suppliers and their customer firms are especially important to technological prowess, particularly in fast-moving industries like microelectronics. In the past two decades, American industry has become steadily more dependent on foreign manufacturers for its production machinery. Japanese suppliers have come to dominate the market for workhorse CNC machine tools; Swiss, German, Japanese, and other European makers lead the market for textile and paper industry machinery; and U.S. producers of semiconductor production equipment are fast losing the lead to Japanese rivals.

In textile industry machinery, where the domestic market share fell from 93 percent in 1960 to less than half in 1986, the reasons for the demise of most U.S. producers are instructive. The industry's decline, which began in the 1960s, was due largely to its unresponsiveness to customer needs and to a short-term perspective, reflected in scanty spending on research and development compared with foreign competitors. The neglect of R&D spending was made worse by the merger mania of the 1960s. Most of the U.S. textile machinery companies were bought by conglomerates.

Although the decline of the American textile machinery industry has not, it seems, crippled American textile makers. Nearly all report satisfactory service from their foreign suppliers. However, the situation is different in the semiconductor industry. As recently as 10 years ago, American firms held more than three-fourths of semiconductor production equipment world market. By 1988, the U.S. share was down to 47 percent and still dropping (table 1-2, figures 1-16, 1-17, and 1-18). This year, Perkin-Elmer, one of the major remaining U.S. manufacturers of lithography equipment, dropped out of that market, which had become a money loser for the company.

Already, losses in the American semiconductor equipment industry are a handicap for U.S. semiconductor producers. U.S. producers say that, for some critical production equipment, they are unable to buy the latest model from Japanese makers only after it has been in wide use by Japanese chipmakers for months. Many U.S. chipmakers are concerned that their ability to get state-of-the-art equipment will decline further in the future. The next generation of lithography equipment is expected to use X-rays, and the Japanese are well ahead of U.S. companies in developing X-ray lithography equipment. If commercial use of X-ray lithography equipment begins, as expected, in the 1990s, it is likely that the first use will be in Japan. That development would add to the already substantial number of microelectronics technologies dominated by Japanese producers.

Sematech, the U.S. industry-led consortium to develop a process to manufacture a 16-megabit DRAM, has given top priority to improving relations between chipmakers and equipment producers. Sematech's directors see better relations as essential to develop a range of high-quality, affordable equipment and materials for American producers.

U.S. producers of supercomputers also risk dependence on Japanese suppliers of components. Significantly, many of those suppliers are also competitors, making supercomputers themselves, or else are closely aligned with competitors. For example, the highest performance memory and bipolar logic components for supercomputers come only from Japan. The management of Cray, a U.S. manufacturer of supercomputers, has at times been told that the latest and best of these components are ''not yet available for export" from Japan.[16] They are, however, available to Japanese supercomputer

[16] IEEE/USAB Committee on Communications and Information Policy, "U.S. Supercomputer Vulnerability,' report to the Institute Of Electrical and Electronics Engineers, Inc., prepared by the Scientific Supercomputer Subcommittee, Committee on Communications and Information Policy, United States Activities Board (Washington, DC, August 1988).

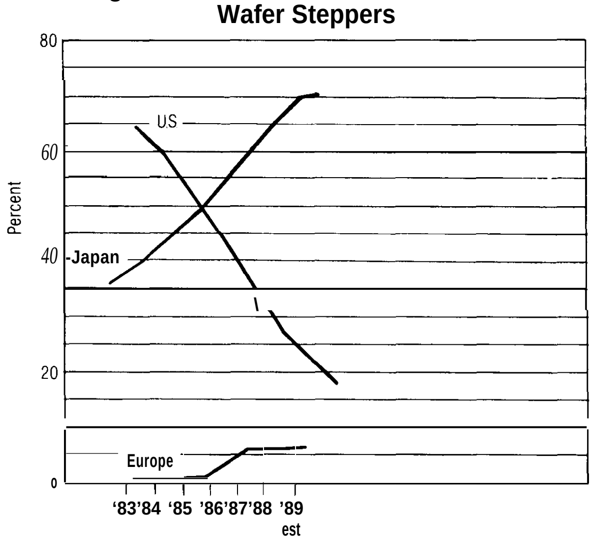
Table 1-2—Top Ten Semiconductor Equipment Suppliers, World Sales
(millions of dollars)

1982		1988	
Perkin Elmer	$162	Nikon	$521
Varian	100	*Tokyo Electron (TEL)*	*508*
Schlumberger	96	*Advantest*	*385*
Takeda Riken(Advantest)	*84*	Applied Materials	382
Applied Materials	84	General Signal	375
Eaton	80	*Canon*	*290*
Teradyne	79	Varian	211
Canon	*78*	Perkin Elmer	205
General Signal	77	Teradyne	190
Nikon	*58*	LTX	180

(Japanese Firms Italicized)

SOURCE: VLSI Research, Inc.

Figure l-16-Shift in Market Shares for Wafer Steppers



NOTE: The wafer stepper is a device central to manufacturing semlconductors.

SOURCE: VLSI Research, Inc.

makers, and the Japanese supercomputers themselves are ready for export. Closer relations with U.S. suppliers is not just an advantage but a necessity for maintaining market share, in a world where a firm's major suppliers are its fiercest competitors.

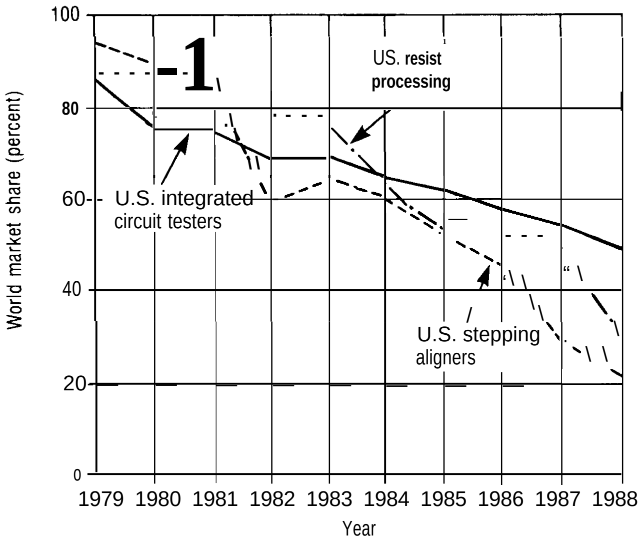
Another wellspring of Japanese technical prowess is cooperative research and development, which has the advantages of shared expenses and synergism. Participants in consortia to develop new products or techniques can gain access to research results they could not afford on their own, and have the chance to work with scientists or engineers from other firms and institutions.

Complex manufacturing processes and sophisticated products demand increasing inputs of research and development. The higher the cost of R&D, the riskier the investment-too risky, perhaps, for all but the largest and most stable fins. For example, it is costing billions of dollars to develop X-ray lithography, an amount that strains the resources of even giant firms. In Japan, a government-sponsored consortium is helping to share the risk and effort involved in developing commercial X-ray lithography.

R&D consortia have other attractions. For example, they are often effective at diffusing technology to participants; they help to avoid problems of redundancy, or wasting of resources on reinventing wheels; and they can be valuable training grounds for researchers. Especially when government is a participant, censortia can help to provide adequate investment in technologies that have a great many externalities—where the rewards cannot be captured by a single firm. In this way, consortia can help lengthen the short time horizons of American management.

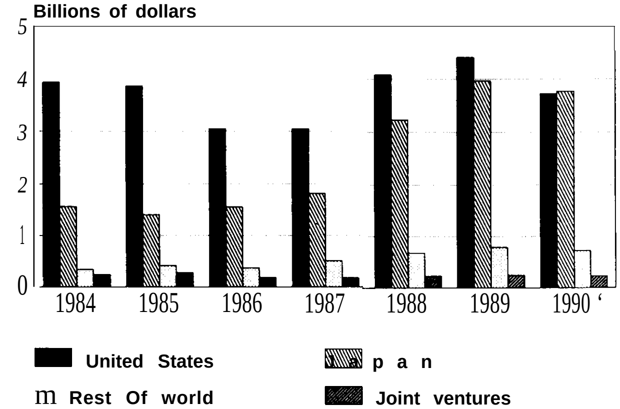
Consortia are not,of course, a panacea.They seem to work best when there are clear goals and least potential for conflict among members--for example, in catch-up projects, where no firm can hope to get a monopoly on a new technology. If America were in the competitive position it occupied two decades ago, we might well conclude that the case for stimulation of consortia (especially ones with government participation) is dubious. But that is not the situation. The

Figure 1-17—U.S. Market Shares of Selected Semiconductor Equipment



SOURCE: VLSI Research, Inc.

Figure 1-18--World Semiconductor Equipment Sales



•Forecast
SOURCE: VLSI Research, inc.

United States has serious competitive problems to solve. The European Community, moreover, has opted to support a profusion of new science and technology consortia. These consortia are largely aimed at overcoming what are perceived as substantial foreign leads in a wide variety of technologies. While the EC's technology consortia probably will never amount to more than 10 percent of all the Community's expenditure on R&D, that small percent is viewed as critical, both because it adds to the amount spent, and because it gives the EC an important strategic lever for guiding European manufacturing technology.

American industry and government have moved cautiously toward collaborative R&D in the past few years. The Federal Government put up half the funding for Sematech, and it has contributed $5 million per year for 3 years to the National Center for Manufacturing Sciences, a consortium designed to do generic research on metalworking and other manufacturing technologies. The National Science Foundation's Engineering Research Centers offer another approach. ERCs are university-based centers that get half their funds from NSF, one-third from industry—which must cooperate with the university in generating and running the research program-and the rest from university, State, and local funds. This small program encourages interdisciplinary engineering research and education and promotes cooperation among university and industry researchers.

One obstacle that sometimes hinders greater collaboration-more in downstream activities like manufacturing than in R&D--is our antitrust law. The discouragement comes not because all collaborative projects would actually violate antitrust law, but because the law is rather unclear, its penalties can be harsh, and trials are expensive. Antitrust law can also interfere with U.S. firms' merging to face competition from larger foreign fins.

These problems suggest the need for modest changes in our antitrust laws. They need to be made carefully, so as to preserve the laws' protection against price-fixing and other anticompetitive practices. Possible approaches include clarifying that conduct should be judged with full consideration of the long-term benefits of cooperation, reducing harsh penalties, and providing for advance approval of cooperative projects.

TRANSFERRING KNOWLEDGE

Public and private institutions for diffusing new technologies across the manufacturing sector are thin in the United States. In particular, there is little technical assistance available to small manufacturing enterprises. While some small manufacturers are on the cutting edge of technology-the Silicon Valley startup springs to mind-most are not. Many cannot afford to devote the time and attention to keeping up with technological developments made in the United States, to say nothing of technical advances made abroad.

It is uncommon for large manufacturers in America to lend technical assistance to their suppliers—still less for the first line suppliers to pass along technical help to smaller subcontractors. Both are everyday practice in Japan. There is little in this country to compare with Japan's dense nationwide network of free, public technology extension services for small and medium-size firms. Nor do we have anything like the huge programs of financial assistance that accompany technical assistance to small and medium-size firms in Japan. In 1988, low-cost direct loans to smaller firms from Japanese national government financial institutions amounted to more than $27 billion, not to speak of $56 billion in loan guarantees, plus additional technical and financial assistance from prefectural and local governments.

In the United States, aside from some small programs for disadvantaged individuals, the Federal government makes no direct loans to small business. In fiscal year 1989, the Small Business Administration underwrote guaranteed loans worth $3.6 billion. A few States have industrial extension services to help small manufacturers make informed decisions about improving their production methods and implementing new technology. No accurate count is available, but these State programs are probably funded at about $25 to $40 millions per year. Federal involvement in industrial extension is sketchy, although Congress has recently taken some steps to strengthen it. The Federal program of technology extension consists mainly of three Manufacturing Technology Centers created in the Omnibus Trade and Competitiveness Act of 1988 and funded at $7.5 million in fiscal year 1990; three more centers are planned. Altogether, current industrial extension programs, State and Federal, reach only a small fraction—probably less than 2 percent per year-of the Nation's small manufacturing firms.

Government technical assistance to small manufacturers in Japan far outpaces similar programs in America. Because financial and technical assistance programs are interrelated, an estimate of the size of these programs is not available, but they are large. For example, Japan's national government provides half the funding for the nationwide system of 185 technology extension centers with the other half provided by prefectural governments. Total funding for the centers is over $470 million per year. Local governments support additional technology extension centers as well. But government assistance is not the only or even the major form of technical assistance. In a recent survey done by MITI's Small and Medium Size Enterprise Agency, 45 percent of respondents (small and medium-size businesses) reported that they received technical assistance from a parent company, 37 percent got information, 28 percent were loaned or leased equipment, and 24 percent got training for their employees.[17] In some cases, vertical transfer of technology within Japanese supplier groups is effective enough to allow major manufacturers to delegate other functions to their suppliers. Both Toyota and Nissan, for instance, have delegated assembly of some of their cars to former first-tier suppliers.

American companies—including all the Big Three motor vehicle companies—have instituted similar programs recently, becoming both

[17] D.H. Whittaker, "New Technology Acquisition in Small Japanese Enterprises: Government Assistance and Private Initiative," contractor report prepared for the Office of Technology Assessment, May 1989, p. 23.

more demanding and more supportive of their suppliers. They have pared down the numbers of suppliers, given more technical assistance, and are moving towards performance-based standards. But U.S. firms are still far behind Japanese manufacturers in diffusing technology and know-how along supplier chains, or among firms within an industry, or from public institutions to private fins.

Because of Japanese direct investment, some American firms are experiencing the Japanese system firsthand. According to a recent GAO study, U.S. auto parts producers who work with Japanese transplant assembly firms report that their Japanese customers keep in closer contact than their U.S. customer firms, and send many more staff on site visits to the supplier's plant. They characterized the Japanese companies they work with as ''preventative' in solving problems, rather than "reactive," like American firms.[18]

Large U.S. firms as well as small ones suffer from isolation. Their customary arm's-length, adversarial relation with suppliers deprives them of the back-and-forth collaborative work on new technologies that takes place between large firms and first-line suppliers in much of Japanese manufacturing. This collaboration is important to innovation in Japan. Japanese manufacturers of all kinds of products, from automobiles to office copier machines, are quick to make incremental changes in products and bring new models embodying the latest technology to market ahead of their competitors.

Another contributing factor to firms' competitive position is their readiness to scan the world, find out what new technologies are available and plug them into new products. American firms seem much less inclined to exploit technologies that originate outside the fro-a stance often called the not invented here (NIH) syndrome. One study of 50 large Japanese firms and 75 large American firms found that Japanese firms spent considerably less time and money than the U.S. firms in developing new products and processes, mostly because the Japanese were adept at exploiting innovations made elsewhere, while American firms were trying to generate more of their innovation internally .19 The ability to make effective use of external technology is also related to short product cycles. Japanese firms in automobiles and electronics have managed to pare product cycles so that they are shorter than those of American competitors. Since new ideas, from inside or outside, are most likely to be adopted at the beginning of a product cycle, shorter cycles mean more innovation—and they do, for many Japanese industries.

The reluctance of U.S. firms to adopt and work with outside ideas has not undermined their ability to apply big-bang, fundamentally new technologies that can be exploited commercially. American companies in general have been good at this, and many small startup firms have found venture capitalists to stake them. NIH applies more to technologies that are good for incremental improvements. It may also help to explain why U.S. firms take curiously little advantage of new technologies developed in Federal laboratories. However, another reason is that the labs, short of money for technology transfer and hampered by red tape, do not reach out to industry.

Most of the $21 billion per year spent on R&D in Federal labs is for defense or basic research-missions not directly relevant to commercial manufacturing. Some of this R&D could be made useful to civilian manufacturing, both by transferring lab technology to industry for further development and by lab-industry cooperative R&D on subjects of mutual interest. Although Congress passed several bills in the 1980s to encourage commercialization of technology from the Federal labs, such commercialization has been modest.

[18]U.S. General Accounting Office, Foreign Investment: Growing *Japanese Presence in the U.S. Auto Industry*, GAO/NSIAD-88-11, March 1988.

[19]Edwin Mansfield, ''Industrial Innovation *in* Japan and the United States, "*Science*, Sept. 30, 1988.

One main reason is that the labs' efforts at encouraging commercialization have not been adequately funded. Without line-item funding, such efforts are often considered by personnel at the labs and their parent agencies to be mere distractions from their primary missions. Interactions between the Federal labs and private industry require a new philosophy and new procedures, and the resolution of some difficult issues (e.g., potential conflicts of interest). Resolving them is more difficult when agency officials, such as the general counsel, put forward objections and there is no strong countervailing voice to push the process along. In addition, some provisions of the law hinder the labs from granting a firm exclusive rights to technology. Without those rights, firms may not find it worth their while to commercialize technology coming out of the labs.

Concerns about exclusive rights extend to R&D in general. Many American firms complain that in the United States and, especially abroad, their new products and manufacturing processes are copied by imitators who did not pay to develop them. They desire stronger intellectual property protection for new technology-chiefly patent rights, and copyrights for software. Without it, they assert, they face unfair competition and cannot pay for their R&D.

This argument has some merit, and some measures to increase protection would help. The most promising ones include strengthening patent enforcement in the United States and Japan, and negotiating to harmonize and eventually unify the patent systems of different countries. However, there are limits to the benefits to be expected from beefing up intellectual property protection. Developing countries may be induced to add some protection but, on the whole, they do not see stronger measures as in their interest. More generally, strong protection, while encouraging creation of technology, can inhibit its diffusion and, in the long run, cannot make up for disadvantages in manufacturing quality and cost. Therefore, while stronger intellectual property protection can help U.S. manufacturing competitiveness somewhat, measures to improve manufacturing quality and cost will help more.

POLICY ISSUES AND OPTIONS

In building a stronger technological base for American manufacturing, both industry and government have important parts to play. Many of the things that must be done are squarely up to manufacturers themselves. Company managers have to learn to use their people more effectively by promoting a back-and-forth flow of people and ideas between research (or design) and production, insisting on design for easy manufacture, pushing simultaneous engineering of improved products and the processes to make them, and giving shopfloor workers the training and responsibility for improving efficiency and product quality. Likewise, it is managers' job to get the fat out of the American production system—for example, by trimming inventories that cost money and hide problems, and by organizing work for reduction of waste. And it is largely up to managers to make the most of forming cooperative relationships between large firms and their smaller suppliers, or between different segments of an industry complex.

There is also much that government can do. Traditional U.S. R&D support, mainly for defense and science, has been beneficial to the Nation as a whole and often to industry in particular, but it is not enough to maintain technological leads, or even parity, in most industries-especially since most of the other OECD nations are making greater efforts to advance civilian technology.

First, government policies that create an environment more conducive to manufacturing make it easier for companies to concentrate on the things that only *they* can do to improve technology. For example, if government policies succeed in lowering the cost of capital to business, or lifting some of the pressure for short-term profits, they are "preparing the ground' (as the Japanese say) for business to do its job well.

Government can also take more direct actions, some within traditional U.S. policy, and others less so. Starting with broad policies affecting the financial environment and human resources, they could go on to stepped-up programs for active diffusion of technology to private firms and, still further, to a strategic approach that would target government R&D support to critical technologies.

The possibilities for government action do not stop there. Many governments throughout the world use means beyond R&D support to promote industries they consider strategically important. For instance, they may favor certain industries with low-cost capital or government-guaranteed purchases, and they may add further support with trade policies designed to manage competition from dominant foreign producers during developmental phases. In building up its industrial might, Japan relied heavily on coordinated technology, industry, and trade policies to promote key industries. Korea and Taiwan followed Japan's lead, and the European Community is using many of the same industrial and trade policy tools as it prepares for the European single market in 1992.

Whether the United States should or even could try to use such comprehensive government policies to bolster competitiveness will be considered in another report, the final one in OTA's assessment of Technology, Innovation, and U.S. Trade. That report will discuss industry and trade policies of Europe and the Asian rim countries, and in what way they might be relevant to the United States.

In this assessment, the spotlight is on technology. The policy options analyzed in chapter 2 and summarized below are directed toward four principal strategic aims:

- Improving the financial environment for U.S. manufacturing firms. This means lowering capital costs and relieving other pressures in the financial markets to show high short-term profits every quarter. The goal is a more hospitable environment for long-term investment in new technologies and productive equipment.
- Upgrading education and training of the workers, managers, and engineers needed in manufacturing. U.S. manufacturing suffers from the failings of our public schools, but also from failures of managers in organizing work and training people to use advancing technologies effectively. Besides continuing efforts to improve education generally, government can help with the retraining of active workers and the betterment of manufacturing engineering.
- Diffusing technologies throughout the manufacturing sector. Government can be much more active than it has been up to now in helping manufacturers acquire up-to-date production equipment and learn to use it effectively. Options might include stepped-up Federal support for technology extension services and a subsidized equipment leasing system. Such things as easier access to technologies coming from Federal labs or foreign countries could benefit all U.S. manufacturing.
- Supporting R&D for commercially important technologies. Some technologies of great potential benefit to society do not get adequate private backing because the payoff for individual firms is too small, uncertain, and far in the future. The U.S. Government has sometimes given special support to R&D for commercially important technologies, but in an ad hoc rather than proactive way. A coherent, strategic technology policy require having an agency in charge that can set goals and choose technologies to support that fit the goals.

Improving the Financial Environment

To keep up with the competition, U.S. manufacturing firms need two basic things that are mainly the province of government to supply: well-educated workers and capital costs that are not so high as to be disabling. As matters stand, government in this country is not doing well at supplying either of these necessities.

The combination of massive government dissaving (the Federal budget deficit, at historic highs in the 1980s) and anemic personal and business saving (at historic lows in the 1980s) is a powerful force driving up interest rates and the cost of capital to business. Congress has made some progress in reducing the Federal budget deficit but it remains high. Some combination of higher revenue and lower spending over several years will be needed to reduce the budget deficit, and this poses a problem. Many of the policy options suggested in this report would, all other things being equal, have a contrary effect, because they would entail either increased tax expenditure or reduced revenue. If these or other policies are not to have the perverse effect of increasing the deficit, even stronger measures would be needed to reduce it. If the United States succeeds in restoring its strong competitive position, then economic growth will help to shrink budget problems in the future. There will be a price to pay in the short run for improving manufacturing, but if it restores our ability to raise standards of living for the great majority of Americans in the long run, it will be worth it.

The budget deficit is a significant source of upward pressure on interest rates, but not the only one. To make capital less costly, the supply available for capital formation must also be expanded. That means raising domestic savings rates. Although the personal savings rate has risen from its extreme low in 1987—less than 2 percent-it is still below the U.S. norm of 6 to 8 percent, and far below the rates in Japan and most European countries. Some analysts argue that the United States can continue to rely on foreign capital to make up the difference between domestic investment and domestic savings, but that is inconsistent with lowering capital costs. It takes high interest rates to attract foreign capital.

To encourage household savings, Congress could consider a national savings initiative, which would reward increases in regular savings (e.g., payroll savings) for households in all tax brackets. To be effective, such a campaign would need to include several substantial savings inducements, such as guaranteed interest rates, high enough to be attractive, on widely available savings instruments. One suggestion is for anew type of government bond with a fixed coupon rate. Reducing taxes on the interest income to regular savings could also be considered.

Inducements to save may not be sufficient to raise savings rates or promote capital formation in industry without some accompanying measure to discourage consumption. Congress may wish to consider a consumption tax, scaled to tax luxury items most heavily, or with substantial exemptions to avoid the severe regressivity of a flat consumption tax. Another possibility is to limit the deductibility of interest paid on home mortgages more severely. There are some limits now, but they are set very high; this encourages consumption of housing and builds equity for households, but the capital tied up in housing is not available for industrial capital formation.

The measures suggested above could help to bring down interest rates generally, and that would tend to lower capital costs. Interest rates and capital costs are not synonymous, however; capital costs are also a function of taxes and of relationships between capital suppliers and companies. Several measures could help to lower the cost of capital to U.S. companies even if general interest rates remain high. One set of options Congress might wish to consider is special tax inducements for technology development and capital investments. The United States has tried a few such measures in the past. For example, the Accelerated Cost Recovery System (ACRS) and the Investment Tax Credit (ITC) were designed to promote capital investment, and the research and development tax credit to increase R&D spending. While the effectiveness of these measures is debated, there is enough substance to the arguments in their favor that they (or measures like them) are worth considering. And they should be considered separately, for they are very different. ITC and ACRS were very expensive (costing tens of billions of dollars, when they were in full force); such measures could, if designed carefully, promote mainly improvements in manufacturing technique. The R&D tax credit is far less expensive, and has more effect on new technology development than on current practice.

Another set of forces affecting capital costs, especially for long-term investment in technology development and capital equipment, is the current wave of hostile takeover activity and speculative turnover of stock. This activity, and the threat of it, reinforces the effect of high capital costs in impelling managers to focus on short-term profits. The relative influence of the takeover boom and high capital costs is a controversial matter which OTA does not resolve. Nonetheless, it is reasonable to conclude that takeover activity is a significant damper on managers' willingness to commit resources to long-term projects, or to retain earnings for reinvestment. The pressure from this source might be manageable if overall capital costs were lower, or if there were enough effective countervailing measures to promote higher levels of investment in R&D and capital equipment purchase.

As it is, Congress might wish to consider mitigating the pressures of hostile takeover activity by means of incentives for investors to hold investments longer. This might be done by adjusting the capital gains tax rate to favor long-term gains and penalize short-term asset turnover. This measure would have most effect if the tax were extended to pension and other funds that are currently tax-free, but account for more than half the transactions in the financial markets. Another option is to tax securities transactions, which would penalize those whose turnover is greatest. However, without real, steady progress toward eliminating the budget deficit, all of these other measures taken together will probably have only a marginal effect.

Finally, the financial environment of the United States is unstable and unpredictable, compared with our premier international competitors, Japan and West Germany. In Germany, in particular, macroeconomic policymaking concentrates on maintaining stability in prices and exchange rates and controlling inflation. Such stability is an enormous asset to business, especially in a country that is heavily dependent on foreign trade (like West Germany), and especially when supplier-manufacturer-customer links are increasingly likely to span national borders (as the 1992 European Single Market approaches).

Japan's financial environment is also very stable. Policymakers there are highly sensitive to how macroeconomic developments affect business, and they take steps to help the private sector adjust. For example, after the international financial accords were reached to raise the value of the yen (and other currencies) against the dollar in the mid-1980s, the Japanese Government put in place loan programs to help firms (small ones, in particular) adapt to the rising yen (endaka). Japan's economy did slow down in 1985 and 1986, at the beginning of endaka, but the adjustment was swift. Much more painful were the circumstances faced by American manufacturers in the early 1980s when the dollar began its long climb, and no government policy was in place to ease the adjustment. In sum, a major difference between Japanese and U.S. policies is that little concern is evident in the United States about the effects of macroeconomic, trade, and other policies on the competitiveness of U.S. firms in general or manufacturers in particular. In Japan and West Germany, competitiveness is customarily taken into account. It plays a prominent role in making and implementing those governments' policies.

Human Resources

Human resources, like capital costs, have a pervasive effect on manufacturing. In the past, most manufacturing workers learned their jobs by the sides of more experienced workers, and an ordinary grammar school or high school education was plenty of preparation for a production worker in manufacturing. Today, with automation affecting more workplaces and less automated work being exported overseas, production jobs in manufacturing require more conceptual knowledge-and often competence in statistical process control and managing computerized equipment. Jobs typically encompass more diverse tasks than in the past, and workers must grasp the relationships of different parts of production to each other in ways never required before. In other words, more is demanded of manufacturing workers. At the same time, the typical American education is leaving young people less well prepared for their worklives. Managers have remarked for years that young people could be better prepared, but the situation now is commonly described as a crisis. And it is likely to get worse before it gets better. About half the new entrants to the work force between now and the turn of the century will be members of minority groups, and about two-fifths of minority children live in poverty. Poor children typically drop out of school in disproportionate numbers, and many grow up lacking the skills they need to be productive workers.

There is a broad consensus that the Nation's public school system needs help. But even if help arrived tomorrow, the results would be many years coming. A more immediate approach is to help people already in the work force to acquire needed skills. While some large companies are providing education and training themselves, the financial burden of such programs-good ones can run into hundreds of thousands to millions of dollars-is another drain on limited financial resources, Most small companies cannot afford extensive training programs.

Congress could consider several options to help workers raise their educational levels and improve their work skills. One is to offer federally guaranteed student loans to employed people taking classes part-time; another is to let employers and employees deduct the costs of training and education (the present tax law already allows this, subject to some limitations). Another possibility is to tailor military training programs, which are already extensive, to fit more closely the skills required of workers in civilian jobs. The Federal Government provides less than $10 million to a program that partially funds demonstration projects for literacy teaching in workplaces. There is ample evidence of additional demand for such projects; increased funding could be used effectively and immediately. Training could also be made a part of any technology extension services offered by the Federal Government or funded in part by Federal money, (See the section below on *Technology Extension.)*

These suggestions do not constitute a complete list of options for training active workers. A fuller examination of the possibilities for congressional action will appear in a forthcoming OTA report, *Worker Training: Implications for U.S. Competitiveness.*

Although well-educated and trained production workers are essential to improving manufacturing efficiency and quality, there are other, equally critical needs for highly trained people. Production workers are a steadily falling percentage of manufacturing employment; professional and technical employees are a growing share. Engineers, in particular, are essential for excellence in manufacturing. It could be more difficult in the future to maintain an adequate supply of engineers to sustain manufacturing.

There is not now an obvious shortage of engineers in manufacturing; about as many engineers are employed per thousand workers in the United States as in Japan and Germany, whose manufacturing is justly famous for its excellence. But Japan is graduating more engineers per capita than the United States, and Germany has what is probably the world's finest set of training institutions to provide technical people for manufacturing, from the shopfloor to the engineering workstation. Meanwhile, in the United States, the demographic group most inclined to enter engineering—white males-is shrinking as a proportion of young people.

This trend is not new. Several Federal programs, are already in place to encourage women and minorities to enter engineering. Larger programs support the recruitment and training of students generally in scientific and technical careers, and special training for teachers.) Many of these programs are producing good results and could be expanded. But without improvement in math and science education in the elementary and high schools, their effects are bound to be limited. Children who perform poorly in elementary school arithmetic and math are unlikely to choose engineering careers. General education improvement, especially in math, is the first necessity for keeping the engineering pipeline filled.

Some possible programs could help shore up the supply of engineering talent for the next few years, before improvements in education (if they are made) begin to yield results. If defense programs wind down as expected over the next few years, Federal programs might help retrain and equip engineers who have been working in the military sector to enter civilian manufacturing. More generally, programs to encourage or fund midcareer training of engineers whose knowledge needs updating might be considered.

The effective use of engineers is at least as important as an adequate supply. There are indications that U.S. manufacturers could make better use of their engineers. Elitism among engineering staffs, and their aloofness toward shopfloor problems in producing their designs, are often cited as a peculiarity of American manufacturing. This kind of problem is best solved by manufacturers themselves, but the Federal government could encourage manufacturers to recognize and correct the problem, through support of education and research in manufacturing engineering. One option is to increase Federal support of manufacturing engineering, possibly through the creation of a Manufacturing Sciences Directorate in the National Science Foundation.

Diffusing Manufacturing Technology

Making the financial and human resource environment more conducive to improved manufacturing quality, efficiency, and technology may not be enough. American manufacturers have lost too much ground to foreign manufacturers, in nearly every sector. Even with lower capital costs and more competent people, some manufacturers may still lack the resources or the knowledge to find or develop and implement the best technologies.

Congress might consider an array of options to promote technology diffusion and transfer more widely, or remove obstacles to diffusion. None, by itself, will make a great deal of difference; patience and an experimental approach will be required to make any of them work. Some may fail. Yet it is likely that some combination of policies to promote technology transfer could pay off handsomely, given time, the commitment to adapt to changing circumstances, and the willingness to learn from experience.

Technology Extension

Large firms generally have the resources to develop or acquire technologies they need, although they may neglect to take what they could from outside the firm. But many small firms have a hard time staying abreast of advancing technology. Americans like to cherish the notion that all small firms are like Silicon Valley startups—technically and scientifically advanced, staffed and run by entrepreneurial innovators—but the image is hardly typical of small manufacturing fins. For many of America's 355,000 small and medium-sized manufacturing fins, exposure to new technologies is haphazard, and the effort to keep informed is beyond their means.

To contribute to the competitiveness of U.S. manufacturing, small firms need to keep up with technology as much as large ones. While small enterprises are usually not heavily involved in foreign markets themselves, their performance is important to the ability of larger manufacturers, who are their customers, to compete. Large auto companies, for instance, depend on the ability of their myriad suppliers, some of which are quite small, to deliver the right components, well made, on time. As specifications become more exacting, and the tolerance for defects decreases, the demands for small firms to use new technologies effectively grow. America's most adept competitors, Japan and West Germany, have broad, deep institutions that support technology diffusion and transfer to small enterprises.

Large firms can transfer technology to smaller companies quite effectively themselves. Even in Japan, however, an extensive network of government programs and institutions to support technology diffusion and training supplements these private efforts. The United States, in contrast, has a few State programs and, until recently, very little at the Federal level. In 1988, the combined technology transfer and technology/management assistance programs of the 30 States that had such programs came to $58 million, and that included assistance to all kinds of business, not just manufacturing. State industrial extension programs, giving one-on-one technical advice to individual firms, probably add up to about $25 to $40 million per year.

The Federal programs include: 1) three existing and three more planned Manufacturing Technology Centers to demonstrate advanced technologies and provide extension; 2) some assistance to State programs; and 3) the Advanced Technology Program, a mechanism for Federal guidance and participation in joint R&D ventures with private firms. Together, the three programs have funding of less than $19 million for fiscal year 1990. A smattering of other Federal programs also offer some technology extension services; the largest of these is Trade Adjustment Assistance for firms and industries, funded at less than $10 million in fiscal year 1990. These small, scattered programs contrast with billions of dollars' worth of financial and technical assistance to small and medium-sized enterprises in Japan, plus Japanese Government participation in dozens of R&D efforts. While precise comparisons of funding for technical assistance to small manufacturing enterprises are impossible, it is certain that Japan's commitment to upgrading the level of technical ability in small firms is more than an order of magnitude greater than that of the United States. (See chs. 6 and 7 for details of the Japanese and U.S. programs.)

If Congress wishes to deepen its commitment to upgrading technology in small and medium-sized manufacturing enterprises, it could increase funding for the Manufacturing Technology Centers, provide more money for State industrial extension services, or some of both. Manufacturing Technology Centers are managed by the National Institute for Standards and Technology, as authorized by the Omnibus Trade and Competitiveness Act of 1988. They are responsible for transferring technologies developed at NIST to manufacturers, making new technologies usable by small firms, providing technical and management information to small firms, demonstrating advanced production technologies, and making short-term loans of advanced manufacturing equipment to manufacturing firms with fewer than 100 employees. Although funding was authorized at $20 million per year, appropriations have been much smaller: $5 million in fiscal year 1988, $6.85 million in 1989, and $7.5 million in 1990. These amounts cover administration as well as technology extension activities. The three existing Centers have each received $1.5 million per year for their first 2 years, and must match the Federal funding. Federal funding starts to decline after 3 years, and drops to zero after 6 years.

In addition to the Manufacturing Technology Centers, the 1988 trade act authorized a program of Federal assistance to State technology agencies, administered by NIST. This program received no funding until fiscal year 1990, when Congress gave it $1.3 million to help States with industrial extension programs expand those programs. States receiving Federal money from this program must match it with their own funding.

Only a few States have real industrial extension services. (NIST, in a nationwide study, found only 13 that met their definition of "technology extension services," but more have since been established.) Several of those are quite new. Nonetheless, State programs are generally better developed than Federal ones, and a very few have years of experience.

There is room for expansion of both State and Federal efforts in technology extension. States may do abetter job of service delivery, being in better touch with the needs of local manufacturers. But there may be some things the Federal Government can provide that States cannot. By their nature, industrial extension offices specialize in the industries most prominent in their service delivery area. And industries tend to be regionally concentrated, spanning State lines; Federal services are often better suited to serve regional concentrations of industries. Also, while some State programs are excellent, others are less so; a Federal service could help ensure consistent quality of service, or at least minimum standards. If Congress wishes to consider expanding efforts in support of industrial extension, financial support for good State programs, as well as technical and financial support for States which are new to the effort, would be an effective combination with support of Federal extension services.

If Congress were to set a minimum goal of extending industrial extension services to 24,000 small firms per year nationwide (7 percent of the nation's 355,000 small manufacturers), the total cost would be $120 to $480 million, depending on the level of service. If the Federal share of funding were 30 percent, as it is in the Agricultural Extension Service, the cost to the U.S. Government would be $36 to $144 million. That would provide a modest level of service, one that might easily be overwhelmed by requests for assistance. The State of Georgia's experienced, effective industrial extension program serves a roughly similar proportion of its manufacturers, and Georgia Tech, which operates the service, reports that it does not advertise because it would be swamped with requests it could not meet. However, considering the inexperience of State and Federal Governments in providing industrial extension, moderate annual increases may be all that could be handled now.

Financial Aid for Modernizing Manufacturing

Technical assistance to small business is often most useful if it is accompanied by financial aid. Improving the general financial climate for investment or offering special incentives to invest in research, development, and capital equipment, will help all businesses. But small businesses still have special problems raising capital. They usually must pay more for both debt and equity capital, and they often do not have enough retained earnings to finance modernization programs or training on their own. Without help in financing, small firms may not be able to implement the advice of industrial extension services.

In fiscal year 1989, the Federal Government made 47 million dollars' worth of direct loans to small businesses run by special groups (disabled veterans, the handicapped, and others), and guaranteed $3.6 billion in commercial loans to small businesses. It contributed $154 million to investment corporations, which make equity investments and long-term loans to small businesses. These programs are not confined to manufacturing. None is aimed at improving the practice of manufacturing in general.

These programs are in striking contrast, both in funding and in purpose, with Japan's financial assistance to small and medium enterprises (SMEs). Japan's SME programs spend $27 billion annually indirect loans and an additional $56 billion in loan guarantees. Again, this funding is not confined to manufacturing (which makes it comparable to the figures given above for American programs). Much of the Japanese funding is tied to technical assistance, and some is directly targeted to technology improvement. Part of the reason for such heavy support to SMEs in Japan is that for many years, small business was a technological backwater. The same is true in many sectors of American small business.

There are, of course, important differences in manufacturing in Japan and the United States. One is that small firms play a bigger role in Japan's manufacturing sector-74 percent of manufacturing employment is in small and medium-size firms in Japan, compared to 35 percent in the United States. However, because

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of the larger size of the U.S. economy, the difference is less in absolute terms. Small Japanese manufacturing firms employ 10.7 million people, compared to 6.8 million in the United States. In both countries, small manufacturing plants play key roles as suppliers to the large corporations that are major actors in the world economy. And in both countries, small manufacturing fins' needs for technical and financial assistance have much in common.

Congress might consider several options to encourage firms to invest more in advanced technology and in training support required in the service and to use the technology well. One option is an equipment leasing system that would make new production equipment available to manufacturers on below-market terms. If the system bought U.S.-made equipment could serve two related purposes: besides enabling firms to get advanced equipment on easier terms, it could also help assure U.S. makers of production machinery a market for at least part of their output. In both ways, the program would help American manufacturers to focus more on long-term investment and improvement. The program could be open only to small manufacturing business, or to all manufacturers, possibly with more favorable terms for smaller firms.

Another option to encourage technological improvement in small business is more direct financial support. As noted above, the government's financial support (loans, loan guarantees, and investments in development corporations) was about $3.8 billion in 1989. This compares with $487 billion in fixed investment (structures and producers' durable equipment) by all private business in the same year. While exact comparisons with Japan are not possible, we do know that Japanese loan and loan guarantee programs to small firms area at *least* 20 times greater than those of the United States, and the level of subsidy in Japan is more substantial. For example, even a federally guaranteed loan to a small business in the United States may be a couple of percentage points above the prime rate, while in Japan, government-guaranteed loans to small business are typically substantially below market rates, and in some cases interest-free. While Japanese policies clearly are not a template for American action, they do make a difference in the competitiveness of Japanese industry at all levels.

Greater financial aid for small manufacturers could offer an opportunity to upgrade technology. One qualifying condition for financial aid (either direct loans or loan guarantees) could be that the firm receive a technical assessment, possibly from an extension service, and that it either follow the guidance of the assessor or work out an alternative plan. This is not necessarily intrusive. From the late 1970s through 1989, hundreds of small U.S. firms injured by import competition received technical help from a small U.S. Government program, Trade Adjustment Assistance for firms.[20] (The program, formerly funded at about $15 or $16 million per year, including assistance to industries as well as firms, has been substantially reduced. Its fiscal year 1990 funding was $9.9 million in new and carryover funds.) An assessment was a precondition for assistance under the program, and many participating firms found it a valuable service. Many small firms in Japan voluntarily undergo assessments each year in order to learn of new techniques and markets, and to get an independent (though not detailed) assessment of the directions competitors are taking. This option presupposes an industrial extension service that could deliver competent, timely service nationwide.

Another possibility is to target financial aid to investments in advanced equipment, as Japan has done several times. Recently, for example, producers were allowed to depreciate automated electronic ("mechatronic" equipment very rapidly, encouraging many small and medium-

[20]For a description and analysis of the program, and the larger and better known program of Trade Adjustment Assistance for workers, see U.S. Congress, Office of Technology Assessment, *Trade Adjustment Assistance: New Ideas for an Old Program*, OTA-ITE-346 (Springfield, VA: National Technical Information Service, 1987).

sized firms to acquire numerically controlled machine tools. A drawback is that some firms might invest in equipment they aren't prepared to use properly; but a technical assessment or industrial extension service could help here.

Financial and technical assistance to small firms could be explicitly extended to cooperatives of small firms as well. Managers of small fins, with too few staff to dedicate even one person to keeping up with technology-or for that matter, with competitors, customers, or suppliers-often have to depend on a few ad hoc sources for information about changes that affect their business. Cooperative networks can help these managers in many ways, by pooling the time and resources needed to keep up with technology, changing markets, customers' needs, and competitors' doing by obtaining quantity discounts on equipment that individual firms buy in ones or twos; and by providing an independent source of information on new technologies that does not have its own commercial interests at stake, as vendors do.

If Congress wishes to support the formation of cooperative associations, it could consider making the services of federally funded industrial extension services available to cooperatives, or extending financial assistance to cooperatives as well as firms. Congress might also want to make provision for small firms to cooperate in marketing and manufacturing without risking violation of the antitrust law.

Commercialization of Technology From Federal Laboratories

The Federal Government spends $21 billion each year on R&D in Federal laboratories, of which three-fifths goes to defense applications. Some of the defense R&D could be useful to civilian industry, along with some of the basic research done for nondefense applications in Department of Energy (DOE) laboratories. For example, industry has benefited from using specialized facilities at some DOE labs, such as the Synchrotrons Light Source at Brookhaven National Laboratory and the Combustion Research Facility of Sandia National Laboratories.

On the whole it has not been easy for industry to take advantage of the labs' technology—despite legislation enacted throughout the 1980s to facilitate the process. There are still obstacles on the Government's side, and further measures by Congress could help, although ultimately success will depend on industry's willingness to tap into the labs.

Congress could consider earmarking some of the labs' R&D appropriation for promoting commercialization. This would include identification and marketing of promising technologies, patenting when appropriate, and cooperative R&D projects to bridge the gap between the laboratory and commercial exploitation. Earmarking some funds for cooperative R&D could be particularly beneficial. (DOE's high-temperature superconductivity pilot centers in three national laboratories are examples of cooperative R&D projects, planned from the start with industry and funded 50-50 by industry and the labs.) Congress might begin by mandating that a few percent of the labs' budgets be set aside for cooperative projects as appropriate. This would encourage labs to seize opportunities for cooperative work promptly.

Another possibility is increased funding for the Federal Laboratory Consortium. The FLC, with a small central staff and volunteer representatives from over 300 labs, tries to match inquiries from firms with the appropriate lab researcher. Additional funding could help the FLC to perform this function, and also to increase its projects demonstrating new means of technology transfer.

In addition, Congress could consider measures to remove several obstacles to technology transfer and cooperative R&D. For example, DOE's national labs have sometimes been stalled by Agency red tape when they wish to license technology to firms. Congress has already taken some steps to give the labs more independence in this regard and could go further (e.g., by extending to all labs the power to take automatic title to patents from lab research, removing the necessity to wait for extended agency review). To make cooperative projects more attractive to industry. Congress could also clarify DOE's right to keep information developed in the projects proprietary, and allow copyright of computer software created by government employees involved in such projects.

Lab-industry cooperation raises several other issues, such as possible conflicts between lab employees' duties at work and their desire to get consulting work or royalties from the commercialization of their work. Congress could consider forming an interagency legal task force which could give a broader perspective than a single agency has on these and other legal issues raised by lab-industry cooperation. The task force's approval would not be required; but an agency's general counsel, if concerned about an issue, could seek the task force's advice.

Tapping Into Japanese Technology

American firms are often faulted for not making greater efforts to investigate and import technologies developed elsewhere—sometimes, even in another division of the same firm. When U.S. firms were technologically dominant in most industries, this parochial attitude was no great handicap. Now, with technological advantage more evenly distributed around the globe, it is a significant hindrance. Many firms have responded to the challenge to keep up with technology developed abroad, but they face special difficulties getting access to Japanese technologies. One is simply the language. European languages are enough like English, and enough Americans know some European language, that it is not too hard to get the gist of technical articles or to have them translated. But the Japanese language poses much more serious translation problems. Another difficulty is that much of Japanese technology is developed in the industrial sector and thus is inherently less accessible than technical expertise and knowledge freely available at universities and other public or quasi-public institutions.

A sprinkling of U.S. programs promote technology transfer from Japan. A few universities have fellowship programs that send graduates in science and engineering to Japanese companies and research institutions; and the National Science Foundation and the Government of Japan sponsor several new programs to support long-term research by U.S. engineers and scientists in Japan. The NSF-Japan programs were not fully subscribed as this report was written, although there is reason to believe that they will attract more applicants as they become better known. Congress may wish to monitor the progress of government-supported programs, and provide additional funds when and if they become overcrowded.

Other options are to establish a Congressional U.S.-Japanese Fellowship Program, and to encourage government researchers working in Federal labs or elsewhere in the Federal Government to undertake long-term projects in Japan. Postdoctoral or midcareer fellowships for professionals other than scientists and engineers could also be useful, not in directly transferring technology, but in helping more people to understand the workings of Japanese management and government-industry relations.

Congress might wish to consider increasing the funding for the Office of Japanese Technical Literature. While demand for the office's products has been disappointing, expanding the services available could create more interest. Finally, the government could promote Japanese language instruction in public schools, possibly by examining the critical foreign languages program in the 1988 education act to see if it gives sufficient weight to Japanese. Another option is to fund expansion of Japanese language programs in post-secondary and postdoctorate education, especially for scientists and engineers.

Antitrust

Antitrust law and enforcement have been relaxed in the past decade, but fear of running afoul of antitrust statutes is still a potent force in industry, because the law is complex and often vague, penalty for violation can be stiff, and private parties as well as the government can bring suit under the laws. There is good reason for firm enforcement of antitrust law; for many years, it has served this country well in maintaining competition. However, some kinds of cooperation among firms could help American competitiveness, and some modest changes in antitrust law and enforcement could help promote them.

Congress has already amended and clarified the law to make some joint activities easier. Among other provisions, the National Cooperative Research Act of 1984 clarified that joint R&D (as defined in the Act) will be judged under the rule of reason if suit is brought. This rule ensures full consideration of the activity's pro-competitive effects. Congress might wish to consider extending this provision to joint manufacturing and standards-setting. The 1984 Act also reduced private treble damages to single damages for registered R&D projects. Congress might wish to consider reducing treble damages in other circumstances as well.

Advance certification for some kinds of joint activities is another option. Firms could apply to the Justice Department for a determination that a proposed project complies with antitrust law. Private parties could challenge that determination in court but could not collect damages for activity covered by it. Another possibility is to establish safe harbor market shares, below which firms would not be in violation. Finally, Congress could make findings that joint ventures or mergers between U.S. firms are sometimes necessary to fend off foreign competition, and could instruct courts to evaluate such activity based on long-term effects.

Whether modifying the antitrust laws or their enforcement would unleash a great deal of cooperative work, and whether such changes would substantially improve manufacturing competitiveness, is unknown. It is also unknown whether changes such as those suggested would have substantial negative effects from lessening the fear of antitrust suits-effects such as increased hostile takeover activity or more price-fixing. Changes in antitrust law and enforcement should be made cautiously, but they deserve serious consideration.

Innovation and Intellectual Property

Improvement of intellectual property protection could well start at home. Within the United States, the greatest complaint is that patent enforcement is slow. Patent cases that go to trial take, on average, more than 2 *1/2* years before a decision. Congress could consider several ways to speed up enforcement of patent infringement statutes. It might designate special judges for patent cases, or increase judicial manpower devoted to hearing patent cases. In a way, there is already extrajudicial manpower available; the International Trade Commission employs four administrative law judges to hear cases under Section 337 of the Tariff Act of 1930. Under section 337, a U.S. firm whose patent is infringed by imported goods can apply for an order to stop the goods from entering the country. The procedures for hearing and settling cases brought under Section 337 have been found to violate GATT, however, and the Administration is considering how to amend Section 337 to satisfy GATT while keeping its advantages of a quick trial and enforcement at the border.

Effective domestic intellectual property protection is not sufficient, however. U.S. firms need adequate protection in foreign markets as well. To many innovative companies, the Japanese patent system is a particular problem. It is slower than ours in issuing and enforcing patents, and it strongly favors licensing of patents-something U.S. firms do not always wish to do. The Administration is pursuing negotiations to fix these problems. Another problem for American firms is that they don't understand the Japanese system very well, and can't easily find out more. The language barrier adds to the difficulties. Congress might wish to establish a program in the U.S. Patent and Trademark Office to collect and disseminate information about the Japanese system.

Differing patent systems throughout the world present a general problem. Usually, a firm must apply for a patent in each country in which it wants protection; this is expensive and time-consuming. One option is to harmonize international patent law and application procedures, at least among nations that trade heavily in high-technology products. The United States has been negotiating with Japan and the countries of the European Community to this end. Any agreement will probably require substantial changes in the U.S. patent system. While such changes--e.g., changing to a first-to-file system rather than first-to-invent-will be controversial, Congress might give any such proposal serious consideration, since a harmonized (and eventually unified) system could take much of the time and expense out of obtaining international patent protection.

Strategic *Technology Policy*

With few exceptions, the U.S. Government has been reluctant to adopt proactive policies to build competitiveness. For generations, most American academics and policymakers have been convinced that market mechanisms were better than government planners at identifying promising technologies. There are examples of failures of central planning that reinforce these beliefs, and for several decades, the economic performance of the American economy also justified that faith.

There are reasons to challenge this ideology now. First is the simple fact that many American industries are having great trouble in world competition, and some of the ablest international competitors assuredly do not have freer markets or lighter government involvement in supporting industrial technologies than the United States does. The governments of many European nations, Japan, Korea, and Taiwan, have all actively promoted manufacturing technology acquisition, development, and diffusion; and while they have had their failures, they have had many outstanding successes. This is not proof, of course. Many other nations with less than admirable economic performance have also supported technology development and diffusion.

America's own history provides examples of successful commercial industries building on abundant government support of technology. Some of this has been an indirect effect; the Department of Defense's support of the early development of semiconductors and computers paved the way for substantial investments in commercial technologies by the private sector. But the United States has sometimes been willing to make exceptions to the tenet that direct government support should be limit mostly to basic research and national security. The development of a U.S. civilian aircraft industry can be linked directly to government-supported research on airframe and propulsion technologies in the early part of the century. This support was justified on patriotic grounds, and was not drawn so narrowly as to include only military security needs. Government support of agricultural technology through the land grant universities and the Cooperative Extension Service has been a key to the rapid productivity growth of American agriculture in the 20th century. Government support of the space program from the 1950s onward rested as much on national pride as on defense needs, and has had some important commercial payoffs.

Still, the argument most often put forward for Federal support of technology development remains rooted in national security. The Department of Defense depends on the civilian microelectronics and other high technology industries of its procurement needs. This was a key factor in the consideration of whether and how much to support Sematech, high-temperature superconductivity, and lately, high-definition television. But the idea that only the direct, immediate needs of the military justify government support of technology development is wearing thin. The time is ripe for reopening the question of how the Federal government could support development of civilian industrial technology proactively—i.e., before the industry is so weakened that national security is threatened.

Many people still reject this strategy. They argue that selective government support of key technologies or industrial sectors amounts to "picking winners" and that government bureaucrats are ill-equipped to make these choices. This argument rests mostly on politics. The American political system is too subject to manipulation by special interests, it is argued, to make rational choices among all the potential industries and technologies that might merit government support. This is a forceful argument, one to be taken seriously. Another pillar of the argument is the simple claim that the market, with its imperfections, is better than government interference.

The other side has a powerful justification as well. That is, that some technologies are so risky or involve such large investments over the long term that little or no development will be undertaken unless society, which stands to benefit, shares the risk of development. In the U.S. financial environment, with its burdensome penalties on long-term investment, the argument takes on special force.

The debate over "picking winners" has resolved little. Those who argue that government cannot make consistently rational choices can point to failures, such as the money poured into the Synfuels Corporation in the early 1980s to make wood-based, coal-based, and shale-based substitutes for petroleum. Japanese policies have not been invariably successful either. Examples of projects that did not achieve their initial objectives include efforts to jump-start biotechnology development, the fifth-generation computer project, and entry in the civilian air transport industry.

There have been some notable successes as well. U.S. Government support for aircraft technology development, through both civilian and military agencies, and agriculture are examples. These industries, which have had much greater government support than most, are advanced technologically and successful internationally. Both can boast large trade surpluses. Successes in Japan encompass the major industries on which that nation's astounding postwar economic achievements rest—first, steel, chemicals, and shipbuilding; then automobiles; and now microelectronics, computers, and telecommunications.

More to the point, the argument cannot (and should not) be resolved by counting up successes and failures. Any sustained effort to support new technology development will include some failures, and some industries might succeed more in spite of government support than because of it. The fact is, the U.S. Government is increasingly being asked to support technology development, and it is becoming ever more obvious that the reason is to build civilian industrial competitiveness. It is possible to take the best from the "picking winners' debate by focusing on how to design institutions that are open to counsel from and collaboration with industry and other interests, but avoid becoming their captives. Another lesson is that a crisis is a poor crucible for making such decisions. The failure of the Synfuels project can be traced largely to the atmosphere of crisis in which it was born.

A Civilian Technology Agency

Efforts to support industrial technology will require commitment and money. Both have their limits. Public initiatives to help private manufacturing improve its performance cannot afford to plunge into repairing and developing every industry and technology. Yet the Federal Government has no institutional ability to discriminate between technologies and industries that are most promising for the Nation's economic future, and those that have some appeal but are less important. While the U.S. Government has acted to support certain key technologies, the responses to declining competitiveness have been ad hoc, and are usually justified by the seriousness of potential losses in military security. If Congress wishes to consider ways of responding to pleas for support of technology toward the goal of economic security, one option is to create a civilian technology agency.

One approach is to build on existing institutions. NIST's Advanced Technology Program, created in the 1988 trade act and funded for the first time in fiscal year 1990, at $10 million has the potential to develop into a CTA. A bill that passed the Senate in 1989 authorized $100 million for the program to support industry-led joint R&D in economically critical technologies. Five such technologies were spelled out in the Act.

Other bills in both the 100th and the 101st Congress proposed the creation of a Civilian Technology Agency (CTA) within a new Department of Industry and Technology taking the place of the Department of Commerce. The agency would make grants or cooperative agreements with private performers of R&D on high-risk projects that could have exceptional value to the civilian economy. The closest analogy among existing agencies to a CTA is the Defense Advanced Research Projects Agency, or DARPA, which supports development in technologies and industries considered critical to the nation's defense. This small agency (staff of 150, funding of nearly $2 billion per year) has gained a reputation for placing intelligent bets in serving U.S. military technology needs. It makes long-term commitments that have added up to decades for some of its projects. DARPA has at times interpreted its mission broadly, supporting technology development that will benefit the commercial sector because the military depends on that sector. A CTA could learn a good deal from DARPA's experience on how to evaluate the potential benefits and risks of investments in new technology, and how to balance the pressures of industrial and parochial interests in making such decisions. The CTA might be subject to greater special-interest pressures, but the difference is likely to be one of degree rather than kind.

In some ways, a CTA would be quite different from DARPA. Most important, a CTA would interact closely with industry in choosing what technologies to support and designing the R&D projects. Until recently, DARPA did not fund projects jointly with industry; a CTA would probably finance most of its projects with contributions from industry that are at least equal to if not greater than the government share. This joint funding is essential as assurance that industry is genuinely committed that and the projects are really promising commercially, in the opinion of industry. Thus, the problem of government's "picking winners" would be greatly diminished.

Where in the Federal bureaucracy the CTA is placed may not matter very much. There are some advantages to its being an independent agency like the National Science Foundation. With the right mandate, independent agencies, even small ones, can wield influence beyond what their size would indicate. (NSF is funded at less than $2 billion per year.) However, DARPA demonstrates that a small agency within an enormous bureaucracy can be effective and powerful. With the right design, sufficient funds, top-notch staff, and a strong mandate from Congress, a CTA could probably function well either within the Department of Commerce (or a successor department) or independently.

Other issues are more important to a CTA's performance. Judging by the difference between DARPA's performance and the record of other DoD technology development and acquisition, it is clear that the agency should not be constrained by detailed rules and procedures. Giving the agency staff a large degree of freedom and responsibility could help to attract and keep technically first-rate people, which is increasingly difficult as salaries for scientists and engineers rise faster than government salaries.

One of CTA's first tasks would be to develop guidelines for the selection of industries or technologies to consider for support. Here, much can be learned from the debates over whether to support specific technologies or projects like HDTV, superconductivity, and Sematech. There is an obvious preference for industries that are high-tech, provide well-paid jobs, and have high growth potential. In addition, CTA would need to consider entire technological systems, not just particular technologies. For example, if it chose some semiconductor technologies, it would have to be sensitive to R&D needs throughout the system, starting with improved materials, and continuing through things like lithography for etching chips, automated techniques for packaging, and soon. CTA could also look for technologies important to more than one application or industry downstream.

One of the surest ways to doom the effort would be to subject a CTA to unrealistic expectations. If CTA is expected to make strategic choices of high-risk technologies, it would have to be given time for its investments to play out, and some leeway to make less than perfect choices. The ability to make multi-year funding could also be critical. As it is, American business regards government support as volatile and undependable. The fact that Silicon Valley companies took very seriously recent rumors that the Administration proposed to abandon funding for Sematech illustrates the point. If the agency is to succeed at pushing technology, it would need to provide steady support for several years to many different technologies. Even then, it should not be expected to turn American industrial competitiveness around singlehandedly. Coordinated support in other policy areas like trade and macroeconomic policy will be needed to do that.