and thus helped to build an engineering infrastructure of VLSI manufacturing in Japan.

Conclusion

The direction of technological diversification for each industry has been identified quantitatively from our database. However, there are two possible interpretations. If the distribution of R&D expenditures reflects the innovation-producing pattern intrinsic to each industry, then the direction of diversification identified can be interpreted as a sectoral pattern of innovation. If the distribution of R&D expenditures reflects the future metamorphosis of each industry, the directions identified can be interpreted as the sectoral pattern of industrial transformation.

It is not possible to describe anything about individual firm behaviors in technological diversification. The R&D statistical data, at the level of disaggregation used in this article, are not available on an individual company basis; they are confidential. Thus, quantitative analysis of technological diversification is feasible only for sectors. Several case studies of the diversification behaviors of individual companies are needed to elucidate the directions identified here from aggregate data.

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Japanese Research and Technology Policy

LEONARD LYNN

Until recently the Japanese did not spend much on research and what they did spend was concentrated on the commercial development of technology. As a result there have so far been few Japanese breakthroughs in either science or technology. Dramatic changes have recently occurred, however, and Japan now trails only the United States and the Soviet Union in research spending. Beyond this, Japanese policy-makers are making a determined effort to overcome Japan's social and institutional barriers to scientific creativity.

JAPANESE SCIENCE AND TECHNOLOGY HAS TAKEN ON A PARAdoxical image in the West. There is a growing fear of Japan as a technological juggernaut mowing down foreign rivals at will. And yet, many people (including many Japanese) continue to have doubts about the Japanese ability to create new technology.

One reason for this confused image is that although Japan is now a major technological power, spending more on research and development than any but the two superpowers, this is a recent phenomenon. Thus the relative scarcity of major technological breakthroughs that can be attributed to the Japanese. Two decades ago the Japanese research effort was far below that of the major Western countries. In 1965, for example, the Japanese spent less than 6% as much as the Americans on R&D, only about half as much as the British, and far less than either the French or the West Germans (*1*). By 1970 Japanese R&D spending had passed the British and French, and by 1980 it had passed the West German. In the United States, R&D spending remains substantially higher, but primarily only to the extent that the U.S. economy is larger. In 1982 the United States spent 2.61% of its gross national product (GNP) on research, compared to 2.44% for Japan. Much of the U.S. spending, however, whereas hardly any of the Japanese, was defense-related with little spillover value for the civilian economy. In 1982 the ratio of civilian R&D expenditures to gross national product was 2.43% for Japan compared to only 2.01% for the United States (*2*).

The results of Japan's increased investment in technology are reflected in several indicators. The number of Japanese patents granted to Japanese has tripled since the mid-1960's; for comparison, the number of U.S. patents granted to Americans has stagnated. Meanwhile the Japanese have assumed a commanding lead among foreigners patenting in the United States (*3*). Japanese technical managers responding to a survey in the early 1980's rated their companies as being ahead of the Europeans and only a little behind the Americans in the number of technologies in which they led. A survey published in 1985 found that more managers felt that the technological level of Japanese industry led that of U.S industry than vice versa, and virtually none felt that the United States would

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lead by the end of the decade (*4*). Japanese receipts for technology exports have also expanded dramatically. These receipts did not even reach $1 million before 1960. In 1983 they totaled some $569 million, ahead of those for both France and West Germany (*5*).

The growth in Japanese technological strength has been so rapid that some may be tempted to extrapolate from it to a point of Japanese world dominance in another decade or two—just as some who extrapolated from the double-digit annual Japanese economic growth in the 1960's sketched a startling (and, as it turned out, grossly exaggerated) picture of a Japanese economic superpower by the end of the century. But much of the rapid growth has been the result of a concerted effort that was directed not so much at leading as catching up. Levels of spending rose quickly because the Japanese economy was growing quickly and because past strategies of relying on foreign sources of technology were losing viability. It seems likely that the growth in resources committed to R&D (and the output from R&D) in Japan will slow to a respectable, but substantially less extraordinary, rate just as happened with Japanese economic growth during the 1970's and 1980's.

Nor should Japan's current strength in technology be overstated. Although Japan now spends about half as much as the United States on R&D, the $569 million that Japanese received from the sale of technology in 1983 was less than one-tenth as much as Americans received. Indeed, the Japanese still rely heavily on imported technology. Although private nonservice sector firms have enjoyed a favorable technology trade balance for new contracts in each year since the early 1970's, if continuing contracts are included these firms continue to pay more overall for technology than they receive (*6*). And if all payments for continuing and new contracts are totaled, including those for public organizations and firms in the service industry, the Japanese continue to have a large deficit. In 1983 they spent nearly three and a half times as much on foreign technology as they received for selling their own. This was some improvement over 1970, when they paid out seven and a half times as much as they received, but suggests that it will be some time before Japan is a net exporter of technology.

Statistics on technology trade (as well as those on the small number of Nobel and other international prizes awarded to Japanese) have caused many Japanese to have doubts about the creativity of their colleagues. In surveys Japanese technical managers express confidence in the level of technology their firms are using. They doubt, however, that Japanese equal Americans and Europeans in the ability to create new technology. Many managers point to the weakness of Japanese corporate basic research departments, the relatively small numbers of researchers, and the low level of spending on R&D. Because firms are moving quickly to build new R&D facilities, the number of researchers is rising quickly, and spending has been shooting up, it might be expected that these problems are well on their way to solution. About a sixth of those who questioned the Japanese ability to create new technology, however, mentioned the "inferior creative capacity of researchers" in Japan (*7*).

The Science and Technology Agency expressed a similar concern in a 1982 White Paper. The agency noted that Japanese accounted for only 5.3% of the natural science research papers listed in the 1976 edition of the *Science Citation Index*. This placed the Japanese well behind the Americans (who accounted for 41.9% of the papers) and was seen as indicative of a problem that policy should address (*8*). A little context, however, suggests that the 5.3% was hardly disgraceful. Most of the journals in the index are published in English and a large share are American journals. It seems obvious that this would strongly bias this indicator against the Japanese in comparison to Americans, and even to Europeans. Nonetheless, the Japanese share was larger than that of the French (5.1%) and only a little behind that of the West German (5.9%).

Japanese Science and Technology Policy

Although Japanese policy-makers are often credited with the remarkable progress made by Japan in science and technology during recent decades, the Japanese science and technology bureaucracy is neither extraordinarily large or unusually awash in funds. Indeed, government provides a smaller share of R&D funding in Japan than in the United States and other major industrial countries. In the early 1980's, for example, the Japanese government accounted for less than 25% of spending (down from 30% in the 1960's). This compared to roughly half of R&D spending accounted for by government in the United States, the United Kingdom, France, and West Germany. Total Japanese government spending for R&D in 1983 was just over $6 billion, compared to more than $40 billion in the United States. As in the United States, most of the research funded by government is performed by industry, universities, and private nonprofit institutions (*9*). In the United States an important instrument of technology policy has been the use of government purchases to ensure the existence of a good market for certain high-tech products that the government would like to see developed. The Japanese government has not had the funding to pursue this strategy to nearly the same extent as the United States and other technologically advanced countries (*10*).

Japanese science and technology policy, like that in most other advanced countries, has been formed and implemented by several different branches of the government in consultation with other interested groups. Japan has pursued goals similar to those sought by other countries: strengthening the national infrastructure by ensuring an adequate supply of technical personnel, promoting basic and large-scale research that the private sector is unable or unwilling to undertake, and creating a legal and economic environment that will encourage technological and scientific advance.

Japanese science and technology policy, however, appears to have been unusually consistent and unusually focused on technology with economic significance (*11*). Powerful groups from business, academia, and government are joined in the policy formulation process in stable advisory groups attached to the various branches of the bureaucracy. Interests that in the United States might introduce conflicting goals for science and technology, such as those representing the military, "pure" scientists, labor or environmental groups, tend to be either weak or excluded altogether. Since one political party has been in control of the government since the 1950's, there has been less intrusion of politics into science and technology issues than in the United States (*12*). Finally, until recently Japanese policy-makers have looked to the United States to get a sense of likely future developments in Japan. This sense that the near-term future was predictable raised the degree of consensus on appropriate policies. One result of this consensus and consistency has been that Japanese science and technology policy has had a greater economic impact than the amount of government spending would indicate.

Things are changing. Japanese policy-makers increasingly see Japan as having reached a stage of development where it is less able to base its policies on the experience of others. They see a growing need for Japan to base its future economic development on the creation of new technologies. Moreover, they wish to change the image of Japan to one of a nation making original contributions to science and technology. A major thrust of policy has been to overcome several of the factors seen as contributing to Japan's lack of creativity. One area of discussion is reform of the education system, which is widely felt to stifle creativity. Business firms have been rapidly building new facilities for basic research and otherwise stepping up research spending at an impressive rate (*13*). Policies have been implemented by various government agencies to improve the linkages between universities, government research laboratories, and business (*14*).

As Japan has reached the frontier on a wider range of technologies, there has been some strain on the consensus about science and technology policy within the bureaucracy. The Ministry of International Trade and Industry (MITI) has found itself hard pressed to maintain its role as mentor to Japan's leading industries. Many of the technologies underlying the industries that may lead the Japanese economy in coming decades would seem naturally to come under the domain of other ministries—for example, telecommunications under the Ministry of Posts and Telecommunications, biotechnology under the Ministry of Health and Welfare, and computer software under the Ministry of Education. As might be expected, there have been heated disputes between the ministries as they seek to guard and enlarge their domains. These turf battles are very likely part of a decline in the relatively high level of consensus and consistency that have so far characterized Japanese science and technology policy. Even so it seems likely that as long as the same political party continues to rule and as long as there is an absence of strong competing interests tied to defense and other issues, the level of consensus and consistency will remain higher in Japan than in the United States.

The Japanese Science and Technology Policy Bureaucracy

Much of the coherence of Japanese science and technology policy has been provided by the Council for Science and Technology (CST), an advisory council attached to the prime minister's office. The CST makes recommendations to the prime minister and formulates long-term policy goals. One such goal, for example, is to raise the level of R&D spending from the 2.44% of 1982 to 3.5% by the middle of the next decade.

In some respects the CST is an inner cabinet. Its chairman is the prime minister, and its members include the ministers from finance and education, and the director generals of the Science and Technology Agency and the Economic Planning Agency. The other members are the chairman of the Japan Science Council and five members of "outstanding ability" from the scientific community. These members of the "scientific community," it should be noted, also provide a linkage to big business. In 1983 two were chairmen of the boards of major firms and a third was head of an industry association.

Another organization, the Science Council of Japan (SCJ), has functions that somewhat overlap those of the CST. The SCJ, an organization of scientists, was established in 1949 to make recommendations to the government on such matters as the promotion of science and technology, the training of researchers and the utilization of research. The council proved to be intractable to the business and political interests that have largely dominated Japan since World War II and was partly supplanted in its role as adviser by the CST (*15*). The council frequently criticized government policies and itself came under heavy criticism from members of the ruling Liberal Democratic Party. Recently the council regulations were changed so that instead of being elected from the various scientific societies, members are appointed by the prime minister on the basis of recommendations from the scientific societies. The first members were appointed under the new system in July 1985.

Japanese science and technology policy is implemented by the Cabinet ministries (most notably the Ministry of Education and Ministry of International Trade and Industry) and by the Science and Technology Agency. In fiscal 1984 these three agencies together accounted for nearly 90% of Japanese government spending on R&D. Each of these agencies, like the prime minister's office, has its own system of advisory councils to receive inputs on policy from the business community and other interests.

The Ministry of Education, Science and Culture

Nearly half of Japanese government spending on R&D, some $3 billion in 1983, is under the jurisdiction of the Ministry of Education, Science and Culture (MESC) (*16*). This ministry helps ensure the supply of research and technical manpower through its education policies and sponsors research conducted at universities. It also provides grants for research both at universities and elsewhere and administers several research laboratories.

About two-thirds of MESC's budget goes to support research and teaching at the national universities. The ministry played a key role in facilitating a rapid increase in the number of Japanese engineers and technicians in the 1960's and 1970's. The process by which this happened is suggestive of how policies are often generated and implemented in Japan. In the late 1950's, Japanese business started pressuring the government to increase the number of scientists and engineers being trained in universities. This pressure became intense with the coordinated policies in 1960 to double the size of the Japanese GNP. The Science and Technology Council issued a 10-year plan to advance science and technology in which it contended that between 1960 and 1970 Japan would have manpower shortages of 170,000 in science and technology and 440,000 in engineering. MESC moved to increase the number of engineering departments at both national and private universities and also to increase the number of students in these departments. Some MESC officials had reservations about the rapid expansion because they thought the quality of education programs would decline, but MESC gave in. Funding was increased to the national universities and subsidies were given to private universities (*17*). The number of researchers in Japan nearly tripled between the mid-1960's and the early 1980's, and in the 1970's the number of new bachelor's degrees being awarded in engineering each year rose to approach the number in the United States. Despite this apparent success, however, MESC's control over the size of departments at national universities is now being faulted for limiting Japan's ability to adapt to the changing needs of university-based research and manpower training (*10*).

The MESC also provides direct support for research and for the dissemination of research findings through a program of grants-in-aid. In recent years these grants have totaled between $150 and $200 million. Other MESC funds go to national research laboratories under the jurisdiction of MESC (such as the National Research Institute of Genetics) and to support museums.

Like other Japanese government agencies, MESC has been concerned with improving cooperation between different research organizations. It established the National Inter-University Research Institutes (NIURI) program, for example, to centralize large-scale basic science research programs in a broad range of areas including high-energy physics, molecular science, and polar research (*18*).

Science and Technology Agency

Another quarter of the science and technology budget, some $1.7 billion in 1983, goes to the Science and Technology Agency (STA). The STA, which reports directly to the prime minister's office, was established in 1956 to coordinate the science and technology activities of the various ministries and to assume jurisdiction over research that had not yet been added to the domain of other ministries, that is, nuclear energy, aeronautics and aerospace, marine science, and natural resources.

The STA, which receives more than 40% of the government's special coordination funds for promoting science and technology each year, helps decide the R&D budgets for the ministries and works with the Science and Technology Council to plan and promote science and technology. It is widely thought, however, that the funds under its control are not sufficient to allow the agency much control over MESC and other powerful ministries (*15*, p. 157). Beyond this, many STA senior officials are transferees from other ministries. In 1984 there were more than 40 such officials from MITI, including the administrative vice minister, the science counsellor, the director general of the ministerial secretariat, and directors of three of the agency's six bureaus. Most of the other ministries also had two or three transferees among STA officials at the rank of section chief or higher.

STA operates six national laboratories and administers public corporations involved in the development and promotion of nuclear energy, ocean development, and space. The public corporations account for the lion's share of STA's budget. In 1983 three of these organizations, the Japan Atomic Energy Research Institute, the Power Reactor and Nuclear Fuel Development Corporation, and the National Space Development Agency of Japan, jointly received well over half of STA's budget (*19*). Two other STA public corporations serve a broader role. The Japan Information Center of Science and Technology (JICST) collects and disseminates foreign and domestic science and technical information in Japan. The Japan Research Development Corporation (JRDC) promotes the commercial use of government-developed technologies. Under a program designed to encourage the commercial use of government-owned technologies that seem unlikely to have practical applications in the near future, JRDC invites firms to propose development projects. If a firm has its proposal accepted, it can receive financial help from JRDC and exclusive rights for 2 or 3 years to any new products it develops. JRDC is also a part of the widespread Japanese government effort to bring the research efforts of diverse organizations together. Under its System for Exploratory Research for Advanced Technology, which was initiated in 1981, researchers from firms, universities, and government laboratories are brought together to do research on 5-year projects.

Ministry of International Trade and Industry

Only one-eighth of the science and technology budget, some $750 million in 1983, goes to the Ministry of International Trade and Industry, the ministry most closely identified with Japanese industrial policy. MITI's role in science and technology policy is larger than this might imply, however, since some of its activities, such as the granting of special tax breaks, obtaining exemptions from antitrust laws for firms engaged in collaborative research, coordinating corporate and government research, and (until a few years ago) regulating technology imports, are not reflected in large government expenditures.

Until the late 1960's much of the emphasis of Japanese research and technology policy was on finding and introducing the best foreign technologies. MITI vigorously sought to help firms identify important new foreign technologies, purchase them at the lowest possible prices, and get the resources needed to adopt them. When the basic oxygen furnace steelmaking technology was developed in Austria, for example, officials at MITI (who were metallurgical engineers) helped ensure that executives at steel companies knew about the technology, that the different Japanese firms would not bid up the price of the technology, that the technology would be shared between firms, and that there would be some cooperative development of the technology (*20*).

Today one of MITI's major roles in science and technology is to coordinate research done by government and industry. MITI's Agency for Industrial Science and Technology (AIST), for example, is responsible for several major research programs that have attracted considerable attention in the United States. It administers the National R&D Projects, a program intended to help corporate, government, and academic researchers to work together on new technologies that offer excellent long-term prospects, but which because of their cost and uncertainty are not likely to be undertaken by individual firms. Among the eight projects under way in 1984 two that attracted considerable attention in the West were the FMS (flexible manufacturing system complex with laser) and fifth-generation computer projects. Other major research programs administered by AIST include the Sunshine Project, for the development of new energy technologies; the Moonlight Project, for energy conservation; and the Research and Development Project on Basic Technologies for New Industries, which sponsors long-term research in a dozen new fields related to new materials, biotechnology, and new electronic devices. Under yet another program, MITI promotes the formation of research cartels and grants them special tax privileges and conditional loans—perhaps the most publicized of these were the VLSI (Very Large-Scale Integrated Circuit) projects of the late 1970's. The apparent success of these and other cooperative ventures helped motivate changes in 1984 in U.S. law to facilitate collaborative research (*21*).

This agency also administers 16 major national laboratories that account for nearly one-fourth of the budget for all government research institutions. These include the prestigious Electrotechnical and Mechanical Engineering laboratories.

Most of the remainder of the Japanese budget for R&D goes to various other ministries administering laboratories doing research in areas of special concern to them—for example, cancer and population problems by the Ministry of Health and Welfare; agriculture and foods by the Ministry of Agriculture, Forestry and Fisheries; meteorology, earthquakes, ship technology, and railways by the Ministry of Transportation; building and public works construction by the Ministry of Construction; and telecommunications and radio research by the Ministry of Posts and Telecommunications.

Creating New High-Technology Centers

In yet another approach to the problems of facilitating research coordination between industry, government, and universities, Japanese policy-makers have sought to create new high-technology centers reminiscent of Silicon Valley.

One example is Tsukuba Science City, site of the 1985 World Science Exposition. Beginning in the 1960's, planners moved a university and government laboratories to a cluster of small communities near Tokyo in the hope that industry would follow with its own research installations. The results have been mixed. Only a few private firms have moved to Tsukuba so far and the city has only about 140,000 of the 200,000 people expected to live there by now (including 109,000 farmers and others who had lived there before the creation of the "new" city) (*22*). Some of the researchers who moved to Tsukuba became disenchanted and moved back to Tokyo. But shopping and entertainment facilities have been improving in Tsukuba, and the city now boasts of 52 research institutes and two universities.

Another approach to the building of centers for high technology is the "technopolis" program. This program, initiated in the early 1980's, is intended to foster close contact between research and production. Under the program the government helps a would-be technopolis make itself more attractive to high-tech industries by upgrading local academic, cultural, research, and housing facilities. The government also offers tax breaks, special loans, subsidies and other incentives to firms that want to build facilities in the budding technopolis (*23*).

If all goes according to plan, the technopolises will house large-scale research projects linking the laboratories of various industries, joint research associations, and universities. Policy-makers hope that technopolises will become regional centers of research and production in such disparate fields as electronics, electromechanical engineering, new materials, design and fashion, computer software, and biotechnology.

There is some disagreement about the prospects for the technopolis program. The *Economist* reports that the program has become nothing more than a "buzzword." Vogel argues that the idea is still flourishing (*14*, *24*). Schemes for regional development in Japan have failed in the past because of the national government's inability to resist political pressures from regions seeking preferential treatment. A similar fate could await the technopolis program (*25*).

Technologies for Industries of the Future

How well are the Japanese doing in the technologies that underlie what seem to be the industries of the future? Much has been written about Japan's strength in electronics and computers. This is an area where the Japanese are finally being taken seriously. At the International Solid State Circuits Conference in New York in 1985, Japanese wrote 49 of the 109 papers presented (*26*).

Biotechnology seems to exemplify several of the strengths, weaknesses, and efforts to become "more creative" that characterize Japanese technology in the mid-1980's. A 1984 U.S. Office of Technology Assessment report concluded that Japan was likely to be the U.S.'s leading competitor in commercial biotechnology (*27*). This conclusion was based less on the current strength of Japanese research in this area than on two factors that appear to give Japanese industry tremendous potential in commercializing the new technology. First, Japanese firms have long brewed soy sauce and rice wine and produced other food products that relied on "traditional" biotechnology. Many of these firms are now multinational giants with state-of-the-art facilities. Their experience should give them immense advantages in exploiting the newly evolving biotechnology. Second, the Japanese government is showing fast growing interest in biotechnology. Tentative steps were taken to promote the technology in the 1970's; much more has been done since about 1980. Today several Japanese government agencies are involved: the Science and Technology Agency; the Ministry of International Trade and Industry; the Ministry of Agriculture, Forests and Fisheries; the Ministry of Education; the Ministry of Health and Welfare; and the Environmental Protection Agency.

More than 150 Japanese firms have reportedly moved into the new industry including giants from the food, chemical, oil, and brewing industries such as Suntory, Ajinomoto, Kirin Beer, Mitsubishi Chemical Industries, Maruzen Oil, Kikkoman, and Toray. While the Japanese were slower than the Americans to move into biotechnology, nearly half the firms responding to a 1981 survey felt that Japan could overcome the U.S. lead within 5 years. Several firms have built large new basic research laboratories to work on the technology.

It is still not clear, however, how Japan's biotechnology industry stacks up internationally. U.S. spending remains far higher. The Japanese may be having difficulty training enough biotechnology researchers, and institutional barriers have so far made it difficult for Japanese firms to receive as much assistance from Japanese universities as their American counterparts. Indeed, nearly two-thirds of the Japanese biotechnology firms have indicated that they plan to send researchers abroad for training. Some Japanese firms have even sponsored biotechnology research at U.S. universities. Additionally, Japan's bureaucracy has so far shown little of the single-minded effectiveness in promoting biotechnology that is often imputed to it in other industries. The regulation of research has been stricter than in the United States. Bureaucratic in-fighting between the half dozen major government agencies competing for influence over this emerging industry may also cause problems (*28*).

Japanese Science and Technology: Prospects

Japan, with the world's third largest economy for more than a decade, has had fewer Nobel laureates in science and technology than such small countries as Sweden, the Netherlands, Austria, Denmark, and Belgium. Lists of major breakthroughs in technology include few from Japan; indeed some of the technologies most closely associated with Japan (such as transistors) came from other countries. Even such traditional "Japanese" artifacts as *geta* sandals and the Japanese "snake-eye" umbrella originated outside Japan. And then there is the relative scarcity of Japanese researchers in international citation indices. For these reasons, the Japanese have a reputation for being uncreative. Westerners like to think that creativity requires the individualism that Western culture fosters rather than the group-oriented focus of Japanese society. This cultural explanation seems highly dubious. The Japanese have shown a high level of creativity in the arts. It is easy, moreover, to identify noncultural factors that have led to an apparent lack of creativity in Japanese science and technology. It seems likely that Japan is underrepresented in the number of its Nobel laureates (as, indeed, all non-Western countries are), solely because it has only recently joined the Western scientific community. Even today, Japan's distance from Europe and the United States, plus cultural and language barriers make it more difficult for the work of Japanese scholars to become well-known in the western scientific community.

Nor did Japanese industry have much to gain by investing heavily in basic research. The more rational course was to import basic technology and concentrate on adapting it. This strategy was strongly and effectively encouraged by the government. The universities were largely ignored except as a source of manpower. The ability of Japanese policy-makers to give focus to research efforts meant that rapid progress could be made in well-understood areas, but (some would argue) the lack of random exploration may also have made breakthroughs less likely.

Many of these factors have changed. Both government and industry are spending far more on research. Policy-makers are redesigning institutions to facilitate creativity, seeking ways to better support and use university research, and breaking down barriers between researchers in government, academia, and industry. Whether these efforts can succeed at turning a highly successful technology fast-follower into a highly successful technology creator is an open question.

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18. A description of these programs appears in Y. Abe *et al.*, in *Science Policy Perspectives: USA-Japan*, A. Gerstenfeld, Ed. (Academic Press, New York, 1982), pp. 125–174.
19. Science and Technology Agency, *Kagaku Gijutsu Nenpo 28* (Tokyo, 1984).
20. This case is described by L. Lynn, *How Japan Innovates: A Comparison with the U.S. in the Case of Oxygen Steelmaking* (Westview, Boulder, 1982).
21. See L. Lynn and T. McKeown, in preparation.
22. L. Simons, *Smithsonian* **16**, 158 (April 1985); J. L. Bloom and S. Asano, *Science* **212**, 1239 (1981).
23. *Jpn. Econ. J.* **23**, 4 (6 March 1984).
24. "Low-tech island," *The Economist*, **296**, 67 (27 July 1985); for a more optimistic view, see *New Sci.* **41**, 1448 (1985).
25. For a description of some of these disputes, see R. J. Samuels, *The Politics of Regional Policy in Japan* (Princeton Univ. Press, Princeton, NJ, 1983). In the *Economist* [**296**, 41 (1985)], it was reported that MITI had hoped to carefully screen applicants but was unable to resist political pressure from the 14 applicants and ended up accepting them all.
26. "Japan focuses on basic research to close the creativity gap," *Business Week* (25 February 1985), pp. 94–96.
27. Office of Technology Assessment, *Commercial Biotechnology: An International Analysis* (OTA-BA-218, Washington, DC, January 1984). Except where otherwise noted, the information in this section comes from this report.
28. See M. Sun, *Science* **230**, 790 (1985).
29. Supported by NSF grant 3SRS-8409836. This article benefitted from the comments of my co-principal investigator, H. Piehler, as well as those from R. Samuels, J. Bloom, and two anonymous referees. Some of the material in this paper also appeared in L. H. Lynn, "Japanese technology at a turning point," *Current History*, December 1985.

Japanese Competitiveness and Japanese Management

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Japanese-style management and industrial policy are shown to serve as a source of industrial dynamism and are used as a way to illuminate what is wrong with the American system. Japanese labor practices—specifically extra hours of unpaid work—are seen as a form of insurance fee that the worker pays in exchange for job security.

MY INTENT HERE IS TO ANALYZE AND COMPARE JAPANESE and American industrial policy and labor practices in light of a thesis that I first proposed in the early 1980's (*1*). Since the beginning of the 1970's, manufactured goods produced in the United States have been losing out in international competition. American competitive power has been consistently eroding in international markets. Of course, competitiveness in exporting manufactured goods may not be the only criterion of importance for a particular country. However, the recent performance of the United States in international markets has damaged its domestic economy, which in turn has affected developments in other democratic countries in the world. As the postwar leader among the free market–oriented economies, America has been under obligation to be better and to do more. Americans have not lost confidence, but they must be convinced in which direction they should strive. I describe certain aspects of the Japanese system in the hope that some can be adapted by American businesses (perhaps initially by Japanese companies operating in the United States), thereby reviving American international competitiveness.

John Zysman has noted that in the late 1970's America discovered Japan (*2*). During that decade it became clear to many people in Western countries that the Soviet or Chinese types of economy were not useful guides or models for capitalist economies. People in both

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