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ABSTRACT

Japan's postwar research and development (R&D) efforts have passed through several phases to bring the nation to what may be called "relative parity" with the United States. This document examines the characteristics of Japanese and U.S. R&D efforts. Topics compared include: national science resource patterns; science and engineering personnel; government R&D; higher education; and outputs and impacts. Selected highlights show that R&D expenditures in Japan increased nearly fivefold between 1965 and 1985, while U.S. expenditures rose 63%; less than one percent of Japan's R&D expenditures were devoted to defense in 1985 while the United States devoted 30%; Japan had 28% as many scientists in 1985 as the United States had in 1986, while Japan had 187 engineers per 10,000 labor force compared to 183 in the United States; nearly 31% of Japan's natural scientists and engineers engaged in R&D in 1985 were in higher education compared with 14% for The United States; while the Japanese higher education system annually graduates about the same number of engineers as the United States, it graduates only about one-tenth as many first-degree students in the natural sciences. Included are detailed statistical tables, a listing of Japanese government research programs, and awards of the distinguished research program of the Ministry of Education. (MVL)

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foreword

The Division of Science Resources Studies of the National Science Foundation has initiated efforts to obtain more recent and detailed quantitative information on foreign science and technology (S/T) capabilities and activities—principally in the large research and development (R&D)-performing industrialized nations. This report presents a statistical profile of Japan's S/T efforts since 1965 and compares it with that of the United States. R&D trends in Japan at the national level as well as for individual sectors are presented, and data on S/T outputs are discussed.

William L. Stewart
Director, Division of
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June 1988

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acknowledgments

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Efforts are constantly underway to collect the most recent data. Such new data or additional detail may be obtained from the author:

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introduction

Japan's postwar research and development (R&D) efforts have passed through several phases to bring the nation to what may be called "relative parity" with the United States. Almost all key aggregate indicators show that Japan now expends money and supports R&D personnel in the same proportions as does the United States when the size of the national economies and populations are taken into account. In some instances, such as the ratio of company-funded R&D to gross national product (GNP) and nondefense R&D to GNP, Japan's performance has exceeded that of the United States for a number of years.

Given the Japanese postwar economic record, this achievement is not surprising. What is remarkable, however, is that the rate of growth in Japanese R&D expenditures exceeded the high average annual increase in GNP by more than 3 percentage points during the years 1965 to 1986. Such a financial commitment, coupled with Japan's strong emphasis on education, has enabled the country to expand its science and technology (S/T) resources from a fraction of the United States to one of relative parity.

The Japanese R&D system is characterized by some major differences from that in the United States. In Japan, private industry plays a more dominant funding role: industry is by far the largest source of national R&D funds, accounting for 69 percent of R&D funding and 67 percent of R&D performance in 1985. In contrast, U.S. industry provided 49 percent of R&D funds and accounted for 73 percent of R&D performance. These figures suggest an additional distinction in corporate R&D between the two countries; in Japan, industrial R&D is 97-98 percent company-funded compared to 66 percent in the United States (to some extent, this reflects the higher levels of U.S. Government funding of defense-related R&D in industry).

The Japanese Government plays a relatively smaller role in the direct funding of R&D in Japan than does the Federal Government in the United States. In Japan, the government was the source of 21 percent of R&D funds in 1985, whereas the U.S. Federal Government was the source of 48 percent of R&D funds in the United States. This significant difference is largely attributable to two factors. First, defense expenditures typically have been low in Japan and in fact were restricted from 1976 to 1986; consequently, less than 1 percent of Japanese R&D expenditures was devoted to defense purposes, compared to 30 percent in the United States.[1] Second, the Japanese Government traditionally has not provided R&D funding to industry, a policy which, combined with Japanese fiscal restraint, has resulted in a fairly limited transfer of R&D funds between these two sectors.

[1] Under the Japanese constitution—which was designed by American officials controlling Occupied Japan—Japan renounced the threat or use of force. Consequently, Japanese military forces are essentially limited to defensive capabilities. Two subsequent U.S.-Japanese security treaties (in 1951 and 1960) outlined the nature of the military/defense relationship between the two countries. Throughout the postwar era, Japan has made policy decisions limiting the scope of its domestic defense forces and defense industry, culminating in the 1976 policies of restricting defense expenditures to 1 percent of GNP and prohibiting most arms sales abroad. Although the "1-percent rule" was revoked in 1986, there are no immediate plans to increase defense expenditures significantly above 1 percent of GNP. Japanese defense expenditures consistently have been equivalent to about 1 percent of GNP since 1965.

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For virtually all other major S/T indicators, Japan and the United States now demonstrate similar characteristics. For example, both countries have virtually the same ratio of R&D to GNP (2.7-2.8 percent); both distribute their R&D funds in similar proportions across basic and applied research and development; both have approximately the same number of R&D scientists and engineers per 10,000 labor force; and so on. In the years since World War II, Japan has turned itself into the world's second largest market economy, and its S/T indicators reflect the level of effort of a mature industrial economy.

Unlike the major S/T input indicators, Japan and the United States have less similar experiences with their output and impact indicator performance. Japan's share of the world's scientific literature increased slightly (from 5 percent to 7 percent) during 1973-82, while the U.S. share remained fairly constant at 37-39 percent. Over the 1970-86 period, Japan's share of patents granted annually in the U.S. patent system increased from 4 percent to 19 percent; the U.S share declined from 73 percent to 54 percent during this period. The trade performance of the two nations in technology-intensive products was similarly inverse: the United States' share of world exports of technology-intensive goods declined slightly from 28 percent in 1965 to 24 percent in 1985; Japan's share almost tripled from 7 percent to 19 percent.

Japan's accomplishments have been the result of several phases of national effort. The first phase of Japan's S/T efforts, which occurred from the immediate postwar period through the early sixties, did not involve indigenous R&D investment so much as a reorientation of Japanese industry. Throughout the period, there was large-scale financial investment aimed at transforming Japan's economy from light manufactures to heavy industry. The acquisition of foreign technology was an integral part of this strategy, and technology was purchased which would allow Japan to both manufacture new products and introduce new techniques for the production of existing goods. Once the new industrial base was established, Japan embarked on its own research and technology development.

This report is concerned with Japanese S/T efforts following the "pre-R&D" era, and provides a quantitative comparison of U.S. and Japanese S/T activity principally for the period 1965-85. (Comprehensive data are available on Japan only through 1985; where 1986 data are available, they are so reported.) The patterns over the 20-year period reveal two distinct phases of R&D for both countries. In 1965, the United States' R&D effort was beginning to peak in terms of total constant R&D expenditures and concentration of R&D personnel in the labor force; this level of performance bottomed out in the mid- to late seventies and was not regained until the early 1980's. In contrast, Japanese R&D grew throughout the period, increasing substantially from 1965 to the mid-seventies, slowing slightly at that time, and then reestablishing its momentum, as did the United States' R&D.

Much quantitative information is available on Japan's scientific research and experimental development. While most data for the United States and Japan are directly comparable, there are some definitional differences in particular statistical series; in such cases, emphasis is placed on each country's trends rather than on absolute values. Appendix A, "Technical Notes," details such differences and any adjustments that were made to the Japanese or U.S. data to make them more comparable.

Another comparative problem arises when Japanese expenditures are converted into U.S. dollars. Yen-dollar market exchange rates have become rather volatile, reflecting dynamics that are increasingly independent of the relative purchasing power of the currencies. To avoid the distortions that arise from market exchange rate conversions, purchasing power parities calculated by the Organisation for Economic Co-operation and Development are used to convert yen to dollars. Additionally, GNP implicit price deflators are used to convert current dollars into constant 1982 dollars in order to provide time series data that reflect real, rather than nominal, trends in expenditures. A brief discussion of purchasing power parities is included in appendix A.

This report profiles patterns in the major R&D performing sectors and analyzes S/T output and impact indicators in order to provide a comprehensive comparison of Japanese S/T resources with those of the United States.

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highlights

national science resource patterns

- The pace of Japanese R&D expenditures exceeded that of the growth of the Japanese economy over the period 1965-85. The average annual rate of increase in R&D was 9.3 percent compared to 6.0 percent for the GNP. In the United States, R&D efforts expanded at a slightly slower rate than GNP: about 2.5 percent and 2.8 percent, respectively. R&D expenditures in Japan increased nearly fivefold between 1965 and 1985, from constant (1982) $6.1 billion to $36.0 billion dollars. During the same period, U.S. investments in R&D rose 63 percent, increasing from constant $59.4 billion to $96.5 billion. (See pp. 1–2.)
- Although U.S. investments in R&D are nearly three times as high as those of Japan in absolute terms, Japan's investment is now comparable based on the size of its economy. The Japanese R&D/GNP ratio rose consistently during the past 2 decades, reaching a level of 2.8 percent in 1985 and 1986. The U.S. ratio, which was 2.8 percent in 1965, steadily declined to a low of 2.1 percent in 1978 before rising to its 1985-86 level of 2.7 percent. (See pp. 1–2.)
- Slightly less than 1 percent of total Japanese R&D expenditures was devoted to defense purposes in 1985, a significant contrast to the 30-percent figure for the United States. Consequently, Japan has a higher ratio of nondefense R&D expenditures to GNP than does the United States. In 1985, the ratios were 2.8 percent and 1.9 percent, respectively, and Japan has maintained a lead in this indicator since at least 1971. In absolute terms, Japan's nondefense R&D expenditures were one-half of U.S. nondefense R&D expenditures in 1985. Of Japanese Government R&D expenditures, 4 percent were devoted to defense-related R&D, compared to 68 percent in the United States. (See pp. 2 and 14.)
- In Japan, industry is the major source (69 percent) of R&D funds; in the United States, R&D is financed almost equally by the Federal Government and industry (48-49 percent each). Both countries exhibit similar patterns of R&D by performer: in 1985, industry expended the majority of R&D funds (67 percent for Japanese industry and 73 percent for U.S.), higher education accounted for the second largest share of R&D expenditures (20 percent and 12 percent, respectively), and government accounted for nearly all of the remainder (9 percent and 12 percent, respectively). (See pp. 2–4.)

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- The share of Japanese R&D devoted to basic research has declined over the past 10 years. In 1975 and 1980, basic research accounted for 15 percent of Japanese R&D expenditures; however, by 1985 this share had declined slightly to 13 percent. In the United States, basic research as a share of total R&D remained constant during 1975-85 at 12-13 percent. (Note that the data for Japanese and U.S. basic research are somewhat less comparable than those for total R&D expenditures.) (See p. 4.)
- By 1985, the distribution of total R&D funds within the two countries by character of work was very similar. In 1985, Japan devoted 25 percent of its R&D to applied research and 62 percent to development; these shares for the United States were 22 percent and 66 percent, respectively. (See p. 4.)
- Japan traditionally has imported foreign technology to supplement its own R&D efforts. Japan's expenditures on royalties, licensing fees, and other expenses related to imported technology in 1970 were 57 percent of what the United States spent in the same year for technical know-how. Although Japan has continued to purchase a substantial volume of technical know-how (payments for royalties and fees increased 71 percent between 1970 and 1985), R&D has outpaced such expenditures. Consequently, the ratio of Japanese payments for technical know-how to R&D decreased from 11 percent in 1970 to 7 percent in 1985. Japan's exports of technical know-how increased threefold during 1970-85, improving the percentage of receipts to payments from 14 percent in 1970 to 30 percent in 1985. (See pp. 7-8.)

science and engineering (s/e) personnel

- With about one-half of the U.S. population and labor force, Japan had slightly more than 1.5 million employed nonacademic scientists and engineers in 1985, compared with almost 3.6 million in the United States in 1986. Japan has fewer nonacademic scientists and engineers relative to its labor force than does the United States. This condition is attributable to the lower absolute and relative levels of scientists in Japan than in the United States—Japan had 28 percent as many scientists in 1985 as the United States had in 1986. However, Japan had 187 engineers per 10,000 labor force compared to 183 in the United States. (See pp. 5–6.)
- Both countries experienced significant increases from 1980 to 1985/86 in the stock of nonacademic scientists and engineers relative to increases in the labor force. The Japanese stock of scientists and engineers grew 61 percent, with the number of scientists doubling (mostly due to increases in computer specialists) and a 50-percent increase in the number of engineers (principally increases in electrical/electronic engineers). The U.S. experience was similar: increases of nearly 50 percent or more were registered in most categories of scientists and engineers, with computer specialists increasing 119 percent and electrical/electronic engineers increasing 50 percent. During this 5-year period, the size of the labor force in both countries increased 5-10 percent. (See p. 6.)
- The total number of Japanese R&D scientists and engineers engaged in R&D has tripled since 1965; in 1986, it was 405,600—one-half the U.S. 802,300 full-time equivalent. The ratio of Japanese R&D scientists and engineers per 10,000 labor force was about one-third the U.S. ratio in 1965, but by 1986 the two ratios were comparable at 67-69 scientists and engineers per 10,000 labor force. (See p. 6.)

government r&d

- The Japanese Government's share of total national R&D funding reached its peak (33 percent) in 1972; since then, it has declined fairly steadily to its 1985 level of 21 percent. The U.S. Government's share of national R&D funding is much higher, although it also declined between 1970 and 1985, dropping from 57 percent to 48 percent. (See p. 9.)
- Despite its declining relative contribution to total national R&D resources, the value of Japanese Government expenditures steadily increased during the last 2 decades, reaching constant $7.6 billion in 1985, compared to U.S. Federal funding of constant $46.0 billion. (See p. 9.)
- The Japanese Government's S/T budget has received high priority in the last 5 years in spite of an environment of fiscal restraint, and has expanded faster than overall government funding. From 1980 to 1985, Japanese Government R&D funding increased at an average annual rate of 3 percent compared with a higher 6-percent average annual rate in the United States; however, 90 percent of this growth in U.S. federally funded R&D is accounted for by defense-related R&D expenditures. (See p. 9.)
- S/T policy in Japan is largely the result of four institutions: the Prime Minister's Council for Science and Technology; the Science and Technology Agency (STA); the Ministry of Education, Science, and Culture (Monbusho); and the Ministry of International Trade and Industry (MITI). Monbusho and STA have the largest budgets, accounting for 47 percent and 27 percent, respectively, of the Government's total R&D budget.

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MITI is the third largest funder (13 percent). (See pp. 9–13.)

- Besides its funding and policymaking roles, the Japanese Government also performs R&D through more than 80 national institutes and public corporations which conduct ongoing research. There are a number of large-scale, special R&D programs that have been initiated by STA and MITI; these focus primarily on basic research and development of new technologies. (See p. 15.)

industrial r&d

- Industrial R&D has always been the most prominent sector in the Japanese system, accounting for 69 percent of all R&D funds in 1985 (compared with 49 percent in the United States). Less than 2 percent of direct industrial R&D funds comes from the Japanese Government, compared to 35 percent in the United States. (See p. 17.)
- Japanese industrial R&D expenditures increased at an average annual rate of 11 percent from 1965 to 1985; U.S. total industrial R&D increased at a rate of 3 percent and company-funded R&D at a rate of 5 percent for the same period. Consequently, Japanese industrial R&D expenditures increased from less than one-tenth of the U.S. level in 1965 to one-third of the total U.S. level and one-half of the company-funded level in 1985. Japanese industrial R&D expenditures were constant $24.4 billion in 1986; total U.S. expenditures were constant $73.3 billion with company-funded R&D expenditures of constant $47.9 billion. (See p. 18.)
- As a percentage of GNP, Japanese industrial R&D more than doubled from 1965 to 1986. In 1986, this ratio was comparable to that of the United States: 1.9 percent and 2.0 percent, respectively. Since Japanese industrial R&D is almost entirely (98 percent) financed by companies themselves, Japanese company-funded R&D as a percentage of GNP has surpassed the U.S. ratio every year since 1970. In 1985 and 1986, the ratio of company-funded R&D to GNP was 1.9 percent for Japan and 1.3 percent for the United States. (See p. 18.)
- Electrical machinery, chemicals, general machinery, and the motor vehicles industries are the four largest performers of manufacturing R&D in Japan. These industrial sectors together accounted for 68 percent of manufacturing R&D in 1965 and 73 percent in 1985. The United States has a slightly different set of the largest company-funded R&D performers of manufacturing R&D (electrical machinery, chemicals, motor vehicles, and professional and scientific instruments); they accounted for 70 percent of manufacturing R&D in 1985. (See p. 19.)
- The ratio of R&D to net sales for all Japanese manufacturing industries in 1985 was 2.7 percent, compared to 2.8 percent for company-funded R&D in the United States. The ratios for the two countries were similar for many manufacturing industries. Drugs and medicines, communications and electronic equipment, and professional and scientific instruments were the most R&D-intensive industries in both countries. (See p. 20.)
- R&D is slightly less concentrated in Japan than in the United States. In 1985, the top five Japanese R&D firms accounted for 18 percent of total manufacturing R&D, compared to 23 percent for the top five U.S. firms. For most manufacturing industries, the levels of industrial R&D concentration are lower in Japan than in the United States; an appreciably higher level of Japanese industrial R&D dominance is found only in the iron and steel industry. (See p. 20.)
- During the past 2 decades, the number of Japanese industrial R&D scientists and engineers has increased at an average annual rate of 7.1 percent; in the United States, this increase was 2.5 percent. By 1985 Japan employed 231,000 scientists and engineers engaged in industrial R&D, two-fifths as many as the U.S. 570,000 full-time equivalent. (See p. 21.)
- Although Japan has a lower absolute number of industrial scientists and engineers, its ratio of manufacturing R&D scientists and engineers per 10,000 employees is higher than that of the U.S. (which uses full-time equivalent scientists and engineers). The Japanese ratio in 1985 was 470, compared to 400 for the United States. (See p. 21.)

higher education

- In contrast to the U.S. system of relying principally on separately budgeted R&D project awards, Japan depends principally on a system of institutional funding in which universities and colleges receive general university funds (GUF) from the national Government for teaching, research, and facilities and equipment. Three-quarters of all Japanese higher education R&D funds are received through such general funds, whereas an estimated three-quarters of U.S. higher education R&D funds are obtained from specifically budgeted project items. (See p. 24.)
- Nearly 31 percent of Japan's natural scientists and engineers engaged in R&D in 1985 were in higher education (60 percent of these were in health-related fields), compared with 14 percent of such personnel in the United States. As a share of total R&D, higher education R&D expenditures account for 20 percent in Japan and 12 percent in the United States. Both in Japan and the United States, however, the higher ed-

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ucation sectors conduct comparable shares of national basic research efforts (55-56 percent). (See p. 24.)

- R&D expenditures in the Japanese higher education sector more than tripled in constant terms from 1965 to 1985. These expenditures increased at an average annual rate of 6.1 percent, compared with 3.2 percent in the United States. In 1986, R&D expenditures in Japanese higher education totaled constant $7.3 billion, compared with constant $12.7 billion in the United States. (See p. 24.)
- For separately budgeted higher education R&D funds, the funds distribution among fields is significantly different in Japan than in the United States. The highest concentration of Japanese separately budgeted funds is in the physical sciences (36 percent compared to 12 percent in the United States); in the United States, the concentration is in the life sciences (54 percent compared to 26 percent in Japan). Japan spends about 20 percent of its separately budgeted R&D in engineering, compared to 14 percent in the United States. (See pp. 26–27.)
- The Japanese ratio of all first university degrees as a proportion of the 22-year-old population was 22.6 percent in 1985. This proportion was 25.3 percent in the United States. Although the United States confers a much higher total number of doctorates than does Japan, the overall ratio is similar in both countries (0.5-0.7 percent) when the number of doctoral degrees is measured as a proportion of the 27-year-old age group. (See p. 27.)
- While the Japanese higher education system annually graduates about the same number of engineers as the United States, it graduates only about one-tenth as many first-degree students in the natural sciences. The distribution of Japanese first university degrees among fields is dissimilar from that in the United States: there is relatively less emphasis on the natural sciences (3 percent and 11 percent, respectively) and relatively more on engineering (19 percent and 7 percent, respectively). (See pp. 27–28.)

outputs and impacts

- According to the *Science Citation Index*, Japanese researchers increased their share of the world's S/T articles from 5.1 percent in 1973 to 7.6 percent in 1984. Japan's shares of publications are largest in the fields of chemistry, engineering, and physics; they are lowest in the earth and space sciences. (See p. 32.)
- The Japanese share of S/T articles during the 1973-82 period was greatest in the pharmacy subfield, with Japanese publications accounting for 25 percent of the articles written in that subfield. The next largest shares were in polymers (18 percent) and marine biology and hydrobiology (14 percent). (See p. 32.)
- Japan accounts for the largest share of foreign-origin patents in the U.S. patent system. From 1970 to 1986, the share of U.S. patents annually granted to the Japanese increased from 4 percent to 19 percent. As a share of Standard Industrial Classification (SIC) product fields, Japanese patent shares are highest in the office computing machinery, aircraft and parts, and communications equipment and electronic components product groups. (See p. 33.)
- Given their total representation in the U.S. patent system, Japanese patents account for 45 percent more of the top 1 percent most highly cited U.S. patents than expected. The highest citation rates for Japanese patents are in the automotive, semiconductor electronics, photocopying and photography, and pharmaceuticals patent classes. (See p. 34.)
- Japan has made rapid progress in manufacturing productivity during the past decade; its manufacturing output per worker-hour increased 68 percent from 1977 to 1986, compared with a 26-percent increase in the United States for the same period. (See p. 34.)
- Japan's technological balance of payments worsened in dollar terms from a deficit of constant $1.2 billion in 1970 to constant $1.7 billion in 1985; however, receipts increased threefold from constant $194 million to constant $721 million. In 1985, 42 percent of Japanese sales and 99 percent of technical know-how purchases were with the United States and Europe; East Asian nations accounted for about 40 percent of Japanese technical know-how sales. (See p. 35.)
- For several manufacturing industries (textiles, chemicals, iron and steel, and motor vehicles), Japan's technical know-how receipt to payment ratio exceeded 100 percent in 1985. For the iron and steel industry, receipts for Japanese technical know-how exceed Japanese payments by almost 6 to 1. In no industry other than ceramics did Japanese purchases of technical know-how exceed 8 percent of the respective industry's R&D expenditures; in most industries, it was 5 percent or less. (See p. 36.)
- Japanese technology-intensive trade with the United States has markedly improved over the 1965-85 period. The Japanese trade surplus with the United States in technology-intensive goods increased from current $143 million in 1965 to current $13 billion in 1985. Large trade surpluses existed in 1985 in radio and television receiving equipment, communications equipment, office and computing machines, and professional and scientific instruments; however, Japan had a negative trade balance in aircraft and parts, industrial inorganic chemicals, agricultural chemicals, and drugs. Japan similarly has increased its world share of technology-intensive trade from 7 percent in

1965 to 19 percent in 1985; during the same period, the U.S. share declined from 28 percent to 24 percent. (See pp. 36–38.)

- The U.S. deficit with Japan in high-technology (a slightly different definition than technology-intensive) trade grew fivefold from 1980 to 1986, increasing from current \$3.8 billion to current \$21.9 billion. Telecommunications equipment and electronic components accounted for about 75 percent of the high-technology trade deficit. (See p. 37.)

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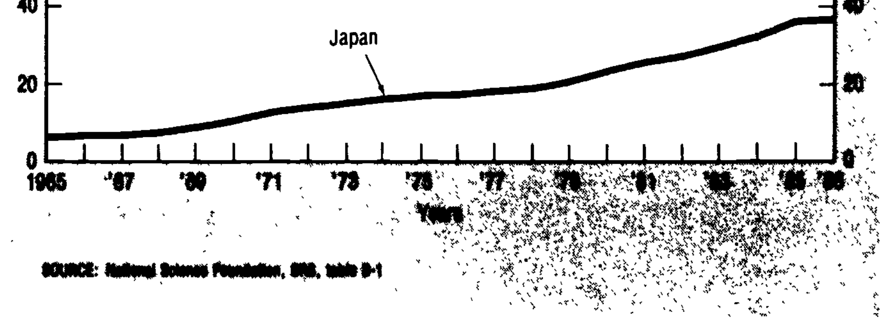
chapter 1.

national r&d patterns

total r&d expenditures

Over the past 2 decades, Japan has substantially increased its investments in R&D. Starting at a relatively small base, R&D expenditures in Japan increased nearly fivefold between 1965 and 1985, growing from constant (1982) $6.1 billion to $36.0 billion—an average annual rate of increase of 9.3 percent (chart 1). During the same period, U.S. investments in R&D rose 63 percent, from constant $59.4 billion to $96.5 billion, increasing at an average annual rate of 2.5 percent. In constant terms, U.S. R&D expenditures experienced virtually no net growth between 1965 and 1975, while Japanese expenditures during the period more than doubled. U.S expenditures increased from 1965 to 1968, but declined during most of the 1968-75 period. By 1975, U.S. R&D spending was just barely above its 1965 total. Although U.S. expenditures increased by 61 percent from 1975 to 1985, this gain represents only slightly more than one-half of the Japanese increase of 116 percent for the period. During 1980-86, U.S. R&D expenditures increased 37 percent; Japanese R&D expenditures increased 58 percent.

Although U.S. investments in R&D are nearly three times as high as those of Japan in absolute terms, Japan's investment is now comparable based on the size of its economy. The Japanese R&D to GNP ratio rose consistently during the past 2 decades,



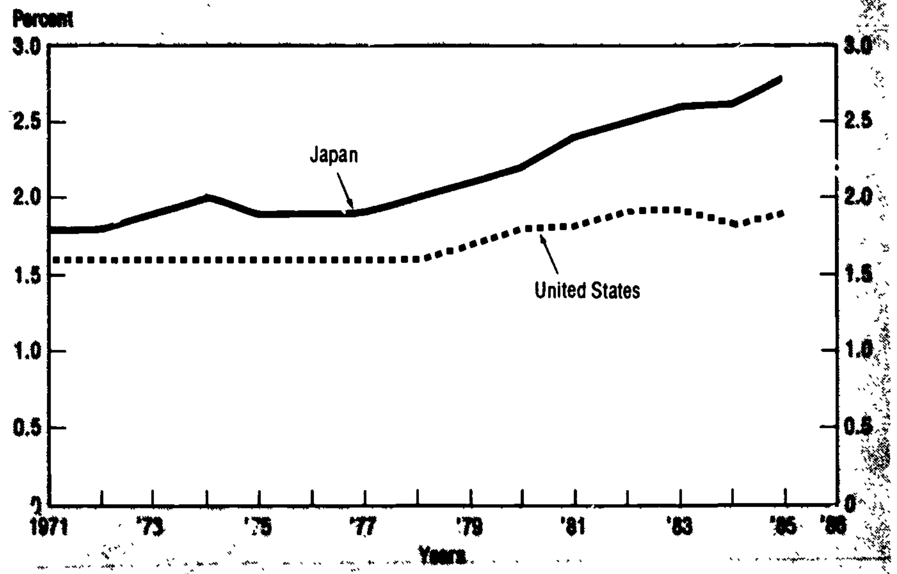
reaching a level of 2.8 percent in 1985 and 1986 (chart 2).[2] In contrast, the U.S. ratio, which was 2.8 percent in 1965, steadily declined to a low of 2.1 percent in 1978; by 1985, it had again risen to 2.7 percent.

Between 1965 and 1985, the increase in Japanese R&D expenditures outpaced the growth of the Japanese economy: Japan's average annual rate of increase in R&D was 9.3 percent; its GNP growth was 6.0 percent. In the United States, R&D efforts expanded at a slightly slower rate than did GNP—2.5 percent and 2.8 percent, respectively.

Less than 1 percent of Japanese R&D expenditures was devoted to defense purposes in 1985; this is a significant contrast to the 30-percent figure in the United States. Consequently, Japan has a higher ratio of nondefense R&D expenditures to GNP (2.8 percent) than does the United States (1.9 percent). Japan has maintained a lead in this indicator since at least 1971 (chart 3). In absolute terms, Japan's nondefense R&D expenditures were one-half of U.S. nondefense R&D expenditures in 1985.

[2]Japanese reports often give a different ratio because they use only natural science and engineering R&D and/or national income instead of GNP

Chart 3. Nondefense R&D/GNP ratios



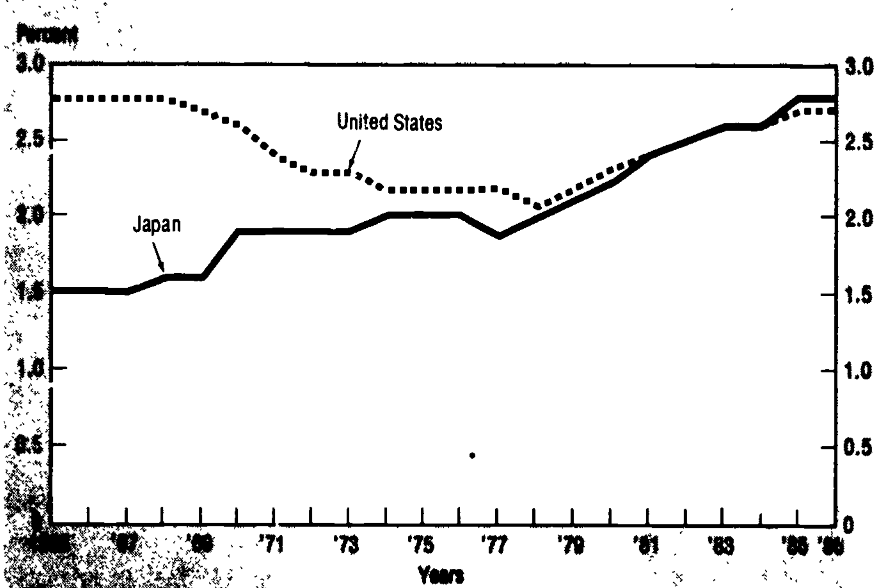
SOURCE: National Science Foundation, SIG, table 8-3

r&d expenditures by source and performer

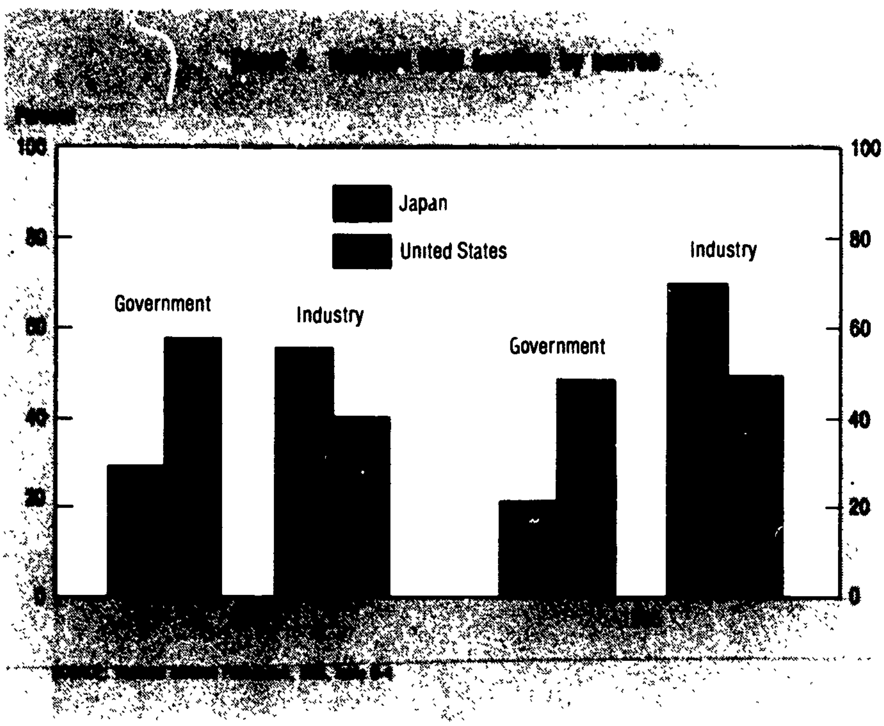
The Japanese Government's funding of R&D is substantially less than that of industry, and—although steadily increasing—it has not kept pace with the growth in industrially funded R&D. From 1970 to 1985, government R&D funding increased at an average annual rate of 5 percent while industrial funding increased at a rate of 9 percent. Also, in 1970, the government supported 29 percent of all R&D, but by 1985 its share had decreased to 21 percent (chart 4). This decline is attributable both to Japan's strict deficit reduction policy and to the growing relative share of industrial R&D funding. Nevertheless, the government allowed a higher growth rate for R&D support than for many other program areas.

Compared with the United States, the Japanese Government supports a smaller proportion of national R&D

Chart 2. Total R&D/GNP ratios



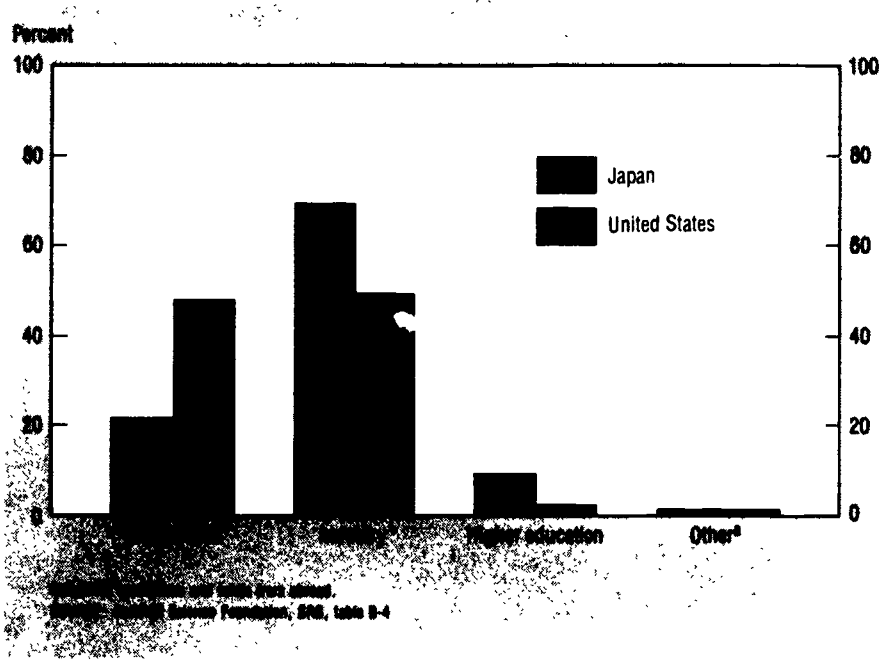
SOURCE: National Science Foundation, SIG, table 8-2



expenditures while Japanese industry supports a greater share (chart 5). In 1985, the U.S. Government funded 48 percent of R&D; the Japanese Government funded 21 percent. Much of this difference in Japanese-U.S. Government shares of total funding derives from the U.S. Government's strong support of defense-related R&D. On the other hand, Japanese industries provide a relatively larger share of national R&D funding—in 1985, Japanese industry funded 69 percent of total R&D compared to the U.S. industry share of 49 percent.

Although there are major differences in the primary sources of R&D

Chart 5. National R&D funding by source: 1985



funding in Japan and the United States, both countries exhibit similar patterns of R&D by performer. In 1985, industry expended the majority of R&D funds (67 percent for Japanese industry and 73 percent for U.S.), higher education accounted for the second largest share of R&D expenditures, and government accounted for nearly all of the remainder (chart 6). In terms of the flow of R&D funds from source to performer, there is a higher level of funds transfer among sectors in the United States than in Japan, especially from government to industry. In Japan, the flow from government to higher education is greater.[3]

[3]Japan and most European countries include in R&D a category of expenditures called "general university funds" (GUF), which are nationally allocated funds for the general operating expenses of colleges and universities The United States has no equivalent to GUF, since nearly all nationally allocated R&D monies are "separately budgeted R&D" Thus, the larger Japanese flow from government to higher education is mainly due to the component of general university funds in government expenditure statistics U S State Governments support more than one-half of all American universities, but virtually none of the general operating expenses of these State universities are included in U S R&D expenditures (For a more detailed discussion of these differences, see appendix A)

r&d by character of work

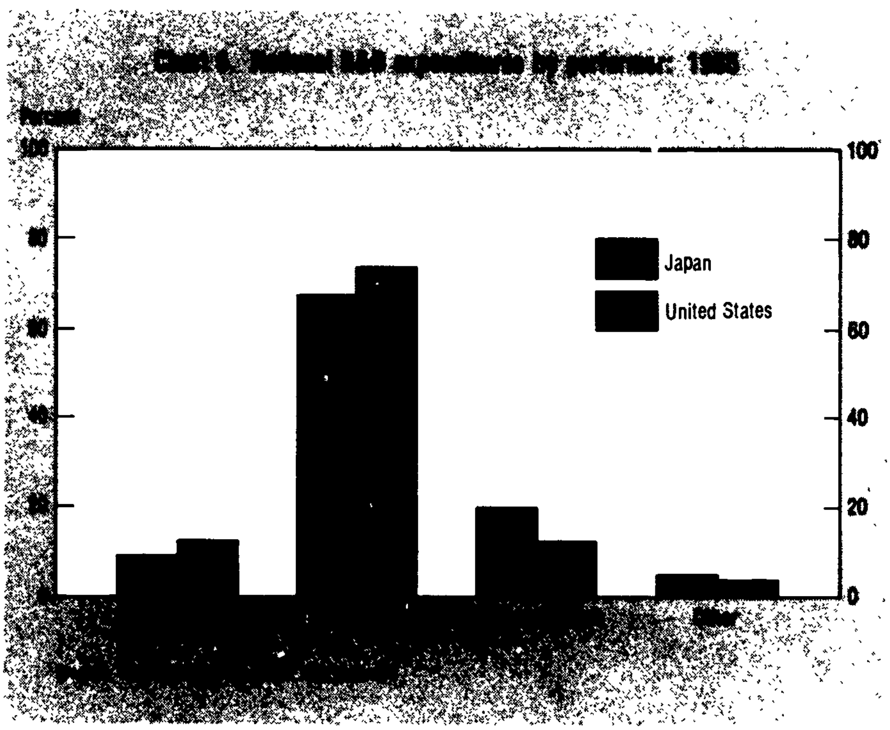
While conceptual distinctions can be established between basic and applied research and between R&D, there are obvious difficulties in measuring and assigning specific R&D activities to the respective categories. These difficulties are increased when making international comparisons of absolute levels of R&D by character of work. Therefore, greater stress should be placed on evaluating trends within each country over time.[4]

By 1985, the overall distribution of total R&D funds within the two countries by character of work was very similar, although it appears that the share of Japanese R&D devoted to basic research has declined somewhat over the past 10 years. In 1975 and 1980 basic research accounted for 15 percent of R&D expenditures; by 1985, however, this share had declined slightly to 13 percent (table B-6).[5] In the United States, basic research as a share of total R&D remained constant during 1975-85 at 12-13 percent. In 1985, Japan devoted a marginally higher proportion of R&D to applied research than did the United States (25 percent and 22 percent, respectively); in contrast, the United States devoted relatively more expenditures to development—66 percent and 62 percent, respectively (charts 7 and 8). This difference largely reflects the greater U.S. defense R&D effort, which is primarily development.

The distribution of R&D by character of work among performing sectors is also very similar for the two countries, with higher education placing nearly equal emphasis on basic research (56-58 percent) and industry placing similar emphases on basic research (4-6 percent), applied research (20-22 percent), and development (72-76 percent).

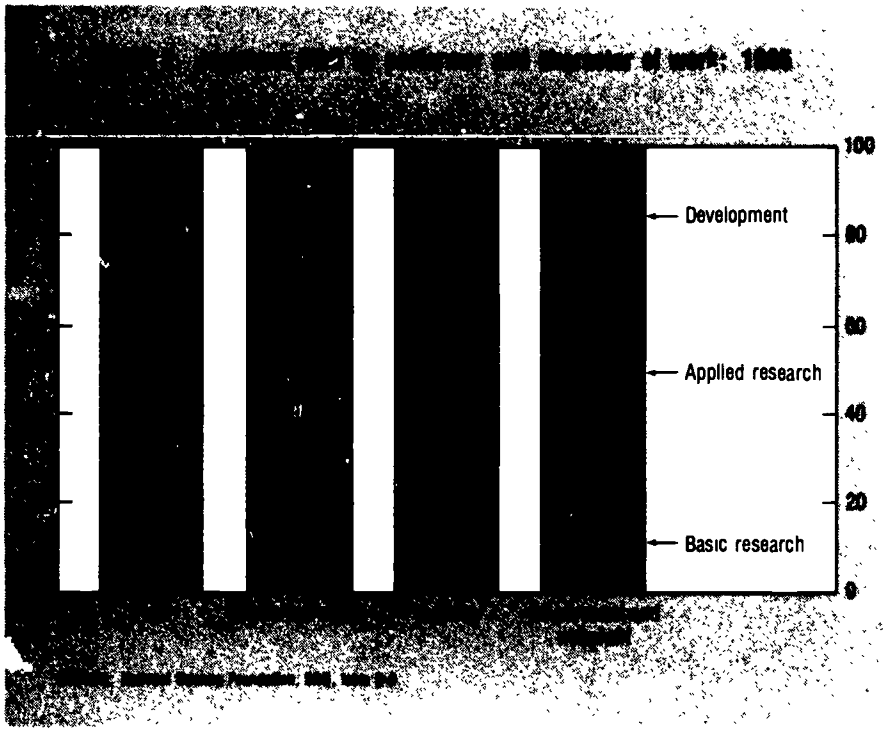
For the past several years, Japanese research leaders—including the Prime Minister's Council for Science and Technology—have urged an increased emphasis on "fundamental research." (The combination of basic

[4]For a discussion of differences in U S and Japanese definitions and treatments of basic research, see appendix A

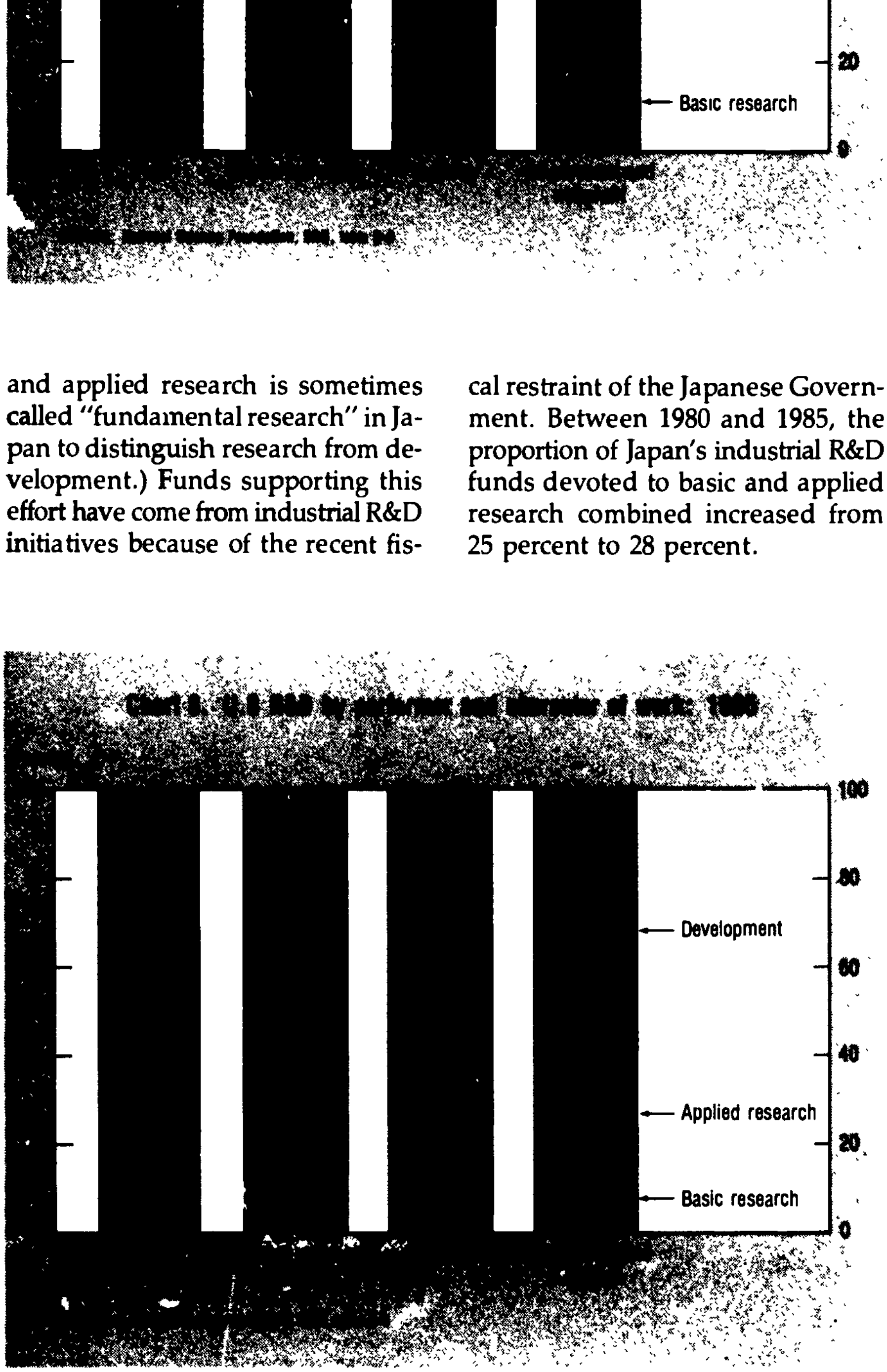


[5]Because of changes in the methodology of the key Japanese national R&D survey, it is not possible to calculate basic research from these data prior to Japan fiscal year 1974 However, in the Science and Technology Agency's *White Paper on Science and Technology, 1983* (Tokyo, Japan, 1983), it was estimated that basic research was 28 percent of R&D expenditures in 1967

This relative decline in basic research expenditures in Japan has occurred exclusively in the higher education sector Here, basic research declined from 72 percent in 1975 to 56 percent in 1985, in turn, the share of applied research *increased* by the same magnitude, rising from 20 percent to 36 percent. However, real higher education expenditures on basic research doubled during this period, indicating that the relative decline is principally the result of a higher rate of growth in applied research expenditures. It is also possible that, over time, Japanese researchers view the distinction between basic and applied research in a manner more similar to U S perceptions (See appendix A) This would imply that the relative decline of basic research (and the concomitant increase in applied research) is also a function of a reclassification of research activity, rather than simply a reflection of a shift in research focus



and applied research is sometimes called "fundamental research" in Japan to distinguish research from development.) Funds supporting this effort have come from industrial R&D initiatives because of the recent fiscal restraint of the Japanese Government. Between 1980 and 1985, the proportion of Japan's industrial R&D funds devoted to basic and applied research combined increased from 25 percent to 28 percent.



scientists and engineers

Stock of scientists and engineers. Given their central role in the R&D process, the number of scientists and engineers in a country provides a good indication of that country's S/E capability. The stock of scientists and engineers represents the total number of people in a country who are qualified to be scientists and engineers, regardless of their employment status. International data on scientist and engineer stock are difficult to obtain, however, because most countries do not account for those scientists and engineers who are unemployed or employed in fields other than science and engineering. Employment data derived from national censuses are the best source of information on the stock employed in S/E capacities, with the understanding that these data understate the total stock of scientists and engineers because of the above factors.

Japan had slightly more than 1.5 million employed nonacademic scientists and engineers in 1985, compared with almost 3.6 million in the United States in 1986 (table 1). Japan has fewer nonacademic scientists and engineers relative to its labor force than does the United States. This condition is attributable to the lower absolute and relative levels of scientists in Japan than in the United States: Japan had 28 percent as many scientists and one-half as many engineers in 1985 as the United States had in 1986, even though the Japanese labor force is slightly more than one-half that of the United States.[6]

[6] Including social scientists and scientific personnel. Data are from Peter O. Way and Ellen Jamison, *Characteristics of Scientific and Technical Manpower in the United States and Four Other Industrialized Countries* (Washington, D.C.: U.S. Bureau of the Census, 1986); U.S. Bureau of the Census, Center for International Research, *Recent Data on Scientists and Engineers in Industrialized Countries* (Washington, D.C. February 1988); and the National Science Foundation.

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Table 1. Stock of scientists and engineers:[1] 1980 and 1985 or 1986

Scientists and engineers	Japan		United States	
	1980	1985	1980	1986
Scientists and engineers, total	940,301	1,514,200	2,369,200	3,583,300
Per 10,000 labor force	164	251	218	300
Engineers	744,380	1,124,300	1,486,400	2,190,400
Per 10,000 labor force	130	187	137	183
Civil	351,929	485,400	214,300	313,100
Electrical/electronic	119,499	233,100	351,600	528,100
Industrial and mechanical	272,952	405,800	920,500	1,349,200
Scientists	195,921	389,900	882,800	1,393,000
Per 10,000 labor force	34	65	81	117
Natural	63,729	67,100	471,400	652,300
Computer	129,764	320,500	192,100	420,900
Social	2,428	2,300	219,400	319,800

[1]Nonacademic scientists and engineers employed as scientists and engineers See text footnote 7 (p 6) for an explanation of why academics are excluded

NOTE Because of rounding figures may not add to totals shown

SOURCES Peter O Way and Ellen Jamison, *Characteristics of Scientific and Technical Manpower in the United States and Four Other Industrialized Countries* (Washington, D C U S Bureau of the Census, 1986), U S Bureau of the Census Center for International Research, "Recent Data on Scientists and Engineers in Industrialized Countries" (Washington, D C February 1988), U S Bureau of Labor Statistics, and the National Science Foundation

Comparative data for engineers indicate higher relative levels of engineers per 10,000 labor force in Japan: in 1985, there were 187 engineers per 10,000 labor force compared with 183 in the United States in 1986. Japan had 65 scientists per 10,000 labor force compared with 117 in the United States.

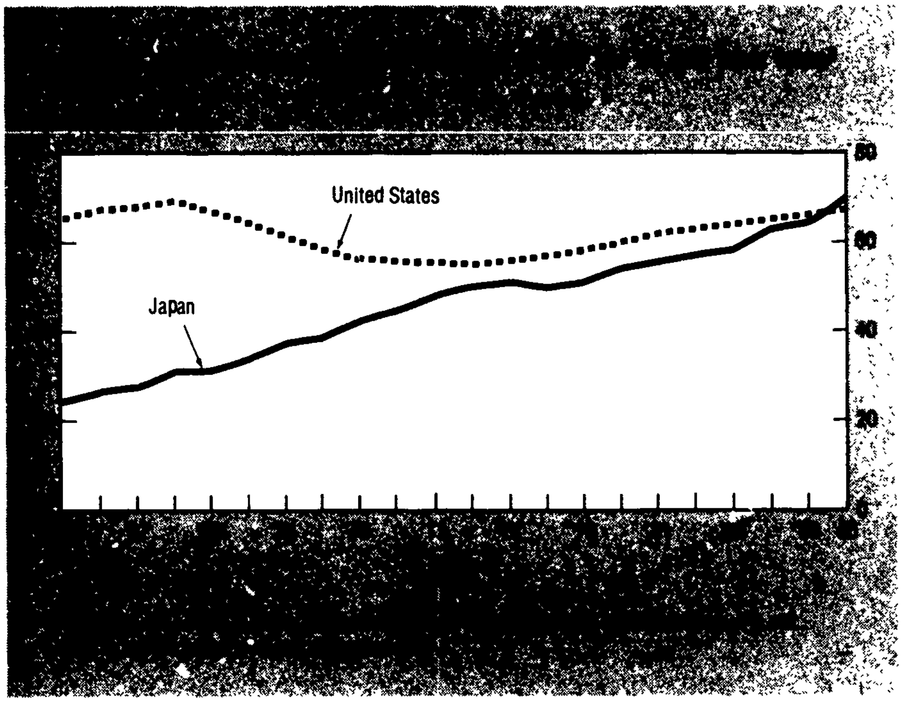
Both countries have experienced significant increases in the stock of nonacademic scientists and engineers relative to overall labor force increases. The Japanese stock of scientists and engineers grew 61 percent from 1980 to 1985; during this period, the total labor force grew by only 5 percent. Concurrently, the number of scientists doubled, largely because of a 147-percent increase in the number of computer specialists (the proportion of natural scientists per 10,000 labor force remained constant from 1980 to 1985). Also, the number of engineers increased by 50 percent, with the stock of electrical/electronic engineers nearly doubling. The U.S. experience was similar: increases of nearly 50 percent or more were registered in most categories of scientists and engineers, with the largest growth (119 percent) occurring in the stock of computer specialists. In contrast, the U.S. labor force increased only 10 percent from 1980 to 1986.

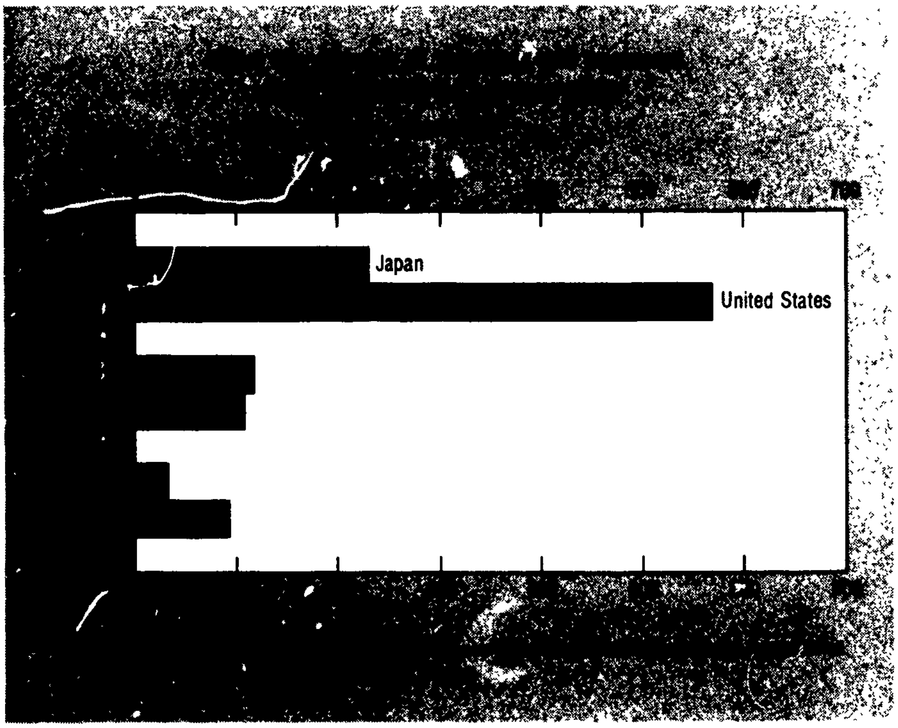
R&D scientists and engineers. Distinct from the total stock of scientists and engineers is the number who are currently active in R&D.[7] Japanese and U.S. surveys on the number of scientists and engineers engaged in R&D are not strictly comparable, because Japanese surveys ask for the total number of scientists and engineers engaged in R&D *regardless* of the amount of time devoted to R&D activities. U.S. surveys, on the other hand, ask for adjustments to estimate full-time equivalence. In order to adjust the Japanese data, information here excludes data on the social sciences and humanities and uses only data on the natural sciences and engineering.[8]

Regardless of these differences, there can be no dispute concerning the rapid increase of Japan's S/E labor force. The total number of Japanese R&D scientists and engineers engaged in R&D has tripled since 1965, and in 1986 was 405,600—one-half of the U.S. full-time-equivalent total of 802,300. Japan's scientists and engineers are also much younger than their U.S. counterparts: in 1985, almost one-half of Japanese nonacademic scientists and engineers were under 35 years old, compared with 28 percent in the United States. The ratio of Japanese R&D scientists and engineers per 10,000 labor force was about one-third the U.S. ratio in 1965; in 1986, however, the two ratios were comparable at 69 percent and 67 percent, respectively (chart 9). Within the R&D-performing sectors, Japan has a slightly larger absolute number of scientists and engineers in the higher education sector than the U.S. full-time equivalent; however, the United States has 2.5 times as many industrial scientists and engineers engaged in R&D as does Japan and nearly three times as many in government and nonprofit settings (chart 10).

[7]Unlike data on the stock of scientists and engineers, which exclude academics, data on scientists and engineers engaged in R&D include academic scientists and engineers Stock data are derived from the occupational categories of national censuses, which do not distinguish academics by discipline Consequently, it is not possible to calculate only that faculty in science and engineering from the census data On the other hand, the numbers of scientists and engineers engaged in R&D are obtained from R&D surveys that do distinguish personnel by discipline

[8]By excluding social scientists from the Japanese S/E data, it is possible to get a closer estimate of those full-time scientists and engineers actually conducting R&D For a more detailed discussion of this adjustment, see appendix A





technical know-how expenditures and receipts

Although receipts for and expenditures on technical know-how (royalties and fees) typically are viewed as S/T outputs, Japan historically has used licensed technology to supplement its own R&D efforts. Consequently, Japanese trends regarding royalties and fees are discussed here as an integral part of the country's R&D efforts (they are discussed again in chapter 5 on S/T outputs and impacts).

In 1970, Japan spent constant $1.4 billion on royalties, licensing fees, and other expenses related to imported technology. These expenditures were 57 percent of what the United States spent in the same year for technical know-how (chart 11). Japan's expenditures for technical know-how in 1970 were 11 percent of total national R&D expenditures, compared to 4 percent in the United States.[9]

Japan has continued to spend a substantial amount on technical know-how.[10] Between 1970 and 1985,

[9]These Japanese royalties and fees data are from the Bank of Japan, which are most comparable to U S data because they include transactions for film rights, book royalties, and other cultural items The Japanese Statistics Bureau also provides technical know-how data, but on manufacturing industries only These latter data are presented in chapter 5, "Outputs and Impacts," and the differences between the two data series are discussed in footnote 43 of that chapter

[10]Increases in the dollar amount of technical know-how purchases cannot be equated on a one-to-one basis with increases in the actual volume of technology transfer Because of uncertainties about the market valuation of technology, it is possible that increasing expenditures on technical know-how reflect purchases of less, but more expensive, technology

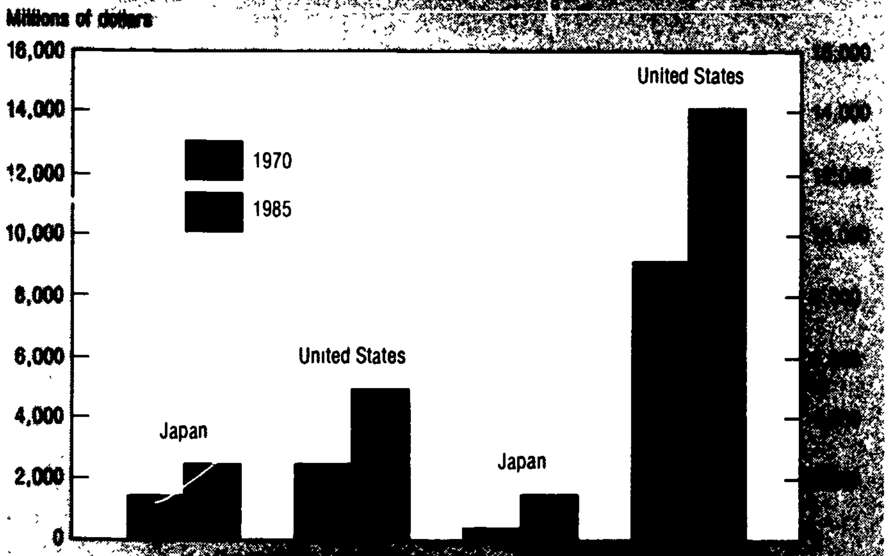


Chart 11.

SOURCE:

its payments for royalties and fees increased by 71 percent; this was not quite as large as the increase for R&D, which nearly tripled. Consequently, the share of Japanese payments for technical know-how to R&D decreased to 7 percent in 1985.

In 1970, Japan exported constant $194 million worth of technical know-how; in the same year, the United States had exports of constant $8.6 billion. Since 1970, Japanese technology has been in greater demand by overseas customers and the Japanese have been more willing to sell their technology; by 1985, Japan was exporting constant $721 million worth of technical know-how, improving the share of receipts to payments from 14 percent in 1970 to 30 percent in 1985.

chapter 2.

government r&d

The Japanese Government's share of total national R&D funding reached its peak in 1972 at 33 percent. It has declined fairly steadily since then to its 1985 level of 21 percent. In comparison, the U.S. Government's share of national R&D funding is much higher, although it also declined from 1970 to 1985, dropping from 57 percent to 48 percent.

Despite its declining relative contribution to total national R&D resources, the actual *value* of Japanese Government funds has steadily increased, reaching constant $7.6 billion in 1985. U.S. Federal funding—which declined during 1970-75, but has increased steadily since then—was constant $46.0 billion in 1985 (chart 12). Despite an environment of fiscal restraint, the Japanese Government's S/T budget has received a high priority in the last 5 years. From 1980 to 1985, Japanese Government R&D funding increased at an average annual rate of 3 percent (a net increase of 16 percent) compared with a 6-percent average annual rate (a net increase of 33 percent) in the United States. In the United States, 90 percent of the growth in government R&D funding is accounted for by increases in defense-related R&D.

organization of s/t policymaking

In spite of its relatively small share of total national R&D funding, the Japanese Government plays an important role in science and technology both by identifying new directions for national R&D efforts and by indicating R&D initiatives to industry through a program of financial incentives and selective funding of particular R&D projects. Chart 13 presents the governmental structure of S/T administration in Japan.

S/T policy in Japan is largely the responsibility of four institutions: the Prime Minister's Council for Science and Technology; STA; the Ministry of Education, Science, and Culture (Monbusho); and MITI.[11] In one capacity or another, these four organizations: (1) develop national S/T policy, (2) coordinate the policies of

[11] Much of this discussion is drawn from Harumitsu Yoshimura, *The Organization of Science and Technology in Japan*, prepared for the International Conference "The Organisation of Science and Technology in Western Industrialized Countries—An International Comparison" (Bonn, West Germany, May 26-27, 1987) Mr Yoshimura is the Assistant Director General for Administration, Science and Technology Agency

Chart 12. Value of government R&D funding
[Constant 1982 dollars]

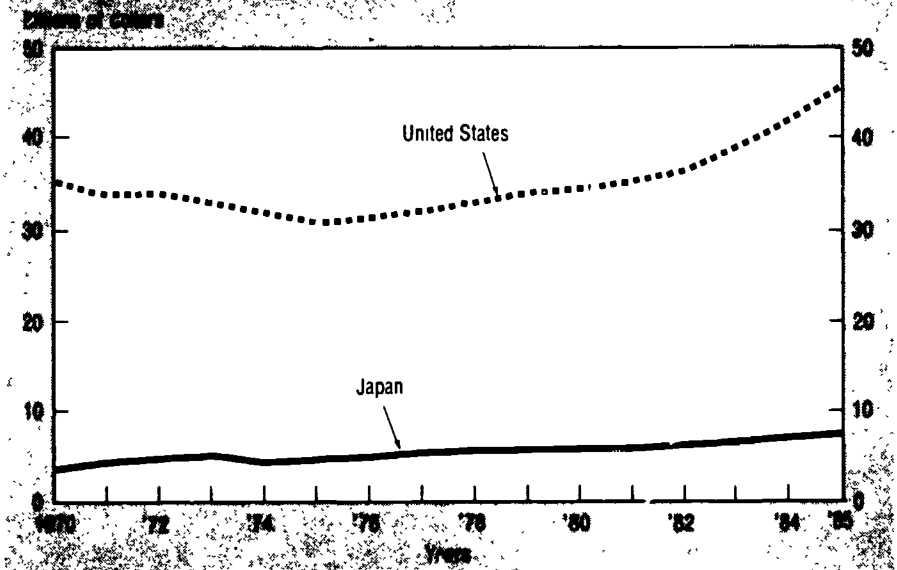
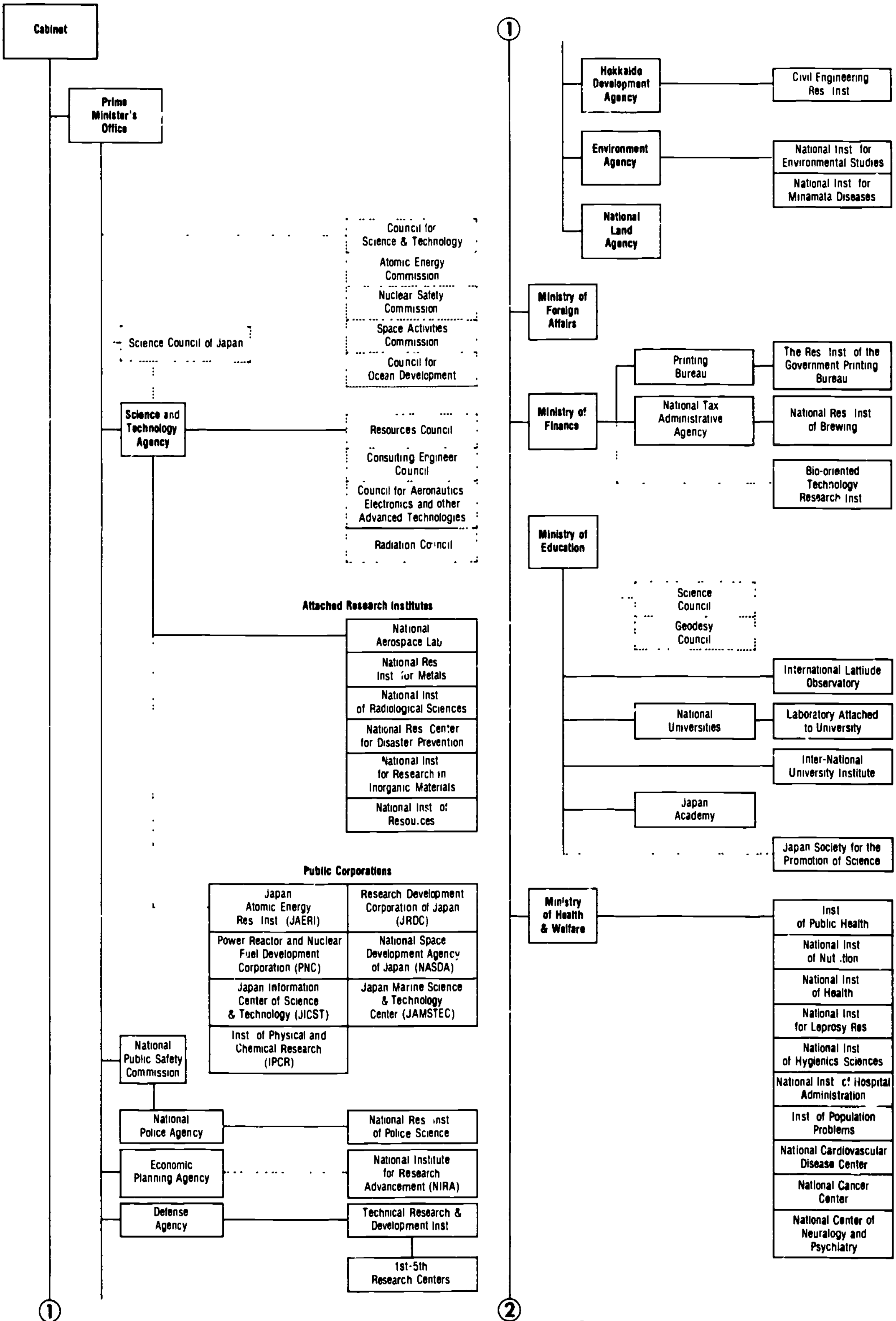
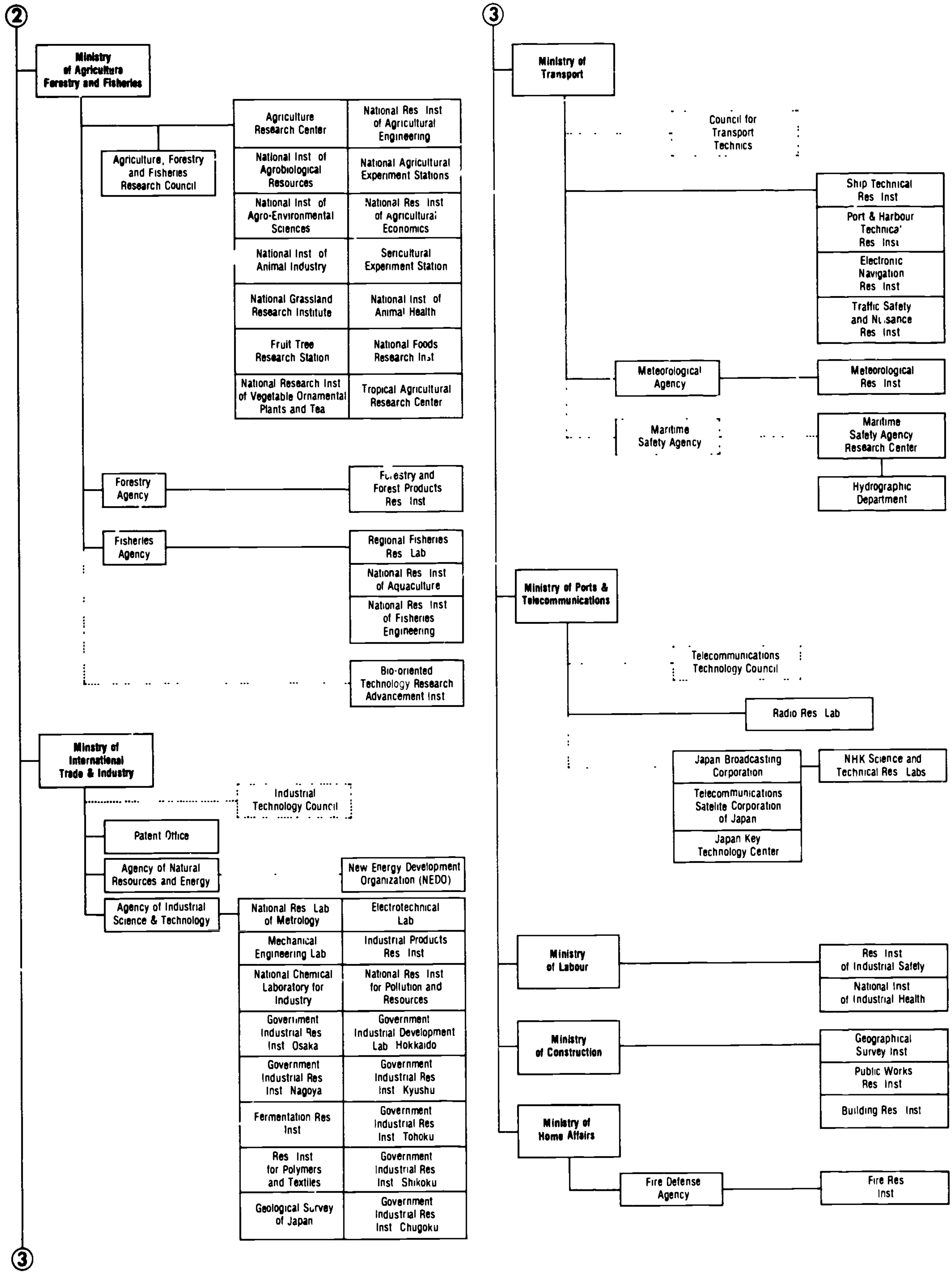


Chart 13. Administrative structure of science and technology in Japan: 1987



SOURCE Japan Science and Technology Agency



②
Ministry of Agriculture Forestry and Fisheries
Agriculture, Forestry and Fisheries Research Council
Agriculture Research Center
National Res Inst of Agricultural Engineering
National Inst of Agrobiological Resources
National Agricultural Experiment Stations
National Inst of Agro-Environmental Sciences
National Res Inst of Agricultural Economics
National Inst of Animal Industry
Sericultural Experiment Station
National Grassland Research Institute
National Inst of Animal Health
Fruit Tree Research Station
National Foods Research Inst
National Research Inst of Vegetable Ornamental Plants and Tea
Tropical Agricultural Research Center
Forestry Agency
Forestry and Forest Products Res Inst
Fisheries Agency
Regional Fisheries Res Lab
National Res Inst of Aquaculture
National Res Inst of Fisheries Engineering
Bio-oriented Technology Research Advancement Inst
Ministry of International Trade & Industry
Industrial Technology Council
Patent Office
Agency of Natural Resources and Energy
New Energy Development Organization (NEDO)
Agency of Industrial Science & Technology
National Res Lab of Metrology
Electrotechnical Lab
Mechanical Engineering Lab
Industrial Products Res Inst
National Chemical Laboratory for Industry
National Res Inst for Pollution and Resources
Government Industrial Res Inst Osaka
Government Industrial Development Lab Hokkaido
Government Industrial Res Inst Nagoya
Government Industrial Res Inst Kyushu
Fermentation Res Inst
Government Industrial Res Inst Tohoku
Res Inst for Polymers and Textiles
Government Industrial Res Inst Shikoku
Geological Survey of Japan
Government Industrial Res Inst Chugoku
③
③
Ministry of Transport
Council for Transport Technics
Ship Technical Res Inst
Port & Harbour Technical Res Inst
Electronic Navigation Res Inst
Traffic Safety and Nuisance Res Inst
Meteorological Agency
Meteorological Res Inst
Maritime Safety Agency
Maritime Safety Agency Research Center
Hydrographic Department
Ministry of Ports & Telecommunications
Telecommunications Technology Council
Radio Res Lab
Japan Broadcasting Corporation
NHK Science and Technical Res Labs
Telecommunications Satellite Corporation of Japan
Japan Key Technology Center
Ministry of Labour
Res Inst of Industrial Safety
National Inst of Industrial Health
Ministry of Construction
Geographical Survey Inst
Public Works Res Inst
Building Res Inst
Ministry of Home Affairs
Fire Defense Agency
Fire Res Inst

all ministries and agencies involved in science and technology, (3) direct a system of more than 80 government research institutes, (4) administer the national university system, and (5) oversee an assortment of public corporations.

The actual development of Japanese S/T policy is a combination of consultation, consensus, decentralization, and coordination. The primary authority, the Council for Science and Technology, consults with the Prime Minister and Cabinet and recommends long-term national policy objectives. STA is responsible for coordinating the individual S/T policies of the various ministries (except Monbusho) and their affiliated research institutes. STA also contributes to the development of national S/T policy. Finally, Monbusho influences the R&D activities of the national university system and its associated research institutions.

The council for science and technology. The Council for Science and Technology is the foremost Japanese institution for promoting a comprehensive national S/T policy; it also bridges the activities of STA and Monbusho. The Council is chaired by the Prime Minister and is composed of several cabinet ministers, the Chairman of the Science Council of Japan, and prominent experts on science and technology. In fulfillment of its role, the Council periodically delivers key recommendations to the Prime Minister. In 1965, the Council recommended that Japan should "seek relief through indigenous research and development from overdependence on foreign technology"; this recommendation was followed by a rapid increase in both government and private R&D funding. The Council's 1971 advice stressed the need for research on means to preserve the environment; the 1977 recommendation, following in the wake of the oil shock, focused on energy research. In November 1984, the Council released its Eleventh Recommendation, which identified the need for a "basic shift in Japan's R&D effort towards the fostering of creative breakthroughs in fundamental research that should benefit not only Japan but the international community."[12] This latter recommendation is expected to have a major impact on future Japanese R&D planning both in the character of research supported and the involvement of foreign researchers in its performance.

The science and technology agency. STA provides policy research and planning inputs for the Council, but its major responsibilities also include the management and conduct of S/T activities in basic research and the "big sciences." Most of this work is carried out in research institutes attached to the agency; these perform work in such fields as aerospace, inorganic materials, and radiological science. Other work is performed by quasi-autonomous public corporations within STA's authority such as the Institute of Physical and Chemical Research (RIKEN) and the Japan Atomic Energy Research Institute.

Affiliated with STA is the Japan Information Center for Science and Technology (JICST), which collects S/T publications from around the world, summarizes these, and stores the abstracts in an on-line service accessible to most Japanese researchers and now available in the United States.[13] Another STA-directed public corporation is the Japan Research and Development Corporation, whose main function is to encourage the commercialization of promising R&D developed at the national universities and research institutes.

Among numerous other projects, STA publishes an annual "White Paper on Science and Technology" and sponsors a Delphi Survey administered every 5 years. This survey is sent to approximately 2,500 industry, university, and government leaders and asks them to identify those research areas deserving the highest emphasis. The results of the most recent survey are presented in chapter 6, "Possible Future Directions" (p. 39).

The ministry of education, science, and culture. Monbusho is responsible for administering Japan's system of 95 national universities and their affiliated research institutes, and accounts for the largest portion of government R&D expenditures.[14] In order to foster interuniversity research cooperation, Monbusho established several research institutes for joint use by staff from all universities during the seventies. These institutes are both university-affiliated and independent national joint-university centers; by 1985, there were 24 such institutes covering most major fields of investigation (a list of the institutes is provided on p. 24 in chapter 4, "Higher Education").[15] Similarly, Monbusho issued a directive in 1983 urging universities to open up their facilities to industrial researchers; since then it has initiated several programs promoting this

[12]Council for Science and Technology, *Comprehensive Fundamental Policy for Promotion of Science and Technology to Focus Current Changing Situations from the Long-Term View Recommendation on the 11th Inquiry* (Tokyo, Japan, November 1984)

[13]The on-line service provides abstracts both in Japanese and English. It is available through the National Technical Information Service, Springfield, Va 22161, phone number (703) 487-4819

[14]Monbusho also sets the establishment and accreditation standards for Japan's public and private universities.

[15]An English-language description of these institutes is in the Tokyo Office of the U S National Science Foundation, *Directory of Selected Japanese Scientific Research Institutes Government, National Universities, and Special Corporations*, Report Memorandum #114, December 1986 The report may be obtained from the National Science Foundation, Office of International Programs, 1800 G Street, N W , Washington, D C. 20550

university-industry-government cooperation in research. Also affiliated with Monbusho is the Japan Society for the Promotion of Science, a semigovernmental organization which provides (among other services) funds for cooperative research projects and fellowships for international scientific researchers.

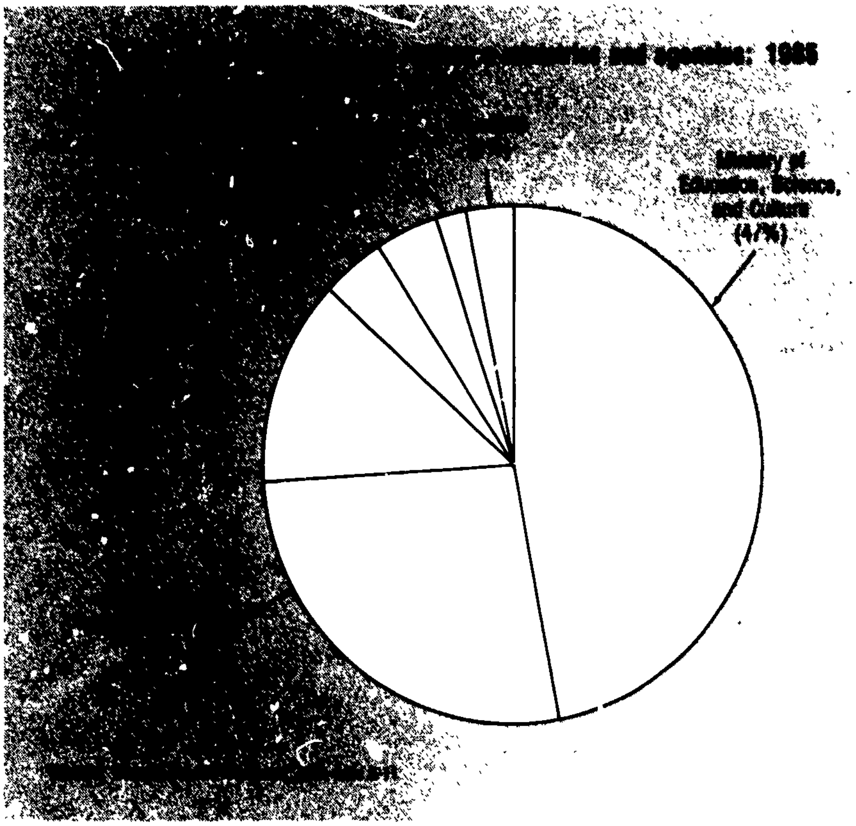
Ministry of international trade and industry. MITI is well known for its role in industrial policy and regulation; however, it also plays an active part in promoting Japanese industrial R&D. Within MITI, the Agency for Industrial Science and Technology (AIST) sponsors a variety of projects to develop technologies with potential commercial value. (These projects are further detailed on p. 66.) Much of this work is carried out in 16 national and regional industrial research institutes administered by AIST. AIST is also responsible for administering special incentives—such as conditional loans, tax deductions, and special financing—for technology development in the private sector. The Japan Key Technology Center, a public corporation affiliated with MITI/AIST, helps finance certain joint industrial R&D projects.

government funding

Ministerial R&D budgets are composed of: (1) funds for ongoing research-related operations and personnel costs of government research institutes and higher educational institutions, (2) funds for research promotion—primarily in the form of external grants, and (3) funds for the special energy budget initiated in 1977.

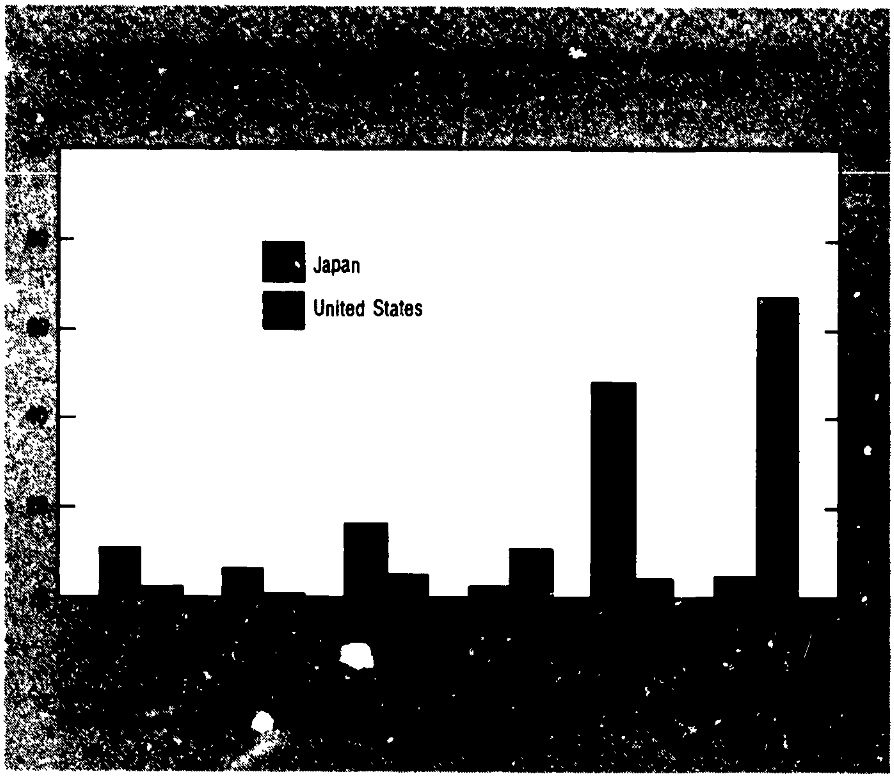
Monbusho and STA have the largest budgets, accounting for 47 percent and 27 percent, respectively, of the Government's total R&D budget (chart 14). MITI is the third largest funder (13 percent); followed by the Ministry of Agriculture, Forestry, and Fisheries and the Defense Agency (4 percent each); and the Ministry of Health and Welfare (2 percent). While most of Monbusho's funds are committed to the ongoing operations of the university system, STA's funds are equally divided among the three funding components listed above.

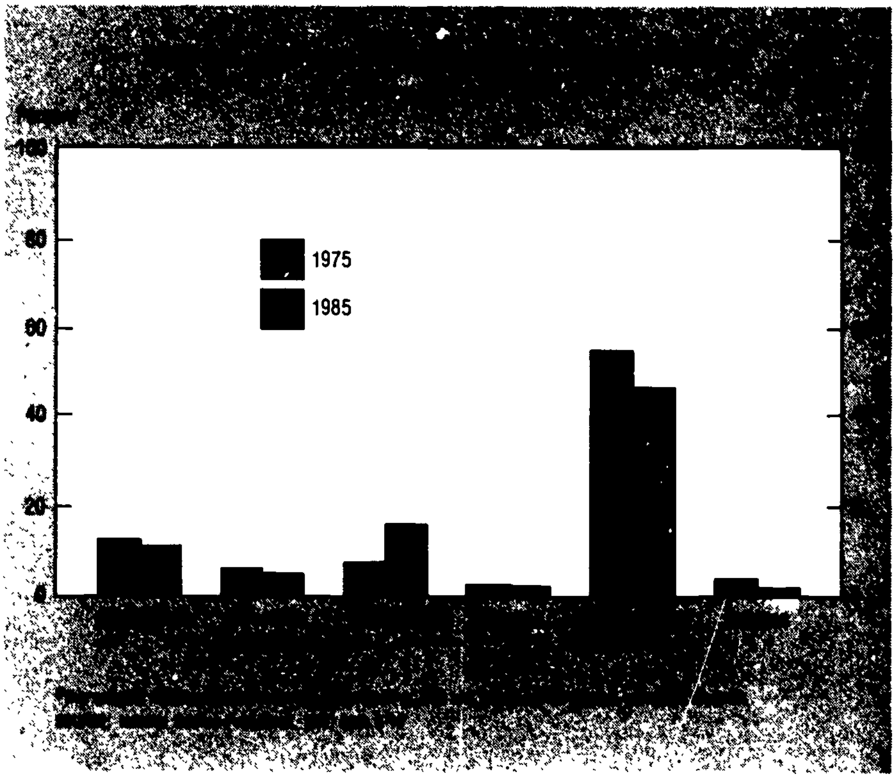
The Japanese Government spends the largest portion of its budget—an estimated 47 percent in 1985—on the general objective of "advancement



of knowledge," a function which includes general university funds (GUF) spent on R&D as well as separately budgeted R&D, and should also not be equated with basic research (chart 15).[16] The U.S. Government spends the preponderance of its R&D budget (68 percent in 1985) on defense.

The emphasis of the Japanese Government on various R&D objectives has been relatively stable over the past decade, with the exception of the shares of funds devoted to energy and defense research. From 1975 to 1985, the proportion of expenditures for energy R&D doubled, rising from 7.5 percent to 16.3 percent; defense expenditures increased from 2.2 percent to 4.1 percent. The relative shares of all other categories declined to compensate for these increases (chart 16). Japan spends a greater proportion of its budget on agriculture, industrial development, energy, and civil space objectives than does the United States, largely because of its much lower concentration of defense-related R&D expenditures.





[16]As noted earlier, the United States does not have the Japanese and European equivalent of general university funds, the U S data on advancement of knowledge do not include expenditures similar to GUF Also note that approximately one-half of the Japanese Government R&D budget goes to the Ministry of Education, Science, and Culture

government r&d programs

In addition to its funding and policymaking roles, the Japanese Government is a performer of R&D through the more than 80 national institutes and public corporations which conduct ongoing research.[17] In addition to ongoing research at the research institutes, there are a number of large-scale, special R&D programs that have been initiated by STA and MITI which focus primarily on basic research and the development of new technologies.

The Exploratory Research for Advanced Technology program (ERATO) was implemented in 1981 to provide basic research in potentially revolutionary technologies that are of prohibitive research cost to private industry. ERATO is directed by the Research Development Corporation of Japan, and research outputs are to be made publicly available for commercial exploitation. Through 1986, 12 different projects—with average expected durations of 5 years and average total budgets of constant (1982) $8 million—have been adopted. These projects are listed in table C-1.

Within MITI, AIST has established several well-publicized joint research enterprises with selected industrial firms (e.g., the Large-Scale, Sunshine, and Moonlight Projects). MITI provides these projects with partial funding and, in some instances, also provides the facilities of its research institutes; the firms contribute key researchers and the remaining funding. A list of major AIST projects and their purposes are presented in table C-2. MITI also sponsors the Fifth Generation Computer Program, a 10-year research program instituted in 1982. Research in conjunction with the Fifth Generation Computer Program is conducted at the specially created Institute for New Generation Computer Technology (ICOT), and focuses on advanced information processing, especially parallel computing and artificial intelligence.

Finally and most recently, the Frontier Research Program was initiated in 1986 under the aegis of RIKEN, a major research institute affiliated with STA. The program aims to discover new knowledge that will serve as the basis for technological innovation in the 21st century; the two research themes of the program are (1) the biological foundations of homeostasis mechanisms in plant and animal life, and (2) frontier materials. A 15-year research agenda is tentatively being planned, with teams of international scientists conducting research at RIKEN's laboratories in specific areas such as chromosomes and bioelectronic elements and devices.[18]

[17] A listing and description of the most significant of these research institutes is in the Tokyo Office of the U S National Science Foundation, *Directory of Selected Japanese Scientific Research Institutes*, op cit

[18] For more information on RIKEN's program, see the Tokyo Office of the U.S. National Science Foundation, *STA and RIKEN to Launch 'International Frontier Research System'*, Report Memorandum #97, April 1986 Note that RIKEN's IFRP is not the same as the yet-to-be implemented Human Frontiers Program The Human Frontiers Program has been a highly publicized new research program, and is still in the planning stage

chapter 3.

industrial r&d

Industrial R&D has always been the most prominent sector in the Japanese system, accounting for 69 percent of all R&D funds in 1985 (U.S. industry accounted for 49 percent of R&D funds). There are two primary reasons for this sector's prominence. First, Japan's postwar agreements have limited Japan's defense establishment; consequently, the share of R&D funds accounted for by government defense-related R&D expenditures is very small in Japan. Second, the Japanese Government has maintained a policy of letting industry support its own R&D, with the result that less than 2 percent of industrial R&D funds comes from the Japanese Government. In contrast, in the United States, slightly more than one-third of industrial R&D is funded by the Federal Government; these expenditures are concentrated primarily in the defense, space, and telecommunications industries.

Low levels of government R&D expenditures relative to industry do not mean that the Japanese Government does not actively encourage or promote industrial R&D. In fact, a system of financing and tax incentives operates to stimulate R&D in the Japanese private sector. Project-oriented incentives for encouraging Japanese industrial R&D include favorable interest rates from the Japan Development Bank for the commercialization of new technology, government contracts for the commercialization of the outputs of public R&D institutions, capital investments, and conditional interest-free loans. Tax incentives—which allow Japanese businesses to maintain the confidentiality of their R&D activities (unlike the project-oriented incentives)—provide special tax credits for incremental increases in corporate R&D expenditures (in effect since 1967); the R&D performed by small and medium firms; and the costs of depreciable assets for R&D in "basic" technologies such as new materials, biotechnology, and high-performance robotics.[19] In comparison, the United States provides tax credits only for incremental corporate R&D expenditures and industry funding of university basic research; the credit was first initiated in 1981 and later extended (in a reduced and modified form) through 1988.

[19]A detailed discussion of Japanese industrial financing and tax incentives is in Ministry of International Trade and Industry, *AIST, 1987* (Tokyo, Japan, 1987) A thorough discussion of the R&D tax system is in the Tokyo Office of the U.S. National Science Foundation, *Preferential Tax Systems for R&D in Japan*, Report Memorandum #109, November 1986.

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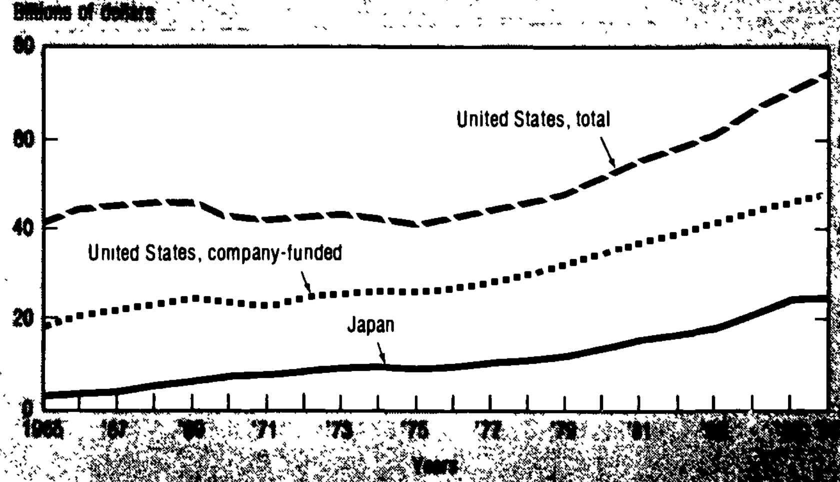
overall industrial r&d trends

From 1965 to 1985, Japanese industrial R&D expenditures increased at an average annual rate of 11 percent; total U.S. industrial R&D increased at a rate of 3 percent and U.S. company-funded R&D at a rate of 5 percent for the same period.[20]

Consequently, Japanese industrial R&D expenditures increased from less than one-tenth the U.S. level in 1965 to one-third of total U.S. industrial R&D and one-half of U.S. company-funded R&D expenditures in 1986 (chart 17). Japanese industrial R&D expenditures were constant $24.1 billion in 1985 (constant $396 million were funded from government sources) compared with total U.S. industrial expenditures of constant $70.4 billion (constant $23.8 billion from government sources).

As a percentage of GNP, Japanese industrial R&D more than doubled from 1965 to 1986. In 1986 this ratio was comparable to the U.S. proportion: 1.9 percent and 2.0 percent, respectively (chart 18). Since Japanese industrial R&D is almost entirely (98 percent) financed by companies themselves, Japanese company-funded R&D as a percentage of GNP has surpassed the U.S. ratio in every year since 1970. In 1985 and 1986, the ratio of company-funded R&D to GNP was 1.9 percent for Japan and 1.3 percent for the United States.

Chart 17. [illegible]



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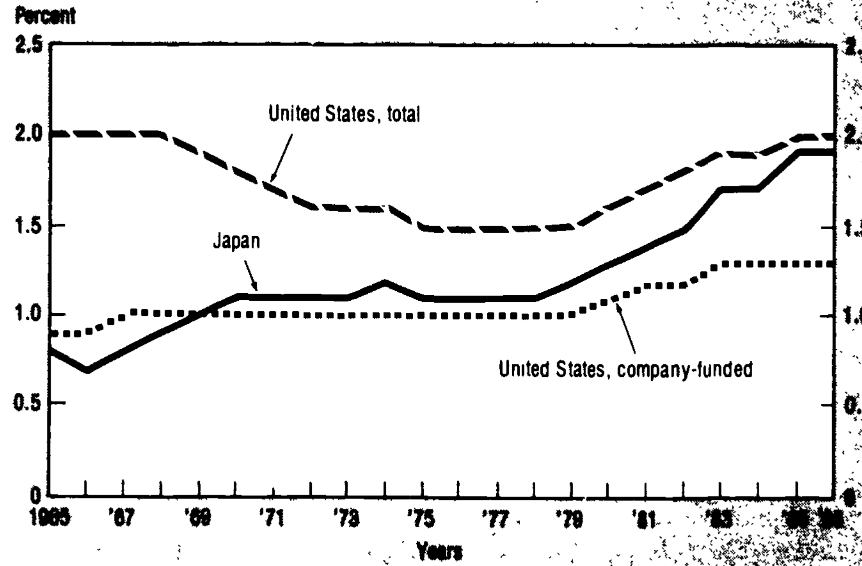
SOURCE: [illegible]

Chart 18. Industrial R&D as a percent of GNP



NOTE: Japanese industrial R&D is almost 98 percent company-funded.
SOURCE: National Science Foundation, SRS, table 8-15

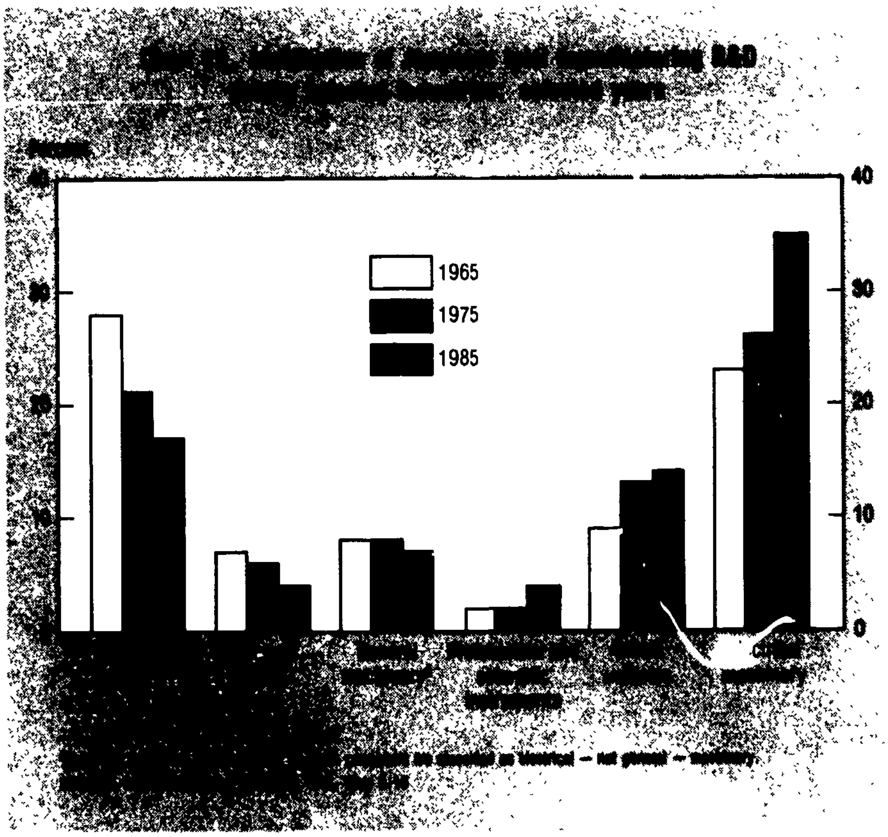
[20]Because less than 2 percent of Japanese industrial R&D funds is from government sources, Japanese company-funded R&D data are not discussed separately

r&d by industry

Because of the congestion and pollution created by the geographic concentration of Japan's heavy industries, Japan's economic planners have de-emphasized industries perceived as environmentally disruptive (e.g., chemicals, steel) and introduced policies to replace them with those perceived as environmentally clean and/or information-based (e.g., electronics, scientific and professional instruments). Industrial R&D investments appear to have been somewhat responsive to these priorities.

In 1965, the chemical industry in Japan was the principal performer of R&D, accounting for 28 percent of total manufacturing R&D; it was followed by the electrical machinery industry, which accounted for 23 percent (chart 19).[21] By 1975, electrical machinery had overtaken the chemical industry as the primary R&D performer, and—by 1985—the electrical machinery industry was outspending the chemical industry 2 to 1. In both 1965 and 1985, the electrical machinery, chemicals, general machinery, and motor vehicles industries were the four largest sources of Japanese manufacturing R&D, together accounting for 68 percent of manufacturing R&D in 1965 and 73 percent in 1985. The industries with the largest real R&D growth from 1965 to 1985 were communications and electronic equipment, rubber (including plastics), motor vehicles, and professional and scientific instruments.

The United States has a different ranking of the top sources of manufacturing R&D depending on whether total or company-funded R&D is examined. For total manufacturing R&D, aircraft and missiles account for 23 percent of R&D performance; electrical machinery, general machinery, and chemicals industries combined account for another 47 percent of the total manufacturing R&D.[22, 23] For company-funded manufacturing R&D, the electrical machinery industry is the single largest source of manufacturing R&D (34 percent), followed by the chemical (16 percent), motor vehicle (12 percent), and professional and scientific instruments (9 percent) industries.[24]



[21]The Standard Industrial Classification for Japan includes computers under the "electrical machinery" classification as communications equipment and electronic components, whereas the United States and the Organisation for Economic Co-operation and Development classify such equipment under "general machinery"

[22]Unlike the United States, Japan does not have a separate industry category for aircraft and missiles, probably because these industries are so small Missiles are not mentioned at all in the product classifications, ordnance is included in general machinery and aircraft are included in the category for transportation equipment other than motor vehicles In 1985, R&D expended by "other transportation" industries was constant $561 million with an R&D to net sales ratio of 2 6 percent

[23]Much of the total U S manufacturing R&D is not available on a sufficiently disaggregated basis to allow for a detailed industry comparison with Japan

[24]Note that the U.S manufacturing industry data have been adjusted to be more comparable with the Japanese data Computers have been reclassified from general machinery to communications and electronic equipment under electrical machinery.

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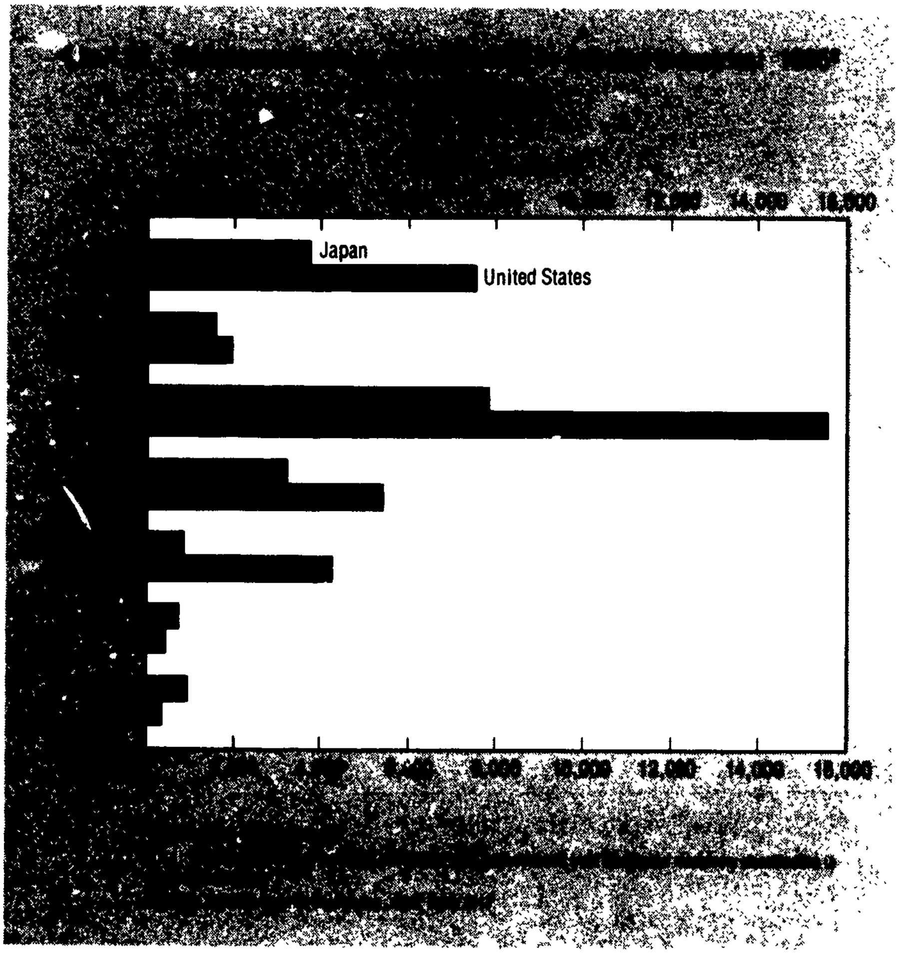
By 1985, most Japanese manufacturing industries were investing at least one-half of the company-funded R&D amount of their U.S. counterparts (chart 20). In the textiles, ceramics, and iron and steel industries, actual Japanese R&D expenditures exceeded U.S. levels by nearly 2 to 1 or more. In only two industries—petroleum and professional and scientific instruments—were Japanese R&D expenditures significantly less than one-half that of the U.S. These high levels of industrial R&D expenditures are particularly impressive if it is recalled that in 1985 Japan's GNP was little more than one-third of the United States'.

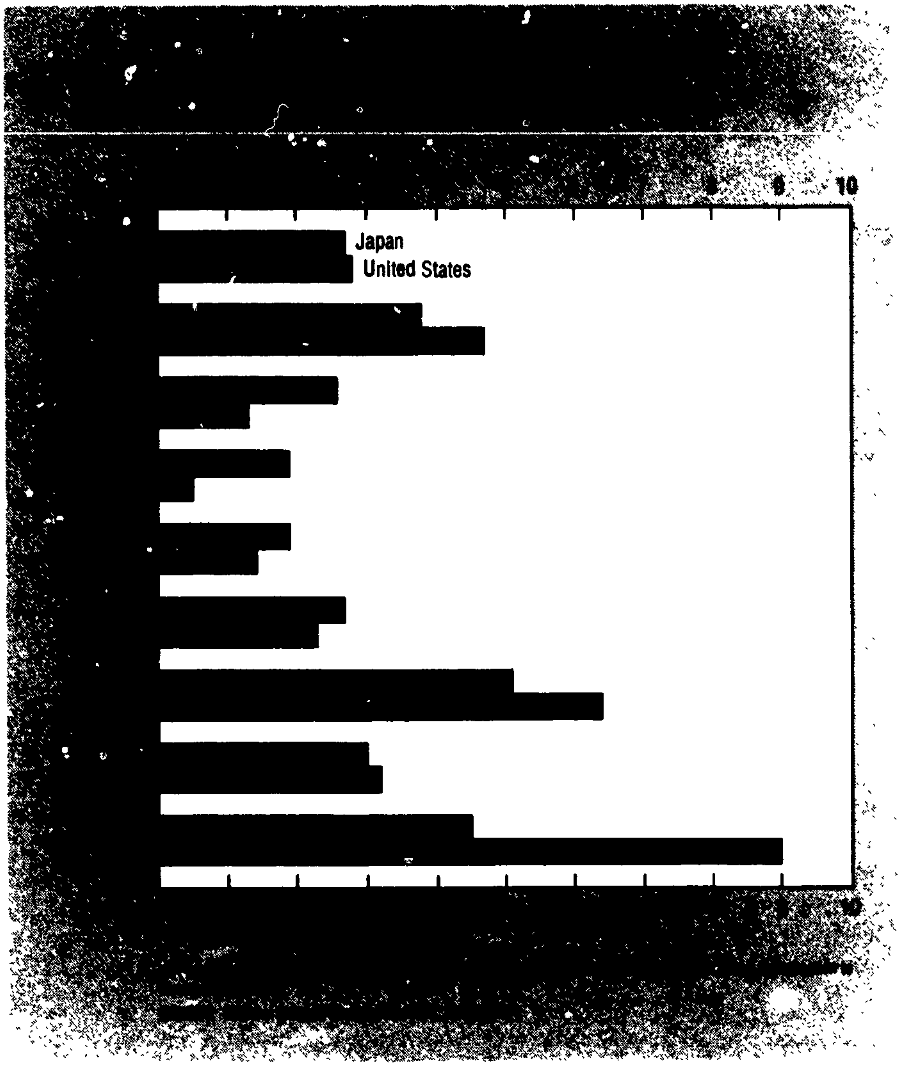


r&d to net sales and r&d concentration

The relative importance of R&D can be gauged by measuring the proportion of available resources being invested in R&D. The ratio of company-funded R&D expenditures to net sales provides a measure of R&D intensity which can be compared across industries and countries. This ratio for all Japanese manufacturing industries in 1985 was 2.7 percent—slightly less than the 2.8 percent reported for company-funded R&D in the United States (chart 21). Generally, those Japanese industries with R&D expenditures equivalent to about 60 percent or more of their U.S. counterparts had the same or higher R&D to net sales ratios as the U.S. industries; Japanese industries with R&D expenditures equivalent to less than about 60 percent of U.S. industries had ratios lower than those for the United States. Drugs and medicines was the most R&D-intensive industry in Japan with an R&D to net sales ratio of 7 percent; it was followed by communications and electronic equipment (5.3 percent) and professional and scientific instruments (4.5 percent). In the United States, the professional and scientific instruments (9 percent), drugs and medicines (8.4 percent), and communications and electronic equipment (7.6 percent) industries were the most R&D intensive.

Evidence indicates that R&D is slightly less concentrated in Japan than in the United States. In 1985, the top five Japanese R&D firms accounted for 18 percent of total manufacturing R&D compared to 23 percent for the top five U.S. firms (table B-18). For most manufacturing industries, the levels of industrial R&D concentration are lower in Japan than in the United States; an appreciably higher level of Japanese industrial R&D dominance is found only in the iron and steel industry. U.S. company-dominance of R&D is much higher than Japan's in the industrial chemicals, ceramics, fabricated metals, general machinery, motor vehicles, and professional and scientific instruments industries.

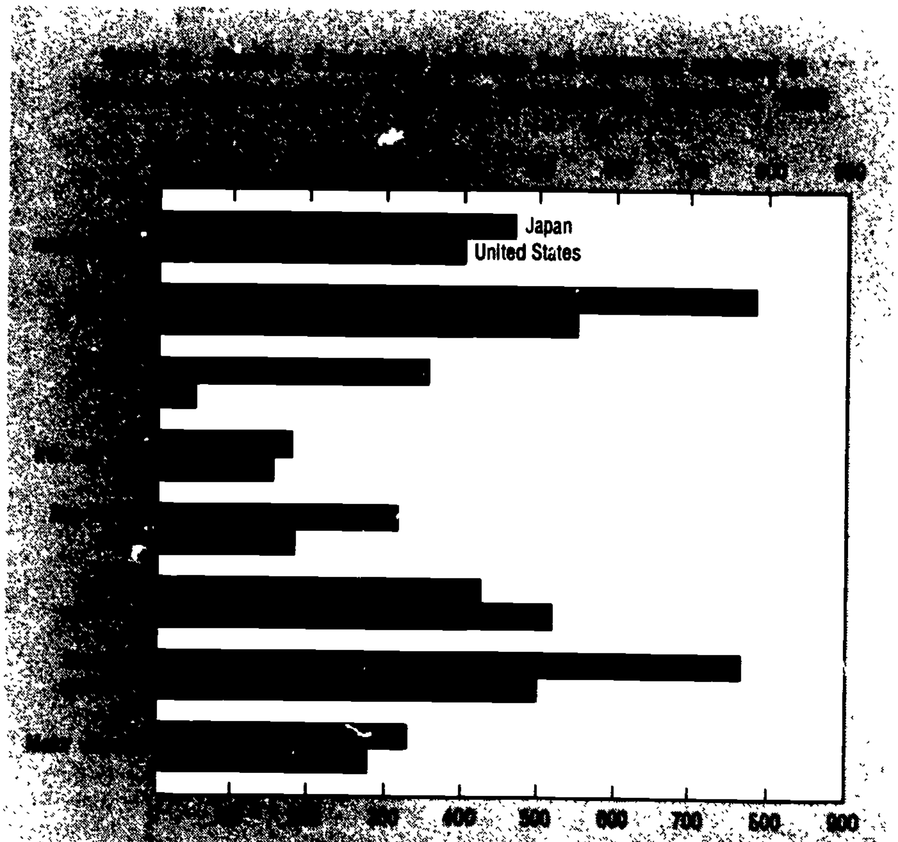
In Japan, the greatest levels of company concentration of manufacturing R&D occurred in the iron and steel (78 percent of R&D accounted for by the top five R&D firms), petroleum and coal (71 percent), motor vehicles (69 percent), and rubber (60 percent) industries. In the United States, the concentration was highest in the motor vehicles (96 percent), petroleum and coal (71 percent), industrial chemicals (70 percent), and professional and scientific instruments (65 percent) industries.



The most R&D-intensive industries were not the most R&D-"monopolized" industries in either country. In Japan, the most R&D-intensive industries (pharmaceuticals, communications and electronic equipment, and professional and scientific instruments) had less than 60 percent of their R&D accounted for by the top five firms. In the United States, the most R&D-intensive industries (professional and scientific instruments, pharmaceuticals, and communications and electronic equipment), had 65 percent or less of their R&D accounted for by the top five firms.

industrial scientists and engineers engaged in r&d

Accompanying the growth of industrial R&D expenditures is the increase in industrial scientists and engineers engaged in R&D. In 1965, there was a total of 59,000 Japanese scientists and engineers engaged in industrial R&D; this represented about one-fifth the U.S. 348,000 full-time equivalent. During the past 2 decades the number of Japanese industrial R&D scientists and engineers has increased at an average annual rate of 7.1 percent, compared to 2.5 percent for the United States. Thus, by 1985 Japan employed 231,000 scientists and engineers engaged in industrial R&D—two-fifths as many as the 570,000 full-time equivalent in the United States (table B-19). Although Japan has a lower absolute number of industrial scientists and engineers, Japan's 1985 ratio of manufacturing R&D scientists and engineers per 10,000 employees was 470 compared to the 400 full-time equivalent for the United States (chart 22).



SOURCE: National Science Foundation, SRE, table B-17.

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chapter 4.

higher education

Because the Japanese and U.S. higher education systems are very different, it is difficult to make international comparisons of the resources devoted to R&D in the higher education sector. For the purposes of this discussion, the Organisation for Economic Co-operation and Development (OECD) definition of higher education is used: it comprises all universities, colleges of technology, and other institutes of post-secondary education whatever their legal status or source of funding; and includes all research institutes, experimental stations, and medical facilities operating under the direct control of, administered by, or associated with higher education establishments. For instance, in the United States, R&D expenditures in the higher education sector include those funds spent not only in universities and colleges but also in federally funded research and development centers (FFRDCs) administered by individual universities and colleges and by university consortia.

Japan's university research system is composed of three types of institutions: universities, research institutes attached to universities, and National Interuniversity Research Institutes.[25] The university system consists of 96 national universities established under the authority of the Ministry of Education, Science, and Culture (Monbusho); 34 public institutions established by local governments; and 331 private institutions. R&D is also conducted at an assortment of junior and technical colleges which account for about 10 percent of the academic staff in the entire higher education system.

Research at the university level is also conducted in research institutes established within the universities as well as in the National Interuniversity Research Institutes. Recent policy emphasis has been on the cooperative use of research facilities: of the 69 institutes attached to the national universities, 12 are available for joint use. The more than 500 research institutes affiliated with public and private universities are devoted primarily to the humanities and social sciences.

To promote research and academic cooperation in those fields of science which require large-scale facilities and equipment or collective

[25]The above discussion of the Japanese higher education research system is drawn from the Ministry of Education, Science, and Culture, *The University Research System in Japan* (Tokyo, Japan, 1986)

research, Japan established 12 National Interuniversity Research Institutes in the 1970's (table 2). These institutes are not attached to specific universities, are open to all university researchers, and are of the same legal classification as the national universities.

While the U.S. system relies mostly on separately budgeted R&D project awards, Japan principally depends on an institutional funding system in which universities and colleges receive GUF from the national Government for teaching, research, and facilities and equipment. Three-quarters of all Japanese higher education R&D funds are received through such general funds, whereas over three-quarters of U.S. higher education R&D funds are obtained from specifically budgeted project items.[26]

Table 2. Joint university and national interuniversity research institutes

Institutes	Location
Joint university research institutes:	
University of Tokyo	Tokyo
Institute for Cosmic Ray Research	
Institute for Nuclear Study	
Institute for Solid State Physics	
Ocean Research Institute	
Tokyo University of Foreign Studies	Tokyo
Institute for the Study of Languages and Culture of Asia and Africa	
Kyoto University	Kyoto
Research Institute for Fundamental Physics	
Research Institute for Mathematical Sciences	
Research Reactor Institute	
Primate Research Institute	
Nagoya University	Nagoya
Institute of Plasma Physics	
Osaka University	Osaka
Institute for Protein Research	
Welding Research Institute	
National Interuniversity Research Institutes:	
National Laboratory for High Energy Physics	Tsukuba
National Museum of Japanese History	Sakura
National Center for Science Information System	Tokyo
National Institute of Polar Research	Tokyo
Institute of Space and Astronautical Science	Tokyo
National Institute of Japanese Literature	Tokyo
Institute of Statistical Mathematics	Tokyo
National Institute of Genetics	Mishima
Okazaki National Research Institutes	Okazaki
Institute for Molecular Science	
Institute for Basic Biology	
Institute for Physiological Sciences	
National Museum of Ethnology	Osaka

SOURCE Ministry of Education, Science, and Culture. *The University Research System in Japan* (Tokyo, Japan, 1986)

overall r&d trends

The higher education sector appears to play a larger role in the Japanese R&D system than that in the United States. In 1985, 31 percent of Japan's natural scientists and engineers engaged in R&D were in higher education (60 percent of Japanese natural scientists and engineers engaged in R&D are in health-related fields). In contrast, 14 percent of the U.S. natural scientists and engineers engaged in R&D were in higher education. As a share of total R&D, R&D performance in 1985 in the higher education sector accounted for 20 percent in Japan and 12 percent in the United States.[27] In both Japan and the United States, the higher education sector conducts comparable shares (55-56 percent) of the national basic research effort.

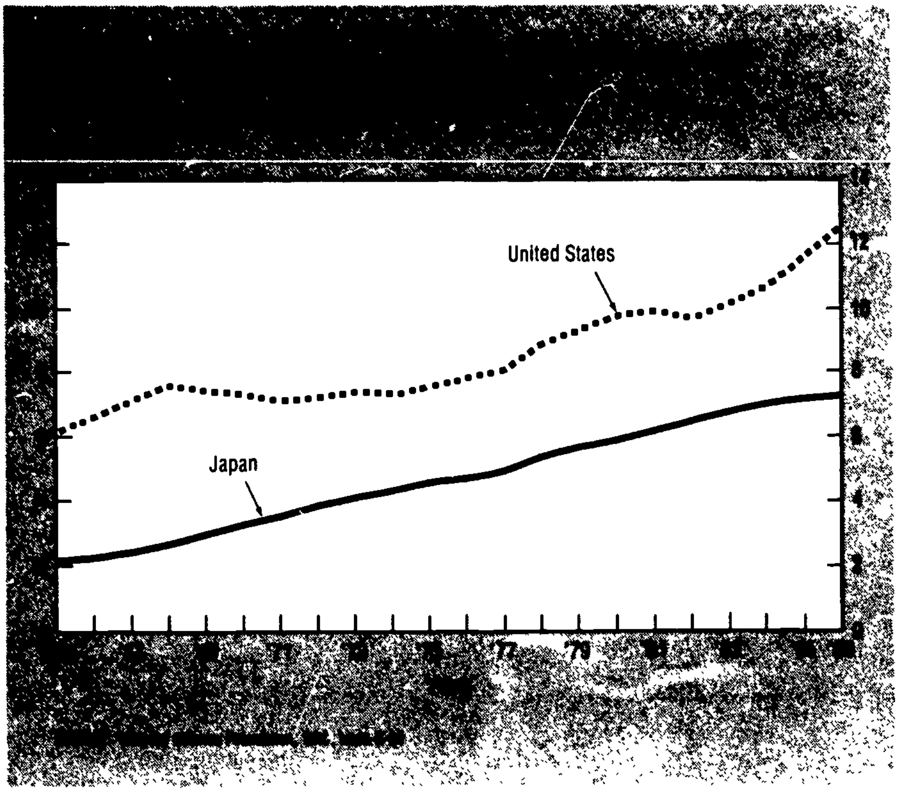
From 1965 to 1986, R&D performance in the higher education sector more than tripled in constant dollar terms in Japan and doubled in the United States (chart 23). Japanese expenditures increased at an average annual rate of 6.1 percent, compared with 3.2 percent in the United States. In 1986, R&D expenditures in Japanese higher education totaled constant $7.3 billion; U.S. expenditures totaled constant $12.7 billion. As a share of total R&D, Japanese higher education R&D declined from 36 percent in 1965 to 20 percent in 1986 (chart 24). This was largely because of the higher average annual rates of increase in R&D expenditures by industry, government, and private research institutes. In comparison, U.S. higher education expenditures as a share of total R&D increased slightly, rising from 11 percent in 1965 to 13 percent during 1975-81; expenditures have remained at 12 percent since 1982.

In Japan, as in most European countries, higher education statistics relating to R&D revenues and expenditures include a sizable portion of GUF, which includes normal operating expenses. A recent study by Martin and Irvine[28] illustrates the implications of including a proportion of such funds for computing government-funded academic research. Of Japan's government-funded academic research, the study found that 75 percent is allocated for GUF, compared with the study's es-

[26] These data are presented in Ben Martin and John Irvine, *An International Comparison of Government Funding of Academic and Academically Related Research* (Sussex, England University of Sussex, Science Policy Research Unit, 1986) The United States does not have the equivalent of GUF, Martin and Irvine have attempted to identify and include those U S funds that are comparable to GUF

[27] If the United States had data on and included data from State and local governments, this 12-percent share for the higher education sector would likely be higher

[28] Martin and Irvine, op cit



timated 23 percent for the United States (table 3). Monbusho reports that of its budget for promoting scientific research, equal shares (38 percent each) go to research institutes and national university facilities; 13 percent is allocated for scientific research grants; and the remaining 11 percent goes to all other programs including, for example, the Antarctic program and subsidies to public and private universities.

Private higher educational institutions occupy a major place in the Japanese system, employing about one-half of all university researchers (38 percent of the scientists and engineers engaged in R&D in the natural sciences and engineering) and accounting for nearly three-quarters of all student enrollments. Further, they account for a substantial proportion of the funds expended on higher educational R&D: 53 percent of the 1985 total. The research activities of private universities place greater relative stress on applied topics, especially in medicine and the social sciences, than do national universities. In general, the national universities are viewed as centers for the most significant basic research

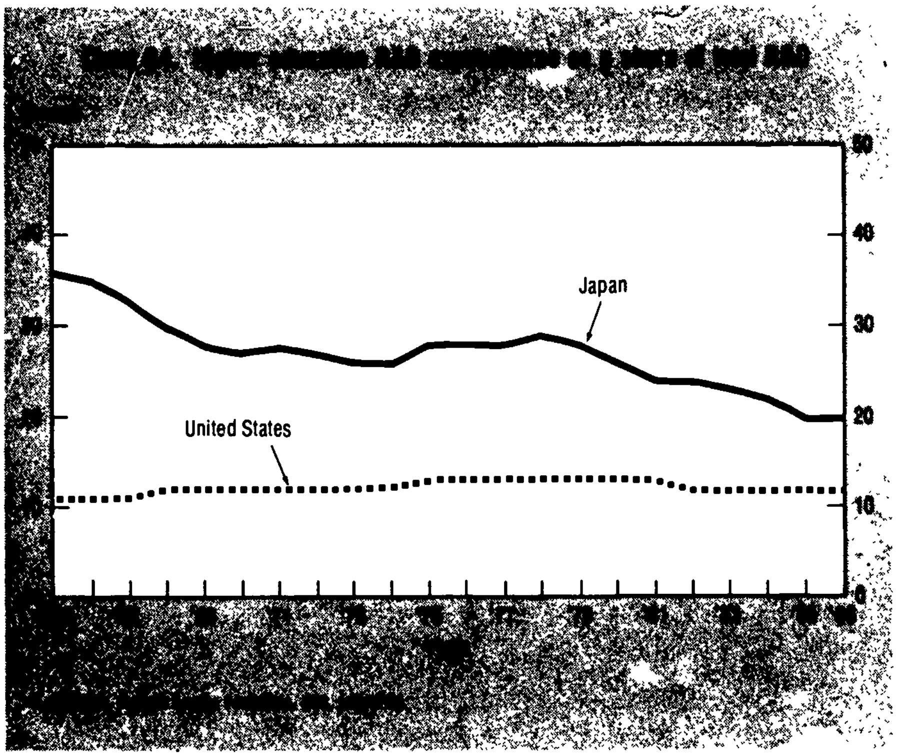


Table 3. Government funding of academic research: 1982

[Percent]

Item	United States	Japan
Total	100 0	100.0
Separately budgeted academic research	77.2	25 1
General university funds[1]	22.8	74.9

[1]The United States does not have a system of general university funds (GUF) like that of Japan and most of Europe Martin and Irvine attempted to identify those U S R&D funds that were similar to GUF in order to distinguish separately budgeted research funds from those of a more general nature

SOURCE Ben Martin and John Irvine, *An International Comparison of Government Funding of Academic and Academically Related Research* (Sussex England University of Sussex, Science Policy Research Unit, 1986)

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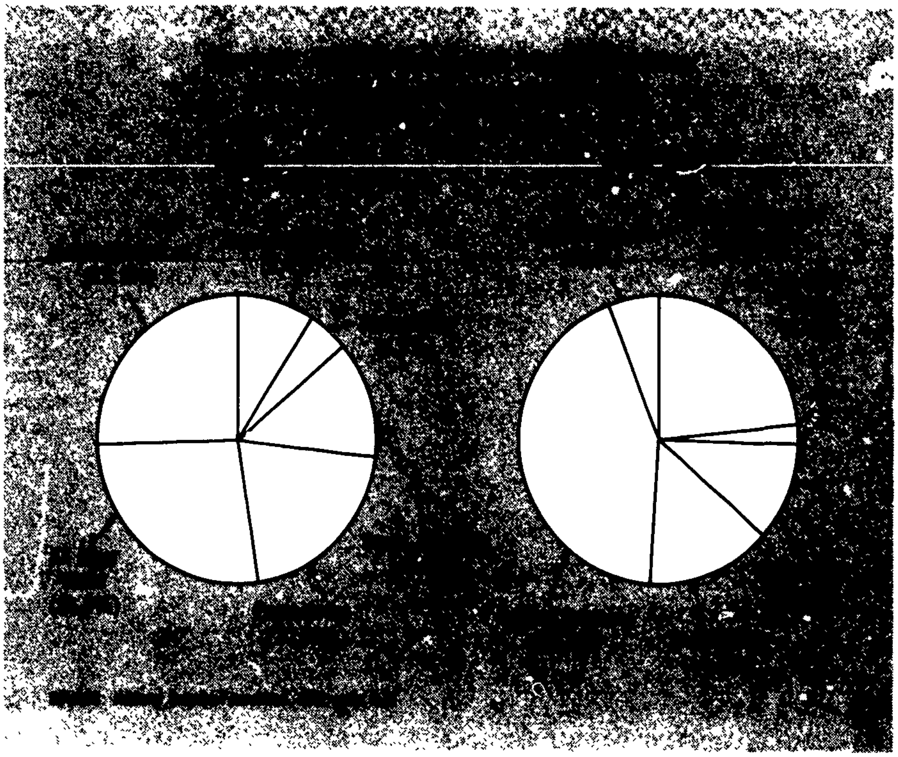
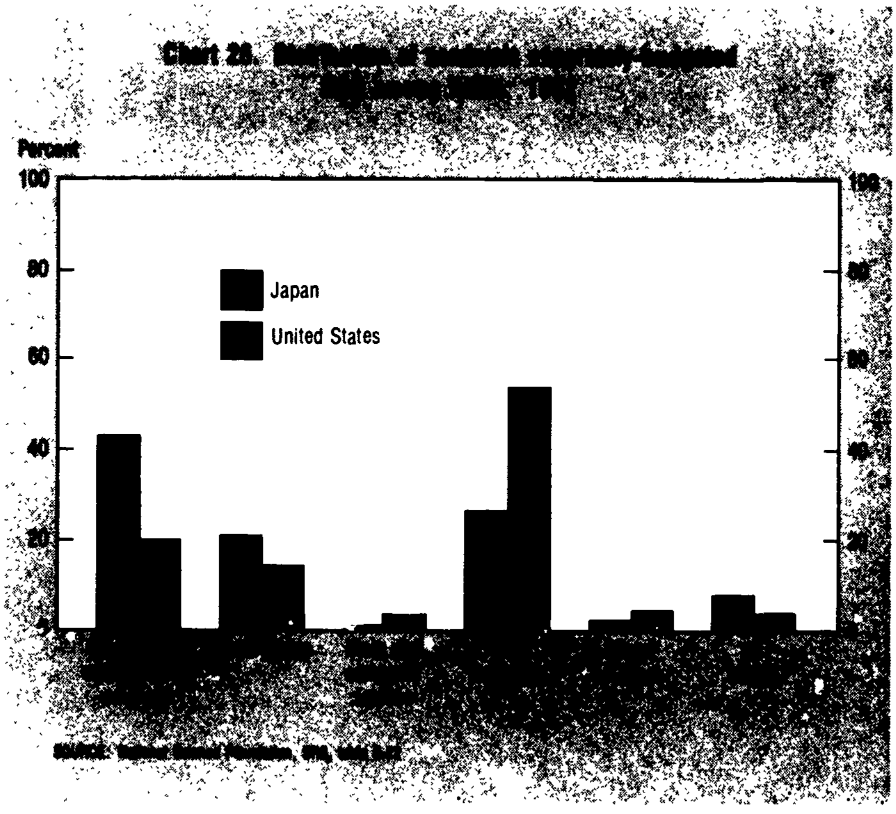
r&d by field

Because the basic infrastructure of Japanese higher education is heavily influenced by private universities in terms of number of institutions, distribution of faculty, and share of student enrollments, the distribution by field of total higher education R&D expenditures is concentrated in the social sciences, humanities, and other related fields since these are the major areas of instruction and research at private institutions. Consequently, the national patterns of Japanese higher education expenditures reflect the emphasis of private institutions: 40 percent of R&D expenditures in Japanese higher education are in the social sciences, humanities, and other liberal arts fields (chart 25).[29] In contrast, the United States expended only 5 percent in social sciences R&D; it does not include liberal arts and related fields in its R&D data.

Japan's separately budgeted R&D figures are more comparable to those of the United States because they do not include GUF expenditures, which help to support infrastructure. The share of academic separately budgeted R&D in Japan going to fields other than the natural and social sciences and engineering was 8 percent in 1982—a sharp contrast to the 27-percent figure for total higher education R&D. The distribution of separately budgeted R&D among fields is significantly different in Japan than in the United States. For example, the highest concentration of Japanese separately budgeted funds is in the physical sciences (36 percent compared to 12 percent in the United States); in the United States, concentration is in the life sciences (54 percent compared to 26 percent in Japan) (chart 26). Japan





[29]More than one-half of the R&D conducted at private Japanese universities is in fields other than science and engineering, compared with only 22 percent at the national universities

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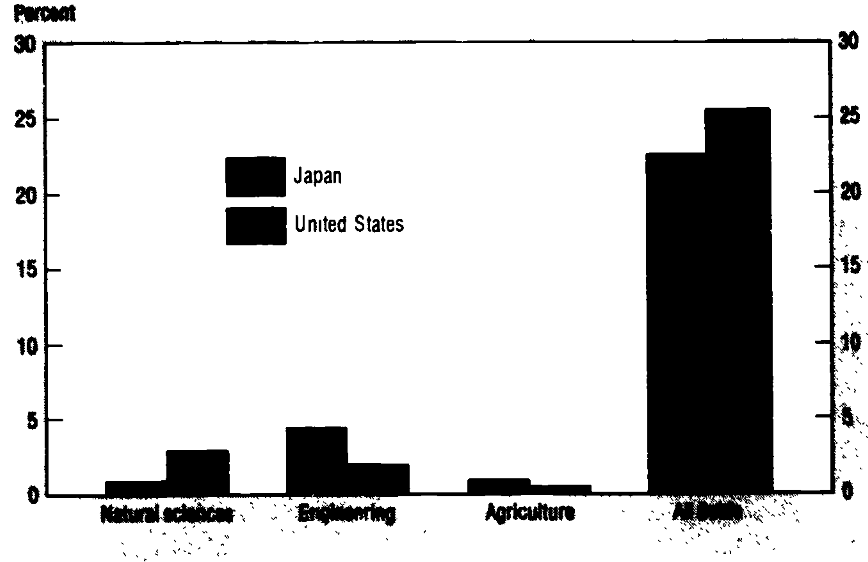
spends about 20 percent of its separately budgeted R&D on engineering, compared to 14 percent in the United States.

Chart 27. First-university degrees as a proportion of the 22-year-old population: 1985



SOURCE: National Science Foundation, SRS, table B-23

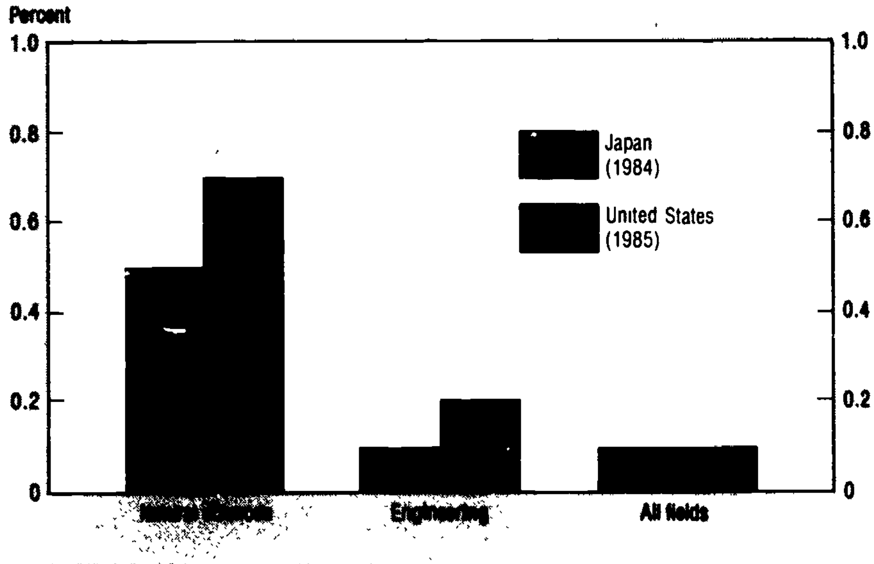
s/e degree production

The higher education system is by definition responsible for advanced education as well as research. This education is closely coupled with research, especially at the postgraduate level; moreover, the output of trained scientists and engineers is a significant contribution to a nation's S/T capabilities.

Japan's undergraduate education system is one of the largest in the world in proportion to the size of its college-age population. In 1985, the Japanese ratio of all first university degrees as a proportion of the 22-year-old population was 22.6 percent, compared to 25.3 percent for the United States (chart 27). The United States confers a significantly higher total number of doctorates than does Japan; however, when the number of doctoral degrees is measured in proportion to the 27-year-old age group, the overall ratios are close: 0.5 percent for Japan and 0.7 for the United States. The difference is in part due to the higher U.S. proportion of natural sciences doctorates (chart 28).[30]

While Japan's higher education system annually graduates about the same number of first-degree engineers as does the United States, it graduates only about one-tenth as many first-degree students in the natural sciences. The distribution of Japanese first university S/E degrees among fields is dissimilar to that of the United States, but both countries grant about the same relative

Chart 28. Doctoral degrees as a proportion of the 27-year-old population: 1984 or 1985



SOURCE: National Science Foundation, SRS, table B-24

[30]Note that an increasingly higher proportion of doctorates granted in the United States go to non-U S citizens In 1985, 28 percent of all S/E doctorates were granted to noncitizens, the proportion was 57 percent for engineering doctorates

proportion of degrees in fields other than science and engineering.[31] Japan grants 19 percent of its first university degrees in engineering (7 percent in the United States) and 3 percent in the natural sciences (11 percent in the United States). Analysis of the career histories of university graduates suggests that many of the graduates of Japan's engineering and agriculture courses assume jobs analogous to those taken on by U.S. science graduates.

With a population size just over one-half that of the United States, Japan in 1976 first exceeded the United States in the granting of first-degree engineering degrees; it retained this lead through 1982, after which time the number of engineering degrees granted in the United States surpassed that of Japan. (In 1985, the United States conferred 9 percent more engineering degrees than did Japan.)[32]

While figures on engineering degrees by detailed field are not available for Japan, it is possible to compare enrollments. Both Japan and the United States have about the same shares of engineering enrollments in mechanical and electrical/computer engineering combined (49-52 percent), but greater emphasis is on mechanical engineering in Japan and electrical engineering in the United States. The distributions of enrollments among engineering fields are also generally different (table 4). The actual number of Japanese students enrolled in engineering significantly exceeds U.S. enrollments in the fields of mechanical, chemical, civil, and metallurgical/materials engineering. U.S. enrollments in electrical and computer and aeronautics/aerospace engineering are much higher than in Japan (the aerospace industry in the United States is much larger than in Japan). One major qualifying factor to these comparisons is that the United States has a much higher proportion of "all other" engineering majors (half of which are undeclared majors) than does Japan (table 4).

Foreign students have traditionally constituted an exceptionally small portion of Japanese undergraduate enrollments (less than 1 percent in 1984); at the graduate level,

Table 4. Enrollments in first-degree engineering programs by field of study:[1] 1985

Field of study	Japan		United States	
	Number	Percent	Number	Percent
Total	343,590	100 0	384,191	100 00
Mechanical	74,354	21 6	66,738	17.4
Electrical and computer	95,429	27 8	132,917	34 6
Chemical	39,679	11 5	23,423	6 1
Civil	75,801	22 1	37,556	9 8
Engineering science	5,966	1 7	7,092	1.8
Nuclear	1,551	5	1,857	5
Mining	1,623	5	2,431	.6
Metallurgical and materials	7,226	2 1	3 204	8
Marine	1,003	3	2,068	5
Aeronautic/aerospace	2,428	7	15,699	4 1
Industri	19,829	5 8	16,434	4 3
All others	18,701	5 4	[2]77,781	20 2

[1]Full-time students only

[2]Half of this group are undeclared engineering majors

SOURCES Government of Japan Ministry of Education, Science and Culture *Annual School Survey 1984* (Tokyo Japan, 1985), and *Engineering Education* (October 1986) p 59

[31]There are some difficulties in comparing social sciences In the United States, undergraduate social sciences include a narrow range of specialties, in Japan, the range is broader and includes such fields as commerce and law Comparisons of the "social sciences" and "all other" categories should be treated with some caution, however, the two categories combined do provide comparable representations of activity in fields other than natural sciences and engineering

[32]Note the difficulties of cross-national comparisons of numbers and proportions receiving first-degree engineering degrees. Some maintain that Japanese training in engineering is at a lower level than U S training. Most Japanese educators dispute this view, and maintain that Japanese engineering students receive greater exposure to both basic science subjects and laboratory work

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foreign students in Japan constitute approximately 7 percent of enrollment. In 1984, Monbusho announced a plan to increase the number of foreign students tenfold by the year 2000. If this occurs, foreign students will constitute approximately 5 percent of all students in Japanese higher education, and possibly one-quarter of all graduate students. Currently, foreign students of Western origin in Japan are most likely to specialize in the humanities and social sciences, while those from Asia and the Third World are most likely to specialize in the sciences and engineering.[33]

[33]Factors influencing foreign student enrollments in Japan are discussed in Joseph Hicks, "The Situation of Asian Foreign Students in Japan—Can Japanese Universities Handle a 10-Fold Increase?", *Higher Education Expansion in Asia* (Hiroshima, Japan, Research Institute for Higher Education, Hiroshima University, 1985), pp. 141-150

postgraduate education

Postgraduate education is not as strongly emphasized in Japan as in the United States and most of Europe; however, statistics may not fully reflect the number of Japanese receiving some form of postgraduate education. Many of Japan's scientists and engineers leave the university for industrial or other employment immediately upon completion of their first degree. While pursuing a career at a new location, they usually maintain contact with their former professor. If they complete a research project that meets with the professor's approval, they may submit a report as a basis for obtaining a thesis degree.

In Japan, the major constraint on graduate enrollment is the lack of associated employment opportunities. For example, in 1983, 51.0 percent of science and 44.9 percent of agriculture doctoral graduates could not get jobs, but this situation is expected to change.[34] During the past 2 decades, employment opportunities for engineers with master's degrees have improved: engineering now accounts for 44 percent of all master's degrees granted. At the doctoral level, the most popular fields are medicine and dentistry. Monbusho would like to see more students enrolled in graduate education, and has developed a program that would lead to a threefold increase in master's degree level enrollments and a fourfold increase in doctoral enrollments by the year 2000.

[34]Keuchi Yamada, "Kagukusha Yosei no Arikata Buneki Suru. Ova-Dokuta Mondai, Chushin ni," *Shizen*, January 1984, pp 76-83

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chapter 5.

outputs and impacts

New knowledge resulting from R&D is sometimes identifiable by discrete events which can be used as measures of the *output* of R&D activity. Scientific literature and patents are two such *output* indicators. Scientific publications reflect research of significance to the scholarly community; patent registration reflects inventive activity of potential commercial consequence.

The *impact* of new knowledge resulting from R&D is more difficult to measure, especially with regard to basic research. R&D would, however, be expected to have an impact on such economic factors as productivity, demand for technological know-how, and international trade. These factors are, in turn, quantifiable in the form of manufacturing output, royalties and fees, and technology-intensive trade; these can be used as rough measures of the impact of a nation's R&D efforts.

scientific literature

The measurable outputs of S/T literature include journal articles, conference papers, technical reports, and literature citations. Conventions for measuring the volume and importance of these various outputs differ among countries,[35] and Japanese-developed indicators for most of the outputs tend to assign higher levels of absolute and relative productivity to Japan than do similar U.S.-developed indicators.

A recent Japanese study by the Mitsubishi Research Institute (MSK) estimated the world volume of scientific literature output for the years 1972, 1977, and 1982 and found that the amount of such literature rapidly increased over this 10-year period.[36] During 1972-82, the volume of Japanese scientific literature grew at a faster rate than the world total, slightly increasing the Japanese share of each type of literature (table B-25). This growth was most substantial in

[35]There are a number of reasons for national differences in indicators Regarding scientific publications, for example, U S and European researchers use the SCI for many of their analyses Critics of this data base argue that it (1) overemphasizes science relative to technology, (2) relies on a limited set of the world's influential scientific journals (over 3,500 since 1981), and (3) the majority of these publications are in English However, coming from the prestigious, world-class journal set which publishes articles from a variety of countries (country-of-author is assigned at the individual article level), the articles do represent a standard of quality and potential impact Another benefit of the SCI data base is that it provides citation data with which to measure an article's subsequent usage or impact

A bibliometric data base has been developed by MSK which includes more than 10,000 journals with greater representation of technology and of non-English journals The MSK system reviews all articles from this broader base, including those articles which present a minimal level of new data collection and/or original analysis For more information on MSK study, see footnote 36 in this chapter

[36]MSK surveyed S/T publications in the fields of mathematics, physics, biology, geology, medicine, engineering, and agriculture Data were collected to cover several newly industrializing countries including Korea, Taiwan, Thailand, and Indonesia, as well as the major industrialized nations For scientific publications, MSK drew from field-specific data bases Mathfile, INSPEC A for physics, CA Search for chemistry, BIOSIS Preview for biology, GEOREF for geology, Excerta Medica for medicine, COMPENDEX for engineering, and CAB Abstracts for agriculture For technical reports, a data base was created from reports listed by the U S National Technical Information Service, Britain's System of International Gray Literature and several Japanese sources The principal sources for the conference papers included the Conference Paper Index, ISI's Index to Scientific and Technical Proceedings, Chemical Abstracts, the EI Engineering Meeting Bulletin, and JICST's International Conference file For more detail, see Mitsubishi Sogo Kenkyusko, *Kagaku Gijutsu Joho no Kokusai-teki Ryutsu no Arikata ni Kansuru* (Tokyo, Japan MSK, March 1984), p 7ff

the presentation of conference papers, which nearly quadrupled over the period; and in the output of technical reports, which tripled (chart 29). Although there was a nearly twofold increase in U.S. conference papers, the U.S. share of this literature declined from 45 percent to 41 percent, and there was an absolute as well as relative decline in the number of U.S.-authored technical reports.

According to the *Science Citation Index* (SCI), Japanese researchers produced 5.1 percent of the world's S/T journal articles in 1973 and 7.3 percent in 1982; U.S. shares were 39.2 percent and 37.2 percent, respectively (table 5). By 1984, the Japanese share had increased to 7.6 percent, compared to 36.8 percent for the United States.[37] The MSK series (see footnote 36) shows a larger Japanese share—10.3 percent in 1973 and 13.1 percent in 1982—but this difference may be partially accounted for by the more select range of journals covered by SCI, which has fewer journals in the fields of engineering and agriculture.

[37] These SCI figures are based on a constant 1973 journal set which includes psychology

Table 5. Share of world's science and technology articles written by Japanese and U.S. researchers, by field: 1972-73 and 1982

[Percent]

Field	SCI[1]				MSK			
	Japan		United States		Japan		United States	
	1973	1982	1973	1982	1972	1982	1972	1982
Agriculture	NA	NA	NA	NA	11.5	11.0	31.3	33.6
Biology	5.3	6.6	46.4	44.0	10.4	10.4	36.4	36.4
Biomedicine	4.0	6.5	39.2	41.1	10.7	12.1	32.2	34.5
Chemistry	9.4	11.6	23.3	21.9	8.3	17.9	38.3	31.6
Clinical medicine	3.5	5.6	42.8	42.1	NA	NA	NA	NA
Earth and space	2.0	2.1	46.7	43.1	5.0	4.3	43.0	45.1
Engineering	5.4	7.9	41.8	41.5	13.4	13.4	36.4	36.4
Mathematics	3.9	6.0	47.9	38.7	7.9	8.0	37.6	37.4
Physics	6.5	9.0	32.7	29.6	11.3	13.4	32.4	24.1
All fieldss[2]	5.1	7.3	39.2	37.2	10.3	13.1	35.7	33.8

[1] Based on articles, notes, and reviews in a fixed set of about 2,300 journals covered by the *Science Citation Index* since 1973

[2] Includes psychology

NOTE NA Not separately available

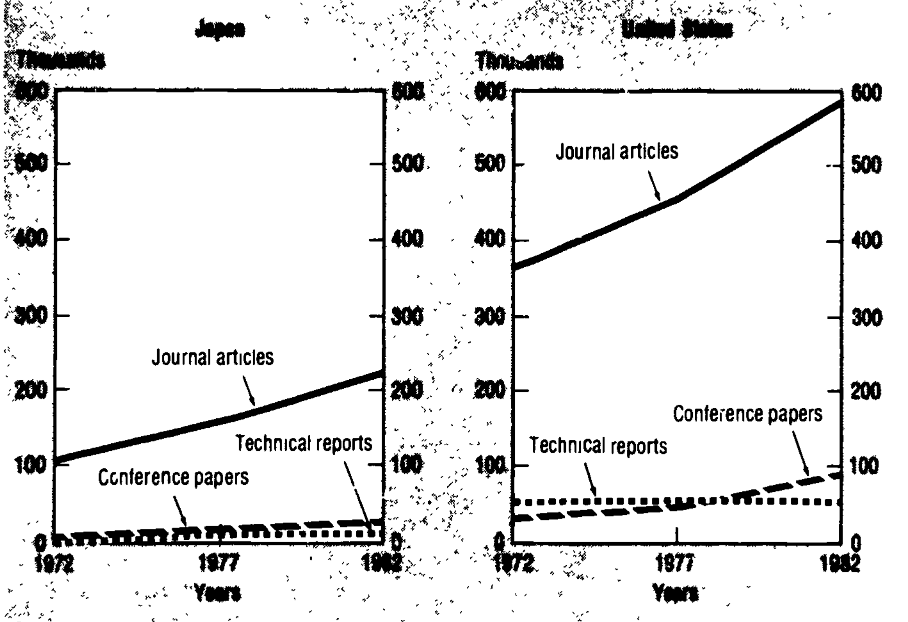
SOURCES SCI data from Computer Horizons, Inc., unpublished findings, MSK from Mitsubishi Sogo Kenkyusho, *Kagaku Gijitsu Joho no Kokusai-teki Ryutsu Arikata ni Kan-suru* (Tokyo, Japan MSK, March 1984), p 12

Although the MSK data show considerably higher Japanese and slightly lower U.S. shares of the scientific literature, both data sets generally reflect similar trends and distributions among fields. Both sources indicate that Japanese researchers' shares of publications are largest in the fields of chemistry, engineering, and physics; and lowest in the earth and space sciences. Both also indicate that the U.S. share of the world's scientific literature slightly declined from 1972 to 1982 by 2 percentage points.

According to the SCI data, the Japanese share of S/T articles during the 1973-82 period was greatest in the pharmacy subfield, with Japanese publications accounting for 25 percent of the articles written in that subfield (table 6). The next largest shares were in polymers (18 percent) and marine biology and hydrobiology (14 percent).

Journal citation rates are one measure of the quality of articles being published. On this indicator, Japanese authors have done slightly less well than expected overall, but have improved significantly over the 1973-83 period and performed strongly in the engineering subfield. Using share of total citations to share of total papers as a relative citation indicator, a value of 1.0 reflects expected performance: articles are being cited at the same rates at which they are

Chart 29. Trends in scientific literature outputs



SOURCE: National Science Foundation, 1986, table 8-25

ERIC

Table 6. Japan's share of world science and technology articles, by selected subfield:[1] 1973-82

Subfield	Percent
Pharmacy	25
Polymers	18
Marine biology and hydrobiology	14
General chemistry	13
Electrical engineering and electronics	12
Applied physics	12
Agriculture and food science	11
Microscopy	11
Organic chemistry	10
General physics	10
Analytical chemistry	10
Embryology	10
Nuclear technology	10

[1]Subfields in which Japanese articles represented 10 percent or more of subfield Data are from a fixed set of about 2,300 journals covered by the *Science Citation Index* since 1973

SOURCE Francis Narin and Dominic Olivastro, *Activity Analysis Using SIC Categories and Scientific Subfields*, interim report by Computer Horizons, Inc, to the National Science Foundation, May 1986

published. On this basis, total Japanese-authored articles have slightly less of an impact than would be expected—in 1983, the relative citation ratio for all Japanese articles was 0 91.[38] However, this ratio was up significantly from its 1973 level of 0.77, and in engineering it increased from 0.76 in 1973 to 1.25 in 1983. In comparison, the U.S. citation ratio for all articles was 1.36 in 1973 and 1.34 in 1983.

patent indicators

Patents are often considered an indicator of the vigor of individual scientists and engineers, corporations, or nations in developing new products and processes. However, national practices regarding domestic patent applications and grants often make comparisons of absolute numbers of patents problematic. For example, in Japan and Germany both actual inventions and practical designs are acceptable as the basis for a patent application; in the United States, the more stringent criterion of actual invention customarily is required for a patent application. Also, in some countries (including Japan), patent applications are viewed as a key indicator of a laboratory's productivity. Under such circumstances, and especially when the cost for submitting a domestic application is modest, companies may submit a number of applications for inventions that have little likelihood of ever being implemented.[39]

On the other hand, since submitting applications to foreign countries is more costly, companies usually make foreign applications only for those inventions that are genuinely believed to have commercial value in the foreign market. Based on this tendency, comparisons of patent applications abroad can indicate the most important or potentially profitable inventions.

Japan accounts for the largest share of foreign-origin patents in the U.S. patent system. Analysis of Japanese-invented U.S. patents granted between 1970 and 1986 demonstrates substantial Japanese patenting activity: during the period, the share of U.S. patents annually granted to the Japanese increased from 4 percent to 19 percent. As shown in table 7, the Japanese share of patents by SIC category also has risen dramatically. In 1975, Japanese-origin patents accounted for 9 percent of U.S. patents granted for all SIC categories; by 1985, this share had doubled to 19 percent. In most SIC categories, the Japanese share of total patents granted was nearly 20 percent or more; the shares were highest in the office computing machinery (33 percent), aircraft and parts (30 percent), and communications equipment and electronic components (26 percent) category.

Table 7. Japanese-invented U.S. patents by SIC category: 1975 and 1985

[Percent]

SIC category	Share of total patents granted 1975	1985
Food	8	11
Textiles	10	17
Chemicals and allied products	10	15
Petroleum	3	6
Rubber	10	18
Ceramics[1]	8	20
Primary metals	13	23
Fabricated metals	5	12
General machinery	7	15
Office computing and accounting machines[2]	13	33
Electrical machinery	10	21
Communications equipment and electronic components	13	26
Motor vehicles	7	23
Aircraft and parts	10	30
Professional and scientific instruments	12	23
All fields	9	19

[1]Stone, clay, and glass products

[2]Includes computers

SOURCE Office of Technology Assessment and Forecast, U S Patent and Trademark Office, unpublished data

In terms of patent class (as opposed to SIC group), Japanese patenting activity during 1975-84 was concentrated in the internal combustion engines, radiation imagery, and photography patent classes; more than 2,000 patents were granted in each of these three classes during the 1975-84 period (table B-26). The Japanese shares were highest in the photography (53 percent), dynamic magnetic information storage (38 percent), photocopying (36 percent), and radiation imagery (35 percent) patent classes.

Table 8 indicates several technology areas in which Japanese patenting activity has been especially vigorous. In all technological areas,

[38]See Francis Narin and Dominic Olivastro, *Identifying Areas of Leading Edge Japanese Science and Technology*, Final Report to the National Science Foundation, Division of Science Resources Studies, April 1988, p. 170.

[39]The standard legal text comparing international patent systems is John P Sinnott, *World Patent Law Patent Statutes, Regulations, and Treaties* (New York, New York. Matthew Bender & Co, Inc, 1974), and is updated annually See also Stephen Ladas, *Patents, Trademarks, and Related Rights, National and International Protection* (Cambridge, Mass Harvard Univ Press, 1974). Note that there have been recent changes in Japanese patent law, including the removal of single-claim restrictions

Table 8. U.S. and Japanese shares of total patents granted in the United States for selected technologies: 1975 and 1986

[Percent]

Selected technologies	United States		Japan	
	1975	1986	1975	1986
Lasers	63	50	14	35
Telecommunications	66	52	14	26
Steel and iron	48	37	18	29
Internal combustion engines	54	28	17	44
Semiconductor devices and manufacture	68	57	13	29
Jet engines	66	60	4	9
General purpose programmable digital computer systems	77	69	5	19
Robots	63	50	20	29
Machine tools—metalworking	65	51	8	17
All technologies	65	54	9	19

SOURCE Office of Technology Assessment and Forecast, U S Patent and Trademark Office, unpublished data

Japan's share of U.S. patents granted has increased. The largest gains have been in internal combustion engines, which rose from 17 percent of the patents granted in 1975 to 44 percent in 1986; and lasers, which rose from 14 to 35 percent. Other technological areas of extensive Japanese patenting activity are semiconductors, computer systems, and machine tools.

Japanese-origin patents are also among the most highly cited U.S. patents; in fact, Japan has one-third more of highly cited patents than expected based on the total number of U.S. patents granted to Japanese inventors. Citations to earlier relevant patents are assigned by U.S. patent examiners to new patents, and as such, define the boundaries of the technology preceding and contributing to the new invention. A high number of patent citations—repeated references to a technological predecessor of a new patent—is (essentially) the indicator of a very significant invention. For the top 1 percent of the most highly cited U.S. patents, Japanese patents account for 45 percent more of the top 1 percent, most highly cited U.S. patents than expected. The highest citation rates for Japanese patents are in the automotive, semiconductor electronics, photocopying and photography, and pharmaceuticals patent classes.[40]

[40]Narin and Olivastro, op cit

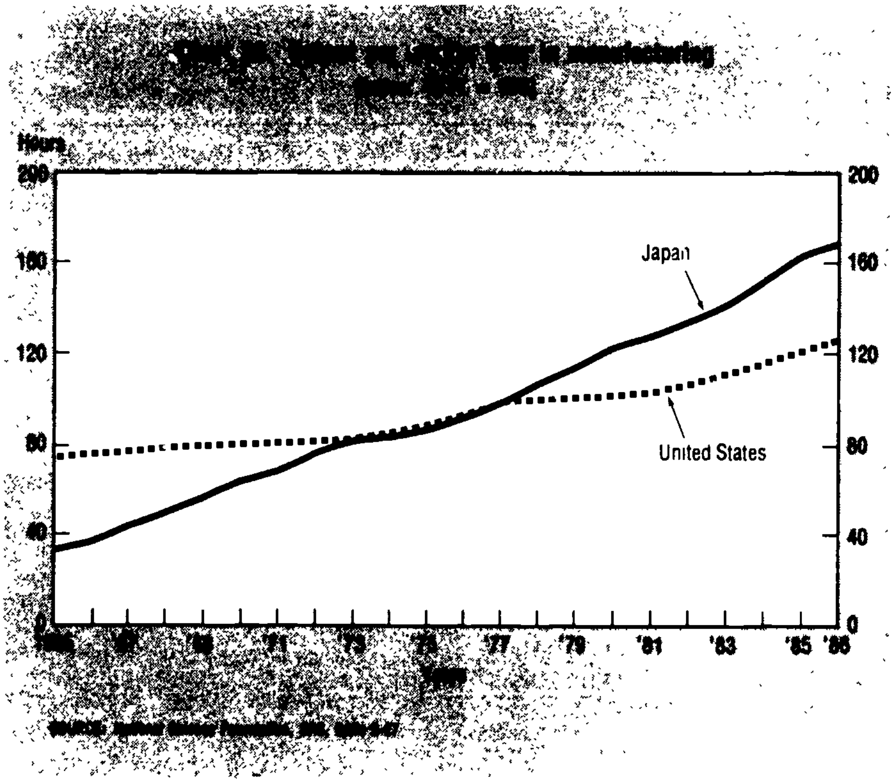
industrial productivity

Recent assessments[41] of Japanese technology have observed that one of Japan's strengths has been in applying technology to production processes. One study indicates that Japanese industries invest their R&D much more heavily in improved process technology than do their U.S. counterparts, and notes that "process R&D tends to have a bigger effect on an industry's own rate of productivity increase than does product R&D."[42]

Japan has made rapid progress in manufacturing productivity during the past decade; manufacturing output per worker-hour increased 68 percent from 1977 to 1986, compared with a 26-percent increase in the United States for the same period (chart 30). In recent years, U.S.

[1]See, for example, Lowell W Steele and N. Bruce Hannay, *The Competitive Status of U S Industry An Overview* (Washington, D C National Academy Press, 1985)

[42]Edwin Mansfield, *Industrial R&D in Japan and the United States A Comparative Study*, unpublished paper, 1987



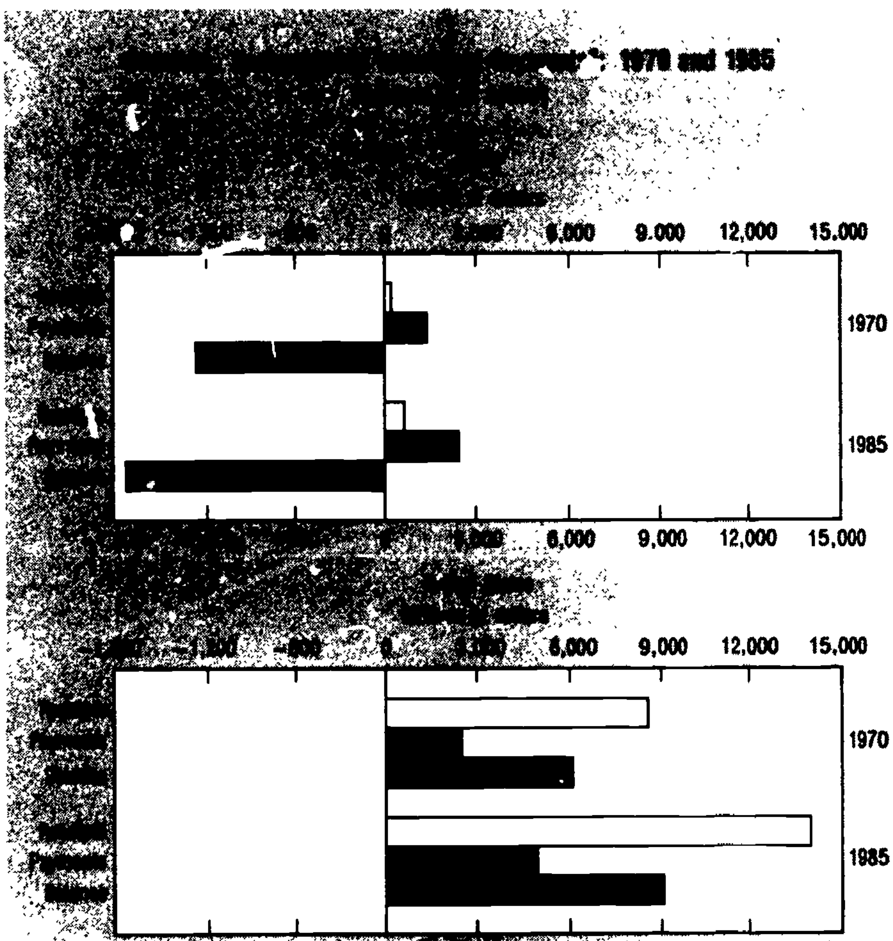
manufacturing productivity has increased more rapidly (at an average annual rate of about 4 percent from 1980 to 1986) than in the late 1970's; this still has not been as fast as Japan's (which increased at an average annual rate of about 6 percent from 1980 to 1986). Although Japan started from a lower absolute productivity base in the fifties and sixties, a recent Japanese study indicates that Japanese levels of actual value-added per worker equaled or surpassed the U.S. level in several key industries—including autos and steel—by 1980, primarily because of the rapid productivity gains made during the seventies.[43]

royalties and fees

National trends in technology transfer. Data on international transactions in royalties and fees are often used as indicators of technology transfer and demand for commercially attractive technology. Royalties and license fees are payments for the use of intellectual property, including patents, inventions or processes, copyrights, etc. Although data on royalties and fees are only partial measures of technology transfer, they do provide information on the direction of technology flows.

Data on international receipts and payments for technical know-how for Japan and the United States demonstrate the major differences between these two countries. The United States is a net exporter of technology whereas Japan is a net importer, and Japan purchases far more technical know-how from the United States than the United States does from Japan. Although Japan's technological balance of payments worsened in dollar terms from a deficit of constant $1.2 billion in 1970 to constant $1.7 billion in 1985, receipts as a share of payments improved, rising from 14 percent to 30 percent. This indicates a possible shift in Japan's dependence on imported technology, an increase in the salability of Japanese technology, and/or a greater willingness by the Japanese to sell their technology. In 1970, Japan received constant $194 million in payments for its technology; this increased to constant $721 million by 1985 (chart 31). Most Japanese technical know-how sales are to newly industrializing countries; most purchases are from industrialized nations. In 1985, 42 percent of Japan's sales and 99 percent of its purchases were with the United States and Europe (table 9). East Asian countries also purchase a significant share of Japanese technology—nearly 40 percent in 1975 and 1985. Sales to the United States increased from 10 percent in 1975 to 22 percent in 1985; payments also increased, rising from 63 percent to 71 percent.

Manufacturing technology transfer. A review of national patterns indicates that Japan invests heavily in foreign technology. Over the past decade, however, Japan's industrial expenditures on foreign technology relative to other indicators have decreased, as Japan's performance on two technical dependency indicators shows. First, payments for technical know-how as a percentage of



[43]Kazukiyo Kurosawa, *International Comparison of Productivity*, Paper presented to the International Productivity Symposium, May 11, 1983 (Tokyo, Japan).

Table 9. Japanese receipts and payments for technical know-how, shares by country: 1975 and 1985

[Percent]

Receipts and payments	1975	1985
Receipts from:		
Total	100 0	100.0
United States	10 4	22.1
Europe	21 1	19.4
South America	8 8	3.7
East Asia	39 2	37.4
All other countries	20.5	17.4
Payments to:		
Total	100 0	100.0
United States	63.1	71.2
Europe	35 4	27.8
All other countries	1 5	1.0

SOURCE Government of Japan, Science and Technology Agency

R&D expenditures declined significantly from 1975 to 1985 for all manufacturing industries except ceramics (which increased by 1 percentage point) and food processing (which remained the same) (table B-28).[44] In 1975, the ratio of payments to R&D for all manufacturing industries was 11 percent; in 1985, 5 percent. By 1985, in no industry other than ceramics did Japanese purchases of technical know-how exceed 8 percent of the respective industry's R&D expenditures, and in most industries this ratio was 5 percent or less.

As Japanese industry's overall dependence on foreign technology appears to have decreased over the past decade, some interesting industrial patterns have emerged. For several industries (textiles, chemicals, iron and steel, and motor vehicles), the technology know-how receipt to payment ratio exceeded 100 percent in 1985 while real payments for technology declined or remained the same: this indicates that the attractiveness of Japanese science and technology in these areas is increasing. In fact, for the iron and steel industry, receipts for Japanese technical know-how exceeded Japanese payments by almost 6 to 1. The receipt to payment ratio for all Japanese manufacturing industries was 36 percent in 1975 and 72 percent in 1985, and was about 50 percent or higher for most industries by 1985 (table B-28).

technology trade

National R&D efforts are often associated with changing positions in world trade. Comparative experience indicates that there is not a one-to-one relationship between R&D efforts and trade performance; rather, a more indirect effect exists because of the large number of variables affecting international trade.[45] Success in international trade is only partially dependent on having a good innovation; products have to be produced efficiently and marketed effectively to have an impact on trade. In addition, international differences in costs of production, trade barriers, and exchange rates can adversely affect the sales of otherwise attractive products.

Given these caveats, it has nevertheless been shown that R&D and technological innovation do play a major role in trade performance.[46] Japan has improved its position in international trade in tandem with its R&D expansion to such a degree that Japan's improved trade position with the United States has been a salient political issue for several years. Japanese technology-intensive trade with the United States has also markedly improved over the 1965-85 period. The Japanese trade surplus with the United States in technology-intensive[47] goods increased from current $143 million in 1965 to current $13 billion in 1985 (chart 32). Large trade surpluses existed in 1985 in radio and television receiving equipment, communications equipment, office and computing machines, and professional and scientific instruments. On the other hand, however, Japan had a negative trade balance in aircraft and parts, industrial inorganic chemicals, drugs, and agricultural chemicals (table 10). Japan has increased its world share of technology-inten-

[44]There are two series of data available for Japanese technology transfer One series is provided by the Bank of Japan and the other by the Government's Statistics Bureau, and there are some major differences between the two series The Bank of Japan data are on all economic sectors (government, services, etc.), and reflect only transactions involving the payment of royalties and fees. Statistics Bureau data are derived from the annual R&D survey (see appendix A, "Technical Notes") and on the industrial sector only Additionally, the Statistics Bureau data include not only royalties and fees, but services and sales of whole manufacturing plants if technology is transferred in the transaction The consequence is that the Statistics Bureau data show a higher volume of technology exports (32 percent higher in 1985) and a lower volume of imports (51 percent lower in 1985) than do Bank of Japan data

The data discussed in this section are from the Statistics Bureau, as disaggregated manufacturing data are not available from the Bank of Japan (the Bank of Japan royalties and fees data are presented in chapter 1, "National Patterns") For more information on technology transfer data from Japan, see Leonard H Lynn, "Technology Transfer to Japan. What We Know, What We Need to Know, and What We Know That May Not be So," in Nathan Rosenberg and Claudio Frischtak, eds , *International Technology Transfer Concepts, Measures, and Comparisons* (New York, New York Praeger, 1985), pp 255-276

[45]Raymond Vernon, *Then Technology Factor in International Trade* (New York, New York National Bureau of Economic Research, 1970), and Sherman Gee, *Technology Transfer, Innovation, and International Competition* (New York, New York. John Wiley and Sons, 1981)

[46]See, for example, both Vernon and Gee, op cit. Also see Rachel McCulloch, *Research and Development as a Determinant of U S International Competitiveness* (Washington, D C · National Planning Association, 1978), and Regina K. Kelly, *The Impact of Technological Innovation on International Trade Patterns*, Paper presented at the Conference on Government Industry Cooperation in Technological Innovation (Geneva, Switzerland, June 1977)

[47]There is no universally accepted definition of technology-intensive products. The definition used here is one that was adopted by the Organisation for Economic Co-operation and Development and the U S Department of Commerce (DOC2 definition) technology-intensive products are those products for which U S R&D expenditures exceed 2 36 percent of sales See table 10 for a list of the product fields included

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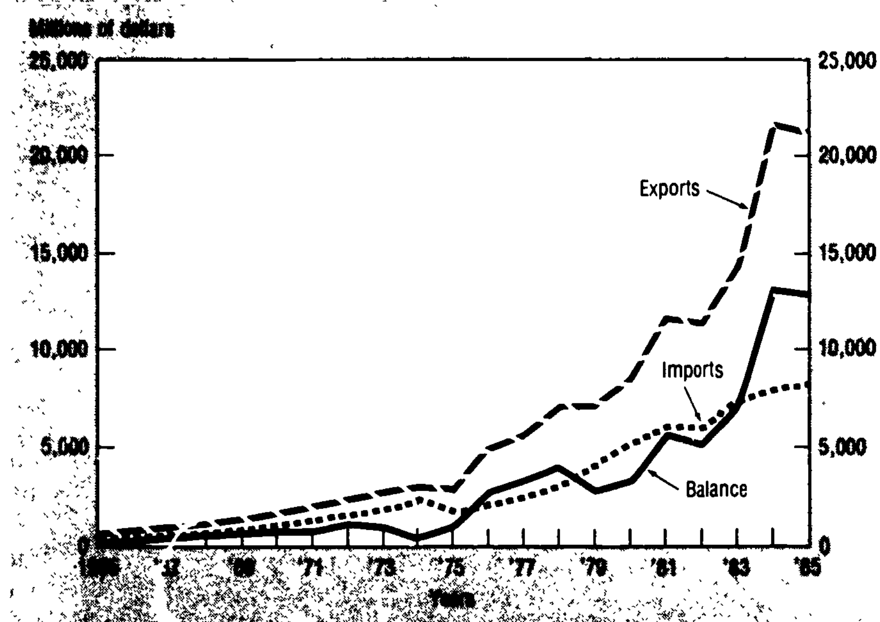


Table 10. Japanese trade with the United States in technology-intensive products:[1] 1985

Product group	Balance	Exports to United States	Imports from United States
Total	13,024 0	21,252 2	8,228 1
Aircraft and parts	− 1,931 1	113 0	2,044 1
Industrial inorganic chemicals	− 886 4	116 7	1,003 1
Radio and TV receiving equipment	5,919 3	5,925.9	6.6
Office and computing machines	2,915 8	4,101 5	1,185 7
Electrical machinery and equipment	713.4	1,922 1	1,208 6
Communications equipment	3,139 6	4,064 8	925 2
Professional and scientific instruments	2,660 0	3,270 6	610 6
Drugs	− 450 0	94 7	544 7
Plastic materials and synthetics	2 3	472 1	469 8
Engines and turbines	1,027 0	1,155 0	128 0
Agricultural chemicals	− 85 8	15 7	101 6

[1]Technology-intensive products are defined as those for which U S R&D expenditures exceed 2 36 percent of sales (U S Department of Commerce DOC2 and Organisation for Economic Co-operation and Development definition) Data reflects information from 24 reporting countries on exports to, and imports from, each of nearly 200 partner countries

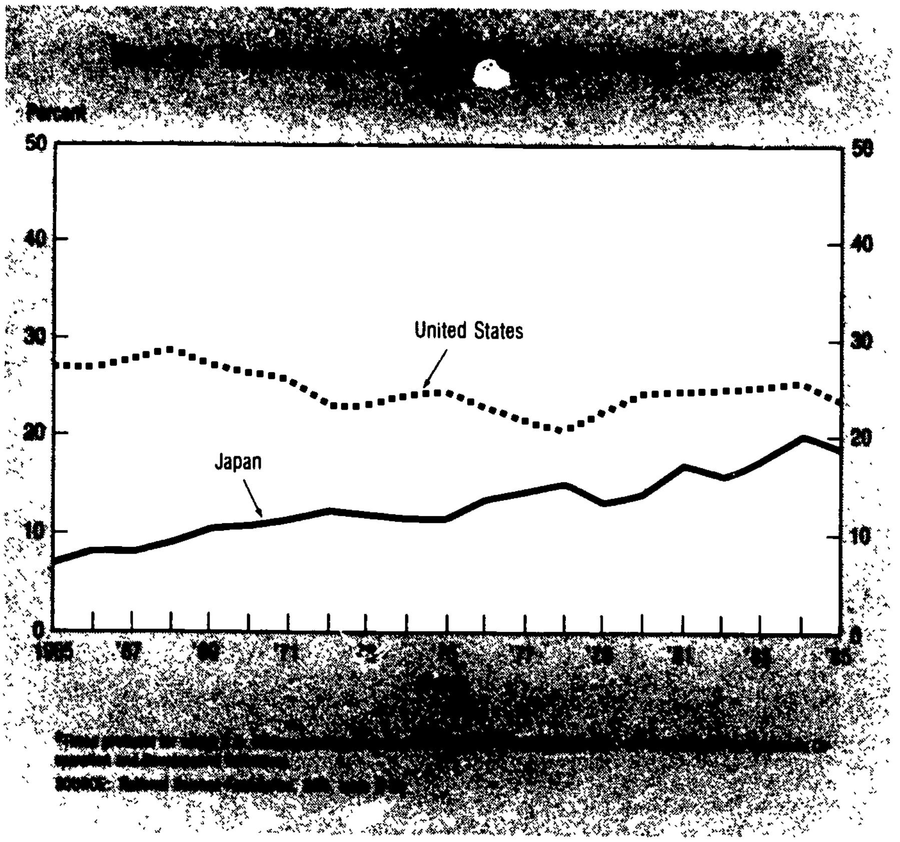
SOURCE National Science Foundation, DRI Special Tabulations of International Trade 1987

sive trade from 7 percent in 1965 to 19 percent in 1985, while the U.S. share declined from 28 percent to 24 percent (chart 33). Japan's share of technology-intensive imports remained extremely stable throughout the 20-year period at about 5 percent.

In 1985, high-technology products accounted for 53 percent of U.S. manufactures exports to Japan and 35 percent of U.S. imports of Japanese-manufactured goods.[48] The U.S. deficit in high-technology trade increased fivefold from 1980 to 1986, growing from current $3.8 billion to $21.9 billion (table 11).[49] According to the Department of Commerce, telecommunications equipment and electronic components accounted for about 75 percent of the high-technology trade deficit. Over the 1981-85 period, the rising deficit in this class constituted nearly 66 percent

[48]High-technology trade includes fewer (and slightly different) product categories than technology-intensive trade because it accounts for the R&D contribution of upstream inputs (U S Department of Commerce DOC3 definition)

[49]U S Department of Commerce, *United States Trade Performance in 1985 and Outlook* (Washington, D C Supt of Documents, U S Government Printing Office, 1986), p 79



of the total increase in the high-technology trade deficit. Within high-technology trade, the U.S. runs surpluses in the aircraft and parts, pharmaceuticals, and industrial inorganic chemicals categories.

On a worldwide basis, Japan has product dominance in the radio and television receiver equipment trade, accounting for 78 percent of world exports in 1985 (table 12). It also has large shares of the world's trade in communications equipment (37 percent) and professional and scientific instruments (30 percent); the United States has large shares of world trade in aircraft and parts (51 percent), office and computing equipment (33 percent), and agricultural chemicals (31 percent).

Overall, Japan has shown an impressive performance in technology outputs and impacts. During the 1975-85 period, the share of U.S. patents held by the Japanese doubled; furthermore, patent citation data suggest that not only are the number of Japanese-origin patents increasing, but that—in particular product classes—they also represent highly influential inventions. Similarly, trends in technology-intensive and high-technology trade reflect the expanded R&D and other efforts of Japan over the last few decades, although the outputs of scientific research as measured by the two bibliometric data bases have increased more modestly.

Table 11. U.S. trade with Japan in high-technology[1] manufactured products: 1980-86

[Current dollars in billions]

Year	Balance	Exports to Japan	Imports from Japan
1980	$ −3 8	$4 1	$ 7 8
1981	−5 9	4 9	10 7
1982	−6 4	4 8	11 3
1983	−8 8	5 6	14 4
1984	−16 0	6.1	22 2
1985	−18 6	6.6	25.2
1986	−21.9	7 6	29.4

[1]High-technology products are those U S products that embody significantly more R&D than other products (U S Department of Commerce DOC3 definition) High technology trade includes fewer (and slightly different) product categories than technology-intensive trade because it accounts for the R&D contribution of upstream inputs

SOURCE U S Department of Commerce, *United States Trade Performance in 1985 and Outlook* (Washington, D C Supt of Documents U S Government Printing Office, October 1986), and unpublished data

Table 12. World export shares of technology-intensive products:[1] 1975 and 1985

[Percent]

Product group	Japan		United States	
	1975	1985	1975	1985
Total	11 6	19 4	24 5	24 2
Aircraft and parts	.3	4	61 9	50.9
Industrial inorganic chemicals	6 4	4 2	18 4	20.7
Radio and TV receiving equipment	46 3	78 2	6.5	6
Office and computing machines	9 2	17 7	31.3	33.1
Electrical machinery and equipment	8.7	18 4	21.2	21.9
Communications equipment	14 9	37 0	24.4	16.1
Professional and scientific instruments	15 3	30 0	19 6	16 9
Drugs	2.0	2 7	13.6	18.4
Plastic materials, synthetics	12 0	9 6	12.0	13.2
Engines and turbines	8 7	17 7	25 9	29 4
Agricultural chemicals	12 0	3 2	24.1	30.7

[1]Technology-intensive products are defined as those for which U S R&D expenditures exceed 2 3 percent of sales (U S Department of Commerce DOC 2 and Organisation for Economic Co-operation and Development definition) Data reflect information from 24 reporting countries on exports to, and imports from, each of nearly 200 partner countries

SOURCE National Science Foundation, DRI Special Tabulations of International Trade 1987

chapter 6.

possible future directions

As Japan's leaders look to the next century, they have identified areas of change for Japanese S/T efforts. These areas are characterized by three major policy themes involving (1) a shift in research focus to more fundamental scientific research, (2) a reform of some of the more constraining aspects of the Japanese S/T system, and (3) greater participation within the international scientific community.

shifts in focus

Perhaps the most important statement concerning the need for change is the Eleventh Recommendation by the Council for Science and Technology, which reflects a growing consensus sentiment in Japan that the nation must become more self-reliant in the production of science and technology. This recommendation acknowledges Japan's use of foreign technology, but cautions:

> Japan will no longer have any model in the world to lead her future. Therefore, it is absolutely necessary for Japan to make efforts, trials, and even errors. That means Japan will have no way to ensure the development of the nation, without plentiful stocks of fundamental basic research activities.[50]

The recommendation goes on to stress the importance of "promoting creativeness in science and technology" by placing greater emphasis on fundamental research and strengthening interaction with scientists from other nations.

A second major concern of the Council's recommendation is to promote new fields of scientific and technological inquiry. Altogether, 103 S/T fields are given high priority: 33 in fundamental and leading science and technology, 33 concerning science and technology for economic development, and 37 concerning science and technology for improving the quality of society and life. The recommendation places greatest stress on the first group, but—since the areas covered by the report are so comprehensive and interdependent—it is difficult to judge which specific needs will actually receive the highest funding priority.

Other sources do provide additional indicators of short-term priorities, however. Concerning basic research, the best resource is the list of topics supported by the Ministry of Education, Science, and Culture (Monbusho) under the Specially Promoted Distinguished Research Program. (See appendix D.) These topics have received exceptionally careful competitive review and represent the highest quality and most advanced Japanese basic research. They are skewed towards biological medicine and biology, physics, and electrical engineering.

Another source for determining future Japanese S/T directions is the list of research areas considered most important by the panelists of the 1986 Delphi Survey. The panelists, consisting of some 2,500 individuals in positions of research leadership from all research sectors, rated research areas in terms of their importance.

[50]Council for Science and Technology, *Comprehensive Fundamental Policy for Promotion of Science and Technology to Focus Current Changing Situations from the Long-Term View: Recommendation on the 11th Inquiry* (Tokyo, Japan, November 1984)

Table 13 lists the areas ranked highest in the 1986 survey. On this, cancer represents four out of the top five areas of concern. Earlier surveys also showed strong emphases on life science and health; however, in the 1986 survey areas related to electronics and computer communications are newly identified. The research areas of major focus involve health, industrial technology, and energy.

Trends in the funding of scientific research and of research leaders' views on high priority areas are confirmed by a similar pattern in government focus: biotechnoloogy, information science, and energy-related research also represent the major ERATO and AIST research programs. Thus, for the next several years, these seem likely to be the major areas of enhanced research activity. At the same time, Japan probably will continue to emphasize other areas of current strength, such as chemistry and advanced materials.

structural reforms

Another areas of prospective change in Japanese S/T concerns the organization of research funding and performance. The government's declining role in terms of R&D funding and expenditures is likely to continue in response to constrained public spending.[51] In addition to limiting R&D funds, the Japanese Government is currently promoting two major reforms that aim to improve the administration of public research funds and stimulate educational diversity.

Administrative reform. As a corollary of fiscal reform, a special external committee has been established to propose various measures of administrative reform, such as the elimination of redundant agencies and improved management methods. One of the principal targets of this committee has been the large number of research institutes supported by the various government ministries. While it is difficult to close down established institutes, a recent trend in establishing new ones has been to set their life span for a fixed period, often between 6 and 10 years. Another outcome has been strengthening the role of STA in science policy formation by increasing its support responsibilities to the Prime Minister's Council for Science and Technology.[52]

Educational reform. Japanese reformers wish to restructure the educational system in order to foster a more creative and international citizenry. The major focus in this initiative is to alleviate the problems associated with extreme educational competition, among which is the excessive homogeneity in the upbringing of young people, all of whom strive to enter the same universities. By restructuring the educational system, it is hoped that more young

Table 13. Areas listed as most important in the 1986 Delphi Survey

Percent of leaders who ranked area high	Area
96	Preventive measures for cancer metastasis
95	Elucidate the biological cause and development of cancer cells
91	Development of technologies for major earthquake forecasting
90	Measures for controlling the growth of cancer cells
89	Clarify growth mechanism of cancer cells
88	Storage and disposal of high-level radioactive solid wastes
88	Automatic protocol conversions to facilitate information flows between communication networks
87	Establishment of global integrated services digital network with automatic domestic access
86	Application of CAD technology to design logic LSI semiconductors of 1 million gates or more
86	Advanced software verification technology for rapid development of error-free, large software systems
86	Introduction of fast breeder reactors and establishing complete nuclear fuel cycle facilities
85	Widespread use of anti-virus agents for treatment of viral diseases
84	Industrial application of superconducting materials with Tc higher than 77K
84	Methodologies for analysis of protein structures so as to predict their functions
84	Technologies for designing primary protein structures to fulfill specific functions
84	Molecular biology of brain development and growth
84	New materials for use in "round-trip" space vehicles
84	Prevention of senile dementia
84	New railway materials to significantly reduce environmental noise and vibration
83	Molecular biology of immunological responses
83	Establishment of commercial space production of semiconductors and pharmaceuticals

NOTE Adapted from translation provided by the Tokyo Office of the U S National Science Foundation

SOURCE Government of Japan, Science and Technology Agency September 1987

[51]In reaction to the heavy deficits incurred by the large-scale public construction programs of the seventies, the Japanese Government has been pursuing a strict deficit reduction policy for the past few years. S/T funding has, however, increased very modestly (about 3 percent a year) and has tended to do better than many other government programs

[52]See the Tokyo Office of the U S National Science Foundation, *Reorganization of Japan's Science and Technology Agency*, Report Memorandum #85, October 1985, and *Reorganization of Science and Technology Agency (STA)*, Report Memorandum #105, July 1986

people will feel free to develop specialized talents and a greater creativity. The reformers also urge for the breakdown of barriers between educational and other institutions.[53]

If carried out, these reforms will have a profound effect on future patterns in the funding and conduct of Japanese R&D. The declining level of government support means that resources provided by other sectors—especially industry—would have to be more widely dispersed if Japan's research resources are to be fully utilized. If the educational reforms are successful, the Japanese can encourage more flexibility and creativity in their educational system and, in turn, foster greater research creativity for Japan's future S/T needs.

University-industry-government cooperation. While Japan's universities now have some of the best researchers and some of the most advanced equipment available, they are relatively short of research funds and, until recently, academic scientists have been restricted in their use of research funds from industry. As Japan promotes fundamental research, it will be necessary to draw on the universities for joint projects with industry. There already have been some important initiatives along these lines. A number of administrative reforms by Monbusho now makes industry-university cooperation easier; further, it is anticipated that a variety of new arrangements will emerge to promote university-government research.[54]

Additionally, during the late seventies one of the most impressive developments in Japan was the fostering of new arrangements in which government and business joined in research projects. MITI's effort to develop future technologies in semiconductors and fifth generation computers is the most noted example, and similar new government programs aimed at basic research are likely to plant the seeds for future industrial commercialization.

Most government-initiated reforms of the Japanese S/T structure are designed to leverage the R&D funds of the three major R&D performers. The decreasing contribution of government funds, combined with an identifiable need for more—and often more expensive—basic research has highlighted the necessity for greater collaborative research and access to resources among the government, industry, and higher education sectors. Many recent and imminent reforms have been aimed at removing the legal obstacles inhibiting the joint use of financial, human, and laboratory resources to enhance the research potential of R&D expenditures, regardless of source.

internationalism

The third dominant theme in Japanese S/T policy is a concern with increased participation in international scientific activities and increased openness to foreign participation in Japanese science. Most of Japan's recent policy statements acknowledge the country's access to and use of Western science and technology during the first century of Japan's modernization. Looking to the future, Japan's leaders wish to reciprocate. Moreover, they hope that increased generosity on Japan's part will enable Japanese researchers to maintain and enhance the quality of their professional contact with Western colleagues.

Over the past few years, the level of Japanese funding for scientific and educational exchanges has increased rapidly, and several new programs have been initiated specifically for foreign scientists. Many of the government's new research programs, including ERATO and the Frontier Research Program, also make specific provision for the participation of foreign researchers. Most recently, the job classifications of civil servants have been revised; this now makes it possible for foreign scholars to hold research and teaching positions in Japanese universities and in government laboratories. Finally, many major Japanese corporations have expressed a willingness to receive American researchers in their laboratories.[55]

The Japanese are also trying to make their S/T literature more accessible to other nations. The Japan Information Center of Science and Technology is establishing an English-language data base of research reports issued by government agencies and research institutes; this data base will be integrated into the international Science and Technology Information Network.[56] These efforts derive from both Japan's assessment of its needs and responsibilities as well as from a certain amount of pressure by other industrialized nations.

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[53]For a more detailed discussion of proposed educational reforms, see U S Department of Education, *Japanese Education Today* (Washington, D C · Supt of Documents, U.S. Government Printing Office, January 1987)

[54]See the Tokyo Office of the U S. National Science Foundation, *University-Industry Cooperation in Japan: New Policy Gives Universities More Flexibility with Funds from Industry*, Report Memorandum #64, January 1985; and *Current Programs to Support University/Industry Cooperation in Japan*, Report Memorandum #69, March 1985. Also see Masahiro Nishio, *Collaboration Between University and Industry—Japanese Case*, the Second Seminar on Japanese-German-Swedish Cross-Country Studies on Structure and Function of Basic Technology Research, unpublished paper.

[55]See the Tokyo Office of the U S National Science Foundation, *Directory of Japanese Company Laboratories Willing to Receive American Researchers*, Report Memorandum #92, January 1986

[56]A comprehensive listing of English-language resources on Japanese science, technology, and engineering literature may be found in U.S. Department of Commerce, National Technical Information Service, *Directory of Japanese Technical Resources 1987* The directory may be obtained from the National Technical Information Service, Office of International Affairs, U S Department of Commerce, Springfield, Va 22161, phone number (703) 487-4819

trends in r&d expenditures

One of the key questions regarding Japan's future R&D efforts is whether the nation is willing and able to sustain the growth rates that have characterized the 1965-85 period. Of some concern to U.S. policymakers is Japan's willingness and ability to follow through on its objective to increase the level of basic research in Japan.

The Japanese have proposed to expand R&D funding to 3.5 percent of national income, a ratio that had not quite been achieved as of 1985.[57] However, given the trends in R&D expenditures and the predominance of industry as the major source and performer of R&D, it would be surprising if the level of R&D funding suddenly stabilized once the 3.5-percent figure was realized. Because the rates of change in industry R&D have been so consistently high for so long, it would seem that real, annual, and large increases in R&D are an integral part of industrial activity in Japan.

However, real growth in industrial R&D from 1985 to 1986 was only 1.3 percent, the lowest increase in the 1965-86 period except for 1974-75. (From 1965 to 1970, industrial R&D spending expanded at a real average annual rate of 20 percent; from 1970 to 1980, 6 percent; and from 1980 to 1985, 12 percent.) While this low increase may reflect a new phase in Japanese industrial R&D effort, it more than likely is a response to the severe economic situation in Japan during 1986. Economic performance in that year was the second worst in the entire postwar period, surpassed only by the oil shock of 1974. However, even in 1986—and except for the years 1971 and 1975-76—real increases in total Japanese R&D expenditures matched or significantly outpaced the real rate of change in GNP.

Concurrent with greater industrial activity is the declining role by government both as a source of R&D funds and as a performer of R&D. Although Japanese Government R&D funding increased at an annual average rate of 6 percent during the seventies, this rate declined to about 3 percent from 1980 to 1985. Similarly, government performance of R&D is slowing down, from an annual average rate of 7 percent during 1970-80 to 4 percent from 1980 to 1985.

The significance of industry in the Japanese S/T system is reinforced given the recent trends in basic research expenditures:[58] the Japanese Government has increased its basic research performance by barely 1 percent a year from 1980 to 1985, compared with 3 percent from 1975-80. In contrast, industry increased its expenditures on basic research by an average annual rate of 16 percent during 1980-85, compared to 7 percent during 1975-80. The higher education sector, which now performs about one-half of Japan's basic research, increased its basic research expenditures by 10 percent annually from 1975-80, but from 1980 to 1985 this rate declined to about 4 percent per year.

Thus, for the 1980-85 period it appears that Japanese industry is rising to the challenge of continued increases in Japan's total R&D and basic research. Although the performance of R&D in Japan has historically been compartmentalized (e.g., the flow of funds among sectors and joint use of resources have been limited), as reforms are made throughout the R&D system, the ability of the Japanese to improve the efficiency of their research funds may be increased. Collaborative research projects among sectors, the opportunity by industry to fund academic research, and the leveraging of research expenditures can enhance the relative productivity of R&D in Japan, especially that of basic and applied research.

While the low real increase in R&D expenditures from 1985 to 1986 is some cause for concern, it is most likely a reflection of the economic contraction and "yen shock" of 1985 and 1986. The macroeconomic structural adjustments that took place in Japan during 1986-87 have put the economy on a stronger footing, and any consequent revival of R&D spending should begin to show up in the R&D data for the years 1987-89.

[57] Japanese policymakers use a different R&D indicator for their decisionmaking purposes than the ones which have been used throughout this report. For them, the key ratio is R&D in natural sciences and engineering to national income; this was 2.4 percent in 1980 and [illegible] percent in 1985.

[58] For a discussion of differences in U.S. and Japanese definitions of basic research, see appendix A.

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appendixes

a. technical notes

b. detailed statistical tables

c. japanese government research programs

d. awards under the specially promoted distinguished research program of the ministry of education

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appendix a

technical notes

Differences in definitions, concepts, and data collection and reporting practices make precise cross-country comparisons difficult. However, much has been done by the Organisation for Economic Co-operation and Development (OECD) to establish uniform standards and definitions for scientific and technical activity. The Japanese and U.S. data presented here generally reflect OECD definitions and guidelines.[1] Differences between the U.S. and Japanese data are discussed in more detail below, together with additional technical information.

sources of science resources data

Japanese science resources data are principally available from two annual publications, *The Report on the Survey of Research and Development* (issued by the Statistics Bureau of the Management and Coordination Agency) and *Indicators of Science and Technology* (issued by the Science and Technology Agency). Data in the *Survey* are obtained from annual questionnaires sent to the performers of research and development (R&D) in Japan—industry, institutes of higher education, and government and nonprofit research institutes. The data in the *Indicators* are primarily a subset of the *Survey* data: the *Indicators* presents much of the same types of data but only for the natural sciences and engineering. However, the *Indicators* also presents additional information not available in the *Survey*, such as student enrollment and degree data, the technological balance of payments, and government budget data.

Science resources data for the United States are derived principally from reports and unpublished data of the U.S. National Science Foundation's Division of Science Resources Studies. A list of available data and publications may be obtained from the Office of the Division Director, Division of Science Resources Studies, National Science Foundation, 1800 G Street, N.W., Washington, D.C. 20550.

Additional data sources are as noted in the report text, tables, and charts, and include the OECD, various U.S. Government agencies, and scholarly works.

expenditure data

Expenditure data for both Japan and the United States are performer-based; that is, financial data on the source of R&D funds and the amount of expenditures are obtained from surveys sent to the R&D performers. In general, there are two major methods of calculating R&D expenditures—on a current operating cost basis and on a disbursement basis. The United States uses the current operating cost method, which includes the costs of labor, materials, and the depreciation of tangible fixed assets. Capital expenditures are excluded by definition as a current operating cost.

An alternative method that Japan and many European countries use for calculating R&D expenditures is on a disbursement basis, which also includes the costs of labor and materials, but substitutes capital expenditures (on facilities and

[1] See Organisation for Economic Co-operation and Development, *The Measurement of Scientific and Technical Activities* (Paris, France, 1981), commonly called the Frascati Manual

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equipment) for depreciation. Although data are available to make some estimates of Japanese R&D on a current operating cost basis, these estimates would still not be precisely comparable to the various U.S. data series and in some instances offer no advantage over disbursement expenditure data. For consistency, all Japanese data are on a disbursement basis, with the understanding that disbursement expenditure data may be slightly higher than operating cost data.[2]

In terms of fields of coverage, both Japan and the United States include research in the natural sciences, engineering, and the social sciences. However, Japan, like many of the European countries, also includes in its R&D figures research activity in the humanities and education. The Japanese data in this report have not been adjusted to exclude the humanities and education, which constituted 6 percent of total Japanese R&D expenditures in 1985, 27 percent of higher education expenditures (this is discussed in more detail in chapter 4, "Higher Education"), and 4 percent of government and nonprofit expenditures.

Japanese expenditure data for all R&D performers are reported for the fiscal year April 1 to March 31; U.S. data are reported primarily on a calendar year basis (industries and universities are allowed to report on their own fiscal year basis, which may or may not coincide with the calendar year). However, any differences between the Japanese and U.S. data series which result from noncoincident periods of time are certainly slight, and do not affect trends over time.

[2]An examination of Japanese industry data for the period 1980-85 showed that for all industries combined, R&D expenditures based on operating costs were consistently about 7 percent less than disbursement expenditures

personnel

The international convention for reporting R&D personnel data is to include only that portion of a researcher's time actually devoted to research. One of the more problematic differences between the Japanese and U.S. data is that the U.S. numbers of scientists and engineers engaged in R&D are reported on a full-time-equivalent (FTE) basis; corresponding Japanese data report the gross total of scientists and engineers engaged in R&D. While this is generally not a problem when comparing scientists and engineers in the industrial and government sectors (since they are presumably working full-time on R&D), it does become a problem for the higher education sector where a researcher's time is divided among research, teaching, and administrative responsibilities.

To compensate somewhat for this difference, this report excludes Japanese scientists and engineers engaged in R&D in the social sciences and humanities. This adjustment results in a 21-percent understatement of the total number of Japanese scientists and engineers engaged in R&D and a 40-percent understatement for the university sector.[3]

[3]This method for estimating the number of FTE scientists and engineers engaged in R&D yields similar results to those obtained by a Japanese study This study surveyed researchers affiliated with universities and derived an FTE coefficient of 0 6 for teaching staff See Institute for Future Technology, *Study on the Situation of Statistics Related to Research and Development Activity in the United States and Europe, and a Comparison with the Situation in Japan* (Tokyo, Japan, March 1987)

currency conversions

This report expresses most monetary figures in terms of constant 1982 dollars while Japanese official documents publish R&D funding and expenditure data in current yen. For this report, current yen have been converted into current U.S. dollars using OECD purchasing power parities (PPPs), and then converted into constant 1982 dollars using the U.S. Department of Commerce gross national product (GNP) implicit price deflators.

Market exchange rates have not been used for the currency conversion because they have become increasingly unsatisfactory in recent years for international statistical comparisons. Given the volatility of contemporary international capital markets, the international value of a currency is not a consistent reflection of the price structure for goods and services within a country, and consequently does not fully reflect the currency's purchasing power. Quite simply, PPPs for Japan are the number of yen needed to buy the same quantity of goods and services in Japan as a dollar can buy in the United States.[4] In this manner, Japanese yen are converted into dollar terms representing the same purchasing power as a U.S. dollar in the United States.

While PPPs provide more comparable data by equalizing how much a respective currency can buy, they are based on a broad index (or basket) of consumer goods and services

[4]The OECD has calculated PPPs for its member countries, all PPPs are expressed in terms of units of foreign currency per U S dollar

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and thus do not exactly reflect price structures specific to the costs of R&D in a country. This is somewhat of a limitation in terms of making precise international comparisons with regard to R&D; nevertheless, the use of PPPs to convert R&D expenditure data and national income data still yields a more accurate picture of relative spending levels than the use of market exchange rates. For a detailed discussion of the methodology for computing PPPs, see OECD, *Purchasing Power Parities and Real Expenditures in the OECD* (Paris: 1985).

basic research

Although basic research is defined in virtually identical terms in both the United States and Japan (i.e., research that is conducted for the purpose of advancing scientific knowledge and without specific applications being directly sought), the interpretation of this definition seems to differ in Japan and the United States. Understandably, the allocation of research as basic or applied is a subjective process, and even in the United States there is disagreement over the distinction between these two types of research.[5]

The conceptual differences between Japanese and American perceptions arise in allocating research that is not "truly" basic research (e.g., particle physics). In the United States, the relationship between basic and applied research is typically seen as both mutually exclusive and linear: applied research cannot be basic, and applied research occurs *after* basic research in a unidirectional flow of research activity. Once a goal or objective other than the pure pursuit of scientific knowledge is assigned to a research program, then it is traditionally seen as applied—not basic—research.

In Japan, however, basic and applied research are perceived in a more multidimensional and interactive way than in the United States. One of the key differences between the two countries seems to be that in considering whether research is applied or basic, the type of science (basic or applied) being used is also considered. Thus, a long-term applied research program (one with a problem or application in mind) that extensively uses basic science experimentation for its problem resolution might be classified as basic research in Japan.[6] Consequently, Japanese data on basic research expenditures probably include some types of research that would be classified as applied research in the United States. Note that the Japanese exclude R&D in the social sciences and humanities in the allocation of research by character of work.

[5]See Arthur Gerstenfeld, *Science Policy Perspectives USA-Japan*, (New York, New York Academic Press, Inc , 1982), especially "Part I Perceptions of the Nature of Basic and Applied Science "

[6]See Gerstenfeld, op cit , and Institute for Future Technology, op cit

manufacturing industries

At the aggregate level, the Standard Industrial Classifications for manufacturing industries in Japan and the United States are very similar, with a key exception being the placement of compu rs in the classification scheme. In the United States, computers are classified as "office, computing, and accounting machines" under general machinery; in Japan, they are classified under electrical machinery as "communications and electronic equipment." To make the R&D data in this report as comparable as possible, the U.S. general machinery subgroup "office, computing, and accounting machines" data has been moved to "communications and electronic components" under electrical machinery.

This adjustment was made because (1) the U.S. data were readily available, and (2) only one straightforward statistical adjustment was required to make the two categories (general and electrical machinery and their subgroups) completely comparable. To adjust the Japanese data would have required several statistical changes for which there were insufficient data.

As a last note, the Japanese Standard Industrial Classification does not contain a separate "3-digit level" category for aircraft and missiles. Aircraft are included under "other transportation equipment"; missiles are not identified in the classification schedule.

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appendix b

detailed statistical tables

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Table B-1. National expenditures for the performance of R&D: 1965-86

[Constant 1982 dollars in millions][1]

Year	Japan	United States
1965	$ 6,133	$ 59,351
1966	6,621	62,589
1967	7,626	64,406
1968	9,060	65,458
1969	10,487	64,672
1970	12,442	62,405
1971	13,321	60,385
1972	14,751	61,414
1973	16,159	62,427
1974	16,395	61,467
1975	16,673	59,883
1976	17,371	62,134
1977	18,042	63,653
1978	19,087	66,769
1979	20,985	70,077
1980	23,139	73,235
1981	25,570	76,610
1982	27,397	73,316
1983	29,904	83 891
1984	32,480	90,541
1985	36,023	96,532
1986	36,605	100,398

[1]Based on Organisation for Economic Co-operation and Development purchasing power parities and U S Department of Commerce GNP implicit price deflators

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-2. National expenditures for the performance of R&D as a percent of GNP: 1965-86

[Constant 1982 dollars in billions]

Year	GNP		R&D as a percent of GNP	
	Japan	United States	Japan	United States
1965	$ 405	$2,087	1 5	2 8
1966	453	2,208	1 5	2 8
1967	501	2,272	1 5	2 8
1968	565	2,366	1 6	2 8
1969	639	2,423	1 6	2 7
1970	671	2,416	1 9	2 6
1971	719	2,485	1 9	2 4
1972	794	2,609	1 9	2 3
1973	851	2,744	1 9	2 3
1974	833	2,729	2 0	2 2
1975	851	2,695	2 0	2 2
1976	891	2,827	2 0	2 2
1977	933	2,959	1 9	2 2
1978	956	3,115	2 0	2 1
1979	1,002	3,192	2 1	2 2
1980	1,040	3,187	2 2	2 3
1981	1,074	3,249	2 4	2 4
1982	1,108	3,166	2 5	2 5
1983	1,144	3,279	2 6	2 6
1984	1,247	3,502	2 6	2 6
1985	1,300	3,607	2 8	2 7
1986	1,317	3,713	2 8	2 7

NOTE Percentages calculated from national currencies

SOURCES Organisation for Economic Co-operation and Development Government of Japan Management and Coordination Agency and the National Science Foundation

Table B-3. Estimated nondefense R&D expenditures as a percent of GNP: 1971-85[1]

Year	Japan	United States
1971	1 8	1 6
1972	1 8	1 6
1973	1 9	1 6
1974	2 0	1 6
1975	1 9	1 6
1976	1 9	1 6
1977	1 9	1 6
1978	2 0	1 6
1979	2 1	1 7
1980	2 2	1 8
1981	2 4	1 8
1982	2 5	1 9
1983	2 6	1 9
1984	2 6	1 8
1985	2 8	1 9

[1]Data on nondefense R&D expenditures are not available prior to 1971

NOTE Percentages calculated from unrounded figures

SOURCES Organisation for Economic Co operation and Development and the National Science Foundation

Table B-4. National R&D funding by source: selected years

[Constant 1982 dollars in millions]

Year	Government	Industry	Higher education	Other[1]
		Japan		
1970	$ 3,663	$ 6,838	$1,861	$ 80
1975	4,899	9,177	2,498	88
1980	6,462	14,090	2,425	161
1983	7,169	19,484	3,024	227
1984	7,315	21,719	3,188	258
1985	7,566	24,809	3,333	315
		Percent		
1970	29	55	15	1
1975	29	55	15	1
1980	28	61	11	1
1983	24	65	10	1
1984	23	67	10	1
1985	21	69	9	1
		United States		
1970	$35,636	$24,851	$1,111	$807
1975	30,986	26,679	1,302	916
1980	34,548	36,066	1,555	1,066
1983	39,097	41,896	1,805	1,093
1984	42,007	45,544	1,871	1,119
1985	46,030	47,310	2,023	1,170
		Percent		
1970	57	40	2	1
1975	51	45	2	2
1980	47	49	2	2
1983	47	50	1	2
1984	46	50	2	1
1985	48	49	2	1

[1] Nonprofit institutions and funds from abroad

NOTE Because of rounding, percentages may not add to 100 Percentages calculated from national currrencies

SOURCE Source of funds statistics are estimates based upon data from the Management and Coordination Agency and in collaboration with officials of the Science and Technology Agency

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Table B-5. Distribution of national R&D expenditures by performer: selected years

[Percent]

Year	Government	Industry	Higher education	Other[1]
	Japan			
1965	12	50	36	2[2]
1970	11	61	27	1
1975	12	57	28	3
1980	12	60	26	3
1985	9	67	20	4
	United States			
1965	15	71	11	3
1970	16	69	12	4
1975	15	69	13	4
1980	12	71	13	3
1985	12	73	12	3

[1]Nonprofit institutions

[2]Estimate made by the National Science Foundation

NOTE Because of rounding percentages may not add to 100

SOURCES Government of Japan. Management and Coordination Agency and the National Science Foundation

Table B-6. National R&D expenditures by performer and character of work: selected years[1]

[Constant 1982 dollars in millions]

Performer	1975				1980				1985			
	Total	Basic research	Applied research	Development	Total	Basic research	Applied research	Development	Total	Basic research	Applied research	Development
	Japan											
Total	$13,332	$2,013	$2,848	$ 8,470	$20,284	$3,121	$ 5,138	$12,025	$32,775	$ 4,379	$ 8,164	$20,232
(Percent)	(100%)	(15%)	(21%)	(64%)	(100%)	(15%)	(25%)	(59%)	(100%)	(13%)	(25%)	(62%)
Higher education	1,670	1 209	339	122	3 383	1 957	1 194	231	4 332	2,415	1 570	347
Industry	9,444	489	1,800	7,155	13,859	694	2,704	10,460	24,068	1,425	5,280	17,363
Government	1,837	291	630	917	1,410	337	695	378	1,592	352	795	445
Other	381	25	80	275	1,632	133	544	956	2,783	187	518	2,077
	United States											
Total	59,883	7,951	13,407	38,525	73,235	9,506	16,456	47,273	96,532	11,727	22,129	62,676
(Percent)	(100%)	(13%)	(22%)	(65%)	(100%)	(13%)	(22%)	(65%)	(100%)	(12%)	(22%)	(66%)
Higher education	7,642	4,727	1,938	977	9,803	5,679	2,822	1,302	11,669	6,675	3,257	1,737
Industry	40,781	1,231	7,705	31,845	51,920	1,546	9,858	40,516	70,350	2,364	15,212	52,774
Government	9,308	1,276	3,008	5,024	9,006	1,395	2,931	4,680	11,590	1,722	2,805	7,063
Other	2,151	717	755	679	2,509	887	846	776	2,924	967	855	1,102

[1]Not all Japanese R&D expenditures are allocated by character of work therefore the total R&D expenditures presented above are not the same as those in table B 1

NOTE Because of rounding, figures may not add to totals shown Percentages calculated from national currencies

SOURCES Government of Japan. Management and Coordination Agency and the National Science Foundation

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Table B-7. Scientists and engineers engaged in R&D: 1965-86[1]

Year	Scientists and engineers (in thousands)		Scientists and engineers engaged in R&D per 10,000 labor force	
	Japan	United States	Japan	United States
1965	117 6	494 6	24 6	64 7
1966	128 9	521 1	26 4	66 9
1967	138 7	534 4	27 8	67 2
1968	157 6	550 4	31 1	68 0
19[illegible]	157 1	553 2	30 8	66 7
1970	172 0	544 2	33 4	64 1
1971	194 3	523 8	37 5	60 7
1972	198 1	515 3	38 1	58 0
1973	226 6	514 8	42 5	56 4
1974	238 2	520 8	44 9	55 6
1975	255 2	527 7	47 9	55 3
1976	260 3	535 6	[illegible]	54 8
1977	272 0	561 0	49 9	55 7
1978	273 1	587 0	49 4	56 5
1979	281 9	614 8	50 4	57 7
1980	302 6	651 7	53 6	60 0
1981	317 5	683 7	55 6	62 0
1982	329 7	702 8	57 1	62 8
1983	342 2	722 9	58 1	63 8
1984	370 0	746 3	62 4	64 8
1985	381.3	772 5	63 9	65 9
1986	405 6	802 3	69 3	67 1

[1] U S figures are full-time equivalents while Japanese represent total numbers of scientists and engineers engaged primarily in R&D in natural science and engineering

SOURCES Government of Japan, Science and Technology Agency, and the National Science Foundation

Table B-8. Number of scientists and engineers engaged in R&D by sector: 1985[1]

[In thousands]

Sector	Japan	United States[2]
Total	381 3	772 5
Industry	231 1	570 3
Higher education	118 0	109 8
Government and non-profit	32 2	92 4

[1] U S figures are full-time equivalents while Japanese represent total numbers of scientists and engineers engaged primarily in R&D in natural sciences and engineering

[2] U S figures for 1985 are estimates

SOURCES Government of Japan Science and Technology Agency and the National Science Foundation

Table B-9. Value of technical know-how receipts and expenditures: 1970 and 1985

[Constant 1982 dollars in millions]

Receipts and expenditures	1970		1985	
	Japan	United States	Japan	United States
Receipts	$ 194	$8,625	$ 721	$14,018
Payments	1,423	2,503	2,437	4.953
Balance	(1,229)	6,122	(1716)	9,065
Ratio of receipts to payments[1]	136	3 45	296	2 83

[1] Ratios calculated from unrounded national currencies

SOURCES Government of Japan Science and Technology Agency and the National Science Foundation Japanese data are statistics of the Bank of Japan

Table B-10. Value of government R&D funding: 1970-85

[Constant 1982 dollars in millions]

Year	Japan		United States	
	Government R&D funding	As a share of total R&D	Government R&D	As a share of total R&D
1970	$3,663	29.4%	$35,636	57.0%
1971	4,307	32.3	33,966	56 1
1972	4,873	33.0	34,146	55.5
1973	5,020	31.1	33,478	53 4
1974	4,732	28.9	31,726	51.3
1975	4,934	29.6	30,986	51.4
1976	5,108	29 4	31,813	51 0
1977	5,331	29.5	32,152	50 5
1978	5,752	30.1	33,172	49 6
1979	6,196	29.5	34,271	48 8
1980	6,506	28.1	34,548	47 1
1981	6,892	27.0	35,685	46 5
1982	6,992	25.5	36,505	46 0
1983	7,169	24.0	39,097	46.6
1984	7,315	22.5	42,007	46.4
1985	7,566	21 0	46,030	47 7

NOTE Percentages based on national currencies

SOURCES Government of Japan. Management and Coordination Agency, and the National Science Foundation

Table B-11. Distribution of Japanese Government R&D budget among key Japanese ministries and agencies: 1985

[Percent]

Ministry/agency	Share of total R&D budget
Total	100
Ministry of Education, Science, and Culture	47
Science and Technology Agency	27
Ministry of International Trade and Industry	13
Ministry of Agriculture, Forestry, and Fisheries	4
Defense Agency	4
Ministry of Health and Welfare	2
All others	3

SOURCE Government of Japan. Science and Technology Agency

Table B-12. Distribution of government R&D expenditures by objective: 1985

[Percent]

Objective	Japan[1]	United States
Total	100.0	100 0
Agriculture, forestry, and fisheries	11 3	2 1
Industrial development	5 9	2
Energy	16 3	4 8
Health	2 6	11 2
Advancement of knowledge[2]	47 3	3 7
Civil space	6 8	5 5
Defense	4 1	67 5
All others	5 7	5 0

[1]NSF-adjusted figures

[2]The category "advancement of knowledge" includes general university funds spent on R&D and should not be equated with basic research

SOURCES Japanese national sources and the National Science Foundation

Table B-13. Distribution of Japanese Government R&D funding by objective: selected years

[Percent]

Objective	1975	1980	1985
Total	100.0	100 0	100 0
Agriculture, forestry, and fisheries	13 0	12 0	11 3
Industrial development	6 7	5 8	5 9
Energy	7 5	12 4	16.3
Health	3 0	2 9	2 6
Advancement of knowledge[1]	54 7	52 5	47 3
Civil space	7 0	5 7	6.8
Defense	2 2	2 3	4 1
All others	5 9	6 4	5 7

[1]The category "advancement of knowledge" includes general university funds spent on R&D and should not be equated with basic research

SOURCES Organisation for Economic Co-operation and Development and Japanese national sources for (NSF-adjusted) 1985 data

Table B-14. National industrial R&D expenditures: 1965-86

[Constant 1982 dollars in millions]

Year	Japanese industrial R&D[1]	U S. total industrial R&D	U.S company-funded R&D
1965	$ 3,043	$41,992	$19,079
1966	3,355	44,474	20,641
1967	4,114	45,590	22,315
1968	5,207	46,194	23,506
1969	6,190	46,023	24,779
1970	7,557	42,986	24,478
1971	7,781	41,280	24,006
1972	8,602	42,056	24,812
1973	9,494	42,893	26,451
1974	9,592	42,415	27,181
1975	9,444	40,781	26,272
1976	9,846	42,805	27,645
1977	10,424	44,330	28,746
1978	10,808	46,115	30,622
1979	12,201	43,652	32,720
1980	13,859	51,919	35,553
1981	15,515	55,140	37,705
1982	16,949	57,995	39,512
1983	18,991	61,047	41,268
1984	21,135	66,342	44,842
1985	24,068	70,350	46,527
1986	24,370	73,268	47,851

[1]Because less than 2 percent of Japanese industrial R&D funds comes from government sources, a separate company-funded R&D data series has not been provided

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-15. National industrial R&D as a percent of GNP: 1965-86

Year	Japanese industrial R&D	U.S total industrial R&D	U S company-funded R&D
1965	8	2 0	9
1966	7	2 0	9
1967	8	2.0	1 0
1968	9	2 0	1 0
1969	1 0	1 9	1 0
1970	1 1	1 8	1 0
1971	1 1	1 7	1 0
1972	1 1	1 6	1 0
1973	1 1	1 6	1 0
1974	1 2	1 6	1 0
1975	1 1	1 5	1 0
1976	1 1	1 5	1 0
1977	1 1	1 5	1 0
1978	1 1	1 5	1 0
1979	1 2	1 5	1 0
1980	1 3	1 6	1 1
1981	1 4	1 7	1 2
1982	1 5	1 8	1 2
1983	1 7	1 9	1 3
1984	1 7	1 9	1 3
1985	1 9	2 0	1 3
1986	1 9	2 0	1 3

[1]Japanese industrial R&D is almost 98 percent company-funded

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-16. Japanese manufacturing R&D expenditures by industry: selected years

[Constant 1982 dollars in millions]

Industry	1965 Amount	1965 Share	1975 Amount	1975 Share	1985 Amount	1985 Share
All manufacturing, total	$2,737	100%	$8,613	100%	$22,462	100%
Food	109	4	259	3	541	2
Textiles	96	4	127	2	254	1
Chemicals and allied products	753	28	1,805	21	3,794	17
Industrial chemicals	293	11	860	10	1,531	7
Drugs and medicines	176	6	534	6	1,385	6
Petroleum and coal	27	1	96	1	277	1
Rubber	43	2	160	2	589	3
Ceramics[1]	66	2	234	3	706	3
Iron and steel	178	7	500	6	974	4
Non-ferrous metals	88	3	146	2	407	2
Fabricated metals	45	2	165	2	416	2
General machinery[2]	214	8	648	8	1,551	7
Electrical machinery[2]	616	23	2,245	26	7,853	35
Electrical equipment	240	9	934	11	2,497	11
Communications and electronic equipment[2]	376	14	1,311	15	5,357	24
Motor vehicles	258	9	1,098	13	3,230	14
Professional and scientific instruments	65	2	201	2	817	4
All others	179	7	929	11	1,053	5

[1]Stone, clay, and glass products

[2]Note that the Japanese industrial classifications for general machinery and electrical machinery do not correspond to those of the United States except where the U S data have been adjusted in this report In Japan computers are classified under electrical machinery as communcations and electronic equipment, whereas in the United States, they are classified under general machinery For more detail see appendix A

NOTE Because of rounding, figures may not add to totals shown Percentages based on national currencies

SOURCE Government of Japan, Management and Coordination Agency

Table B-17. Manufacturing R&D activity by industry: 1985

[Constant 1982 dollars in millions]

Industry	Company-funded R&D expenditures		Japan/U S ratio (percent)	R&D expenditures as a percent of net sales		Number of scientists and engineers engaged in R&D per 10,000 employed[1]	
	Japan	United States		Japan	United States	Japan	United States
All manufacturing, total	$22,462	$45,298	50	2 7	2 8	468	400
Food	541	937	58	8	4	225	NA
Textiles	254	135	188	1 2	5	213	40
Chemicals and allied products	3,794	7,513	51	3 8	4 7	784	550
Industrial chemicals	1,531	3,254	47	2 8	4 0	711	420
Drugs and medicines	1,385	3,189	43	7 0	8 4	796	NA
Petroleum and coal	277	1,894	15	4	7	394	210
Rubber	589	750	79	2 2	2 2	363	NA
Ceramics[2]	706	437	162	2 6	1 3	355	50
Iron and Steel	974	334	292	1 9	5	177	150
Non-ferrous metals	407	348	117	1 9	1 4	316	180
Fabricated metals	416	524	79	1 6	1 3	260	NA
General machinery	1,551	[3]1,990	78	2 7	2 3	425	[4]520
Electrical machinery	7,853	[3]15,575	50	5 1	6 4	767	[4]500
Electrical equipment	2,497	1,817	137	4 8	2 9	647	NA
Communications and electronic equipment	5,357	[3]13,758	39	5 3	7 6	836	[4]550
Motor vehicles	3,230	5,469	59	3 0	3 2	331	280
Professional and scientific instruments	817	4,249	19	4 5	9 0	664	NA
Aircraft and missiles	NA	3,776	NA	NA	4 1	NA	1,060

[1]Numbers of U S scientists and engineers engaged in R&D are in full-t e equivalents Japanese are not

[2]Stone, clay, and glass products

[3]Note that these U S figures have been adjusted, computers have been removed from the general machinery classification to electrical machinery under communications and electronic equipment For more detail, see appendix A

[4]These figures are not comparable to the Japanese because they represent different SIC product groupings

NOTE Percentages calculated from unrounded figures NA Not separately available See appendix A

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

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Table B-18. Shares of manufacturing R&D accounted for by the five largest R&D firms by industry: 1985

[Percent]

Industry	Japan	United States
All manufacturing	18	23
Food	32	37
Textiles	47	[1]45
Chemicals and allied products	17	31
Industrial chemicals	31	70
Drugs and medicines	32	37
Petroleum and coal	71	71
Rubber	60	62
Ceramics[2]	35	[1]57
Iron and steel	78	[1]41
Nonferrous metals	57	[1]56
Fabricated metals	25	[1]36
General machinery	28	[2]40
Electrical machinery	45	[2]49
Communications and electronic equipment	56	[3]55
Motor vehicles	69	96
Professional and scientific instruments	50	65
Aircraft and missiles	NA	64

[1]Four largest firms only

[2]Stone, clay, and glass products

[3]Note that the U S figures have been adjusted, computers have been removed from the general machinery classification to electrical machinery under communications equipment and electronic components For more detail, see appendix A

NOTE NA Not separately available

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-19. Number of industrial scientists and engineers engaged in R&D: 1965-85[1]

[in thousands]

Year	Japan	United States
1965	59.0	348.4
1966	65.4	360.2
1967	69.2	372.0
1968	81.7	381.9
1969	82.5	385.6
1970	94.1	375.6
1971	111.2	358.6
1972	112.8	354.0
1973	124.8	358.9
1974	130.7	361.7
1975	146.6	363.9
1976	145.2	373.6
1977	151.4	393.6
1978	153.7	414.2
1979	157.3	437.3
1980	184.9	498.8
1981	157.3	437.3
1982	192.9	516.0
1983	201.1	533.3
1984	223.9	552.4
1985	231.1	570.3

[1]Numbers of U S scientists and engineers are in full-time equivalents. Japanese are not

SOURCES Government of Japan Management and Coordination Agency and the National Science Foundation

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Table B-20. Higher education R&D expenditures: 1965-86

[Constant 1982 dollars in millions]

Year	Japan Amount	Japan As a share of total R&D	United States[1] Amount	United States[1] As a share of total R&D
1965	$2,214	36%	$6,231	11%
1966	2,319	35	6,750	11
1967	2,491	33	7,220	11
1968	2,669	30	7,712	12
1969	2,948	28	7,526	12
1970	3,358	27	7,406	12
1971	3,681	28	7,366	12
1972	3,940	27	7,345	12
1973	4,187	26	7,655	12
1974	4,332	26	7,454	12
1975	4,707	28	7,643	13
1976	4,886	28	7,854	13
1977	5,002	28	8,132	13
1978	5,430	29	8,843	13
1979	5,761	28	9,366	13
1980	5,910	26	9,802	13
1981	6,179	24	9,983	13
1982	6,464	24	9,755	12
1983	6,870	23	10,116	12
1984	7,094	22	10,741	12
1985	7,252	20	11,669	12
1986	7,297	20	12,656	12

[1]Includes higher education institutions and federally funded research and development centers

NOTE Percentages calculated from national currencies

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-21. Distribution of higher education R&D expenditures among fields: 1985

[Percent]

Field	Japan	United States
Total	100.0	100.0
Agriculture	4 8	10 8
Natural sciences	9.0	43.2
Engineering	20 7	14 6
Medical sciences	25 5	23 7
Social sciences	[1]13 0	[2]5 8
All other fields	[3]26 9	1 9

[1]Law, political science, and "other social sciences"

[2]Including psychology

[3]Home economics, education, and others

NOTE Because of rounding, percentages may not add to 100

SOURCES Government of Japan, Management and Coordination Agency, and the National Science Foundation

Table B-22. Distribution of academic separately budgeted R&D by field: 1982

[Percent]

Total	100 0	100 0
Engineering	20 2	14 1
Physical sciences	35 9	12 1
Environmental sciences	6 8	7 4
Math and computer science	1 0	3 4
Life sciences	26 1	53 6
Social sciences	1 8	4 2
Psychology	6	1 8
All other[1]	7 7	3 3

[1]Professional and vocational studies, arts and humanities

NOTE Because of rounding, percentages may not add to 100

SOURCE Ben R Martin and John Irvine, *An International Comparison of Government Funding of Academic and Academically Related Research*, Science Policy and Research Evaluation Group Science Policy Research Unit, University of Sussex, United Kingdom Advisory Board for the Research Councils, 1986

Table B-23. First-university degrees by field and as a proportion of the 22-year-old population: 1985

Field	Japan Number	Japan Proportion	United States Number	United States Proportion
Total	373,302	22.6%	1,066,439	25 3%
Natural sciences	12,698	8	120,168	2 9
Engineering	71,396	4 3	77,871	1 8
Agriculture	13,450	8	15,879	4
Social sciences[1]	149,715	9 1	107,821	2 6
Other	126,043	7 6	744,700	17 7

[1]There is not a one-to-one correspondence between social science disciplines in Japan and the United States

NOTE Because of rounding, percentages may not add to totals shown

SOURCES Government of Japan, Ministry of Education, Science, and Culture *Basic Education Survey 1985* and the National Science Foundation

Table B-24. Doctora' 'grees by field and as a proportion of the 27-year-old population: 1984 or 1985

Field	Japan (1984)		United States (1985)	
	Number	Proportion	Number	Proportion
Natural sciences and engineering, total	2,712	0 2%	12,101	0 3%
Natural sciences	807	1	7,793	2
Engineering	1,291	1	3,251	1
Agriculture	614	[1]	1,057	[1]
Other[2]	[3]4,765	3	20,871	5
All fields	7,477	5	32,971	7

[1]Less than 0 05 percent

[2]Including social sciences, humanities, and health-related fields

[3]Of these Japanese doctorates 4,502 are in health-related fields

NOTE Because of rounding, percentages may not add to totals shown

SOURCES Government of Japan, Science and Technology Agency, and the National Science Foundation

Table B-25. Trends in scientific literature outputs: selected years

Scientific literature outputs	1972	1977	1982
Journal articles			
Japan	105,200	161,000	227,400
United States	365,800	457,700	587,900
World	1,025,200	1,339,200	1,741,000
Technical reports			
Japan	3,370	5,400	10,320
United States	51,890	49,810	49,010
World	95,500	101,300	130,000
Conference papers			
Japan	7,210	15,050	26,800
United States	33,600	50,330	90,000
World	75,400	121,500	221,500

SOURCE Mitsubishi Sogo Kenkyusho (Mitsubishi Research Institute) *Kagaku Gijutsu Joho no Kokusai-teki Ryutsu no Arikata ni Kan-suru* 1984

Table B-26. Japanese-invented U.S. patents by selected patent classes:[1] 1975-84

Patent classification	Number of patents	Share of patent class
123 Internal combustion engines	2,706	31 5%
430 Radiation imagery	2,273	34 7
354 Photography	2,167	52 5
424 Bioaffecting drugs	1,819	10 2
428 Stock materials	1,696	16 9
350 Optics, systems and elements	1,493	24 7
358 Pictorial communication	1,431	27 6
360 Dynamic magnetic information storage	1,244	37 3
355 Photocopying	1,204	35 6
364 Electrical computers and data processing systems	1,202	15 2
204 Chemical, electrical, and wave energy	1,153	13 7
340 Communications, electrical	1,046	15 2

[1]Those classes for which the total number of patents exceeded 1,000

SOURCE Francis Narin and Dominic Olivastro *Patent Activity and Citation Analysis Using U S POC Classification* interim report by Computer Horizons, Inc , to the National Science Foundation, September 1986

Table B-27. Output per worker-hour in manufacturing: 1965-85

[Index: 1977 = 100]

Year	Japan	United States
1965	35 0	76 6
1966	38 5	77 4
1967 . .	44 2	77 4
1968 . .	49.8	79.8
1969 . ..	57 5	80.8
1970	64 8	80 8
1971 . . .	68.6	85 3
1972 . .	75 3	89 0
1973 . ..	83 1	93 4
1974	86.5	90 6
1975	87 7	92.9
1976 . .	94 3	97 1
1977	100 0	100 0
1978	108 0	101 5
1979 ...	114.8	101.4
1980	122 7	101 4
1981	127 2	103 6
1982 .	135 0	105.9
1983 . .	142 3	112 0
1984 .	152 5	116.6
1985 ...	163 7	121 7
1986 (est)	168 2	126 0

SOURCE U S Department of Labor, Bureau of Labor Statistics

Table B-28. Japanese manufacturing use of technical know-how by selected industries: 1975 and 1985

[Constant 1982 dollars in millions]

Industry	1975				1985			
	Payments	Receipts	Receipts/ payments	Payments/ R&D	Payments	Receipts	Receipts/ payments	Payments/ R&D
All manufacturing .	924	330	36	11	1,169	833	72	5
Food	$ 22	$ 3	15%	8%	$ 42	$ 25	59%	8%
Textiles . .	13	7	59	10	13	16	122	5
Chemicals and allied products .	151	121	80	8	151	155	102	4
Industrial chemicals .	96	101	105	11	55	80	146	4
Drugs and medicines	32	7	23	6	53	53	100	4
Petroleum and coal .	18	NA	NA	18	21	2	11	8
Rubber . .	20	4	18	13	26	16	61	4
Ceramics[1] . .	42	10	24	18	131	38	29	19
Iron and steel .	34	67	197	7	19	106	558	2
Nonferrous metals	19	3	15	13	21	8	38	5
Fabricated metals ..	10	3	34	6	16	10	61	4
General machinery . .	129	25	20	20	99	47	48	6
Electrical machinery	214	41	19	10	341	241	71	4
Electrical equipment .	117	18	15	13	98	72	74	4
Communications and electronic equipment .	97	23	24	7	244	169	69	5
Motor vehicles . . .	77	24	31	7	46	105	228	1
Professional and scientific instruments . .	16	1	8	8	20	7	34	3

[1]Stone, clay, and glass products

SOURCES Government of Japan, Science and Technology Agency and Management and Coordination Agency

ERIC Full Text Provided by ERIC

Table B-29. Japanese trade balance with the United States in technology-intensive products:[1] 1965-85

[Current dollars in millions]

Year	Balance	Exports to United States	Imports from United States
1965	$ 143 4	$ 501 8	$ 358 4
1966	304 2	712.1	407 9
1967	279 9	784.1	504 2
1968	482 9	1,104 1	621.2
1969	724 8	1,502 2	795 4
1970	555 0	1,732.8	1,177 8
1971	822 1	2,064 8	1,242 6
1972	1,204 6	2,538 9	1,334 3
1973	1,174 5	2,869 5	1,695 1
1974	692 2	3,028 5	2,336 4
1975	962 6	2,907.6	1,945 0
1976	2,848 3	5,084.2	2,236 0
1977	3,444 0	5,823.1	2,379 1
1978	4,159 1	7,238 8	3,079 7
1979	2,819 6	7,126 5	4,306 9
1980	3,108.3	8,412 6	5,304 3
1981	5,536 8	11,747 9	6,211 1
1982	5,204.7	11,428 6	6,223 8
1983	7,035.3	14,300 0	7,264 8
1984	13,323.1	21,345 0	8,021 9
1985	13,024.0	21,252 2	8,228 1

[1]Technology-intensive products are defined as those for which U S R&D expenditures exceed 2 36 percent of value-added (DOC2 and Organisation for Economic Co-operation and Development definition) Data reflect information from 24 reporting countries on exports to, and imports from, each of nearly 200 partner countries

SOURCE National Science Foundation, DRI Special Tabulations of International Trade, 1987

Table B-30. World export shares of technology-intensive products:[1] 1965-85

[Percent]

Year	Japan	United States
1965	7 2	27 5
1966	8 3	27.1
1967	8 5	28 2
1968	9 5	29 1
1969	10 7	27 8
1970	10 9	27 0
1971	11 6	26 2
1972	12 7	23 7
1973	12 4	23 7
1974	12 0	24 4
1975	11 6	24 5
1976	13 7	23 5
1977	14 5	22 0
1978	15 2	21 3
1979	13 6	21 9
1980	14 3	22 9
1981	17 4	25 0
1982	16 2	24 7
1983	17 8	25 1
1984	20 2	25 2
1985	19 4	24 2

[1]Technology-intensive products are defined as those for which U S R&D expenditures exceed 2 36 percent of value-added (DOC2 and Organisation for Economic Co-operation and Development definition) Data reflect information from 24 reporting countries on exports to, and imports from each of nearly 200 partner countries

SOURCE National Science Foundation DRI Special Tabulations of International Trade. 1987

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appendix c

japanese government research programs

Table C-1. ERATO[1] projects adopted through 1986

Project	Period	Purpose
Ultrafine particles	1981-86	To explore the characteristics of ultrafine particles for applications in recording media such as magnetic memories, light absorbers, catalysts, and filters
Amorphous and intercalation compound	1981-86	To design and synthesize new inorganic materials for industrial use by modifying the atomic configuration of existing metals, semiconductors, and ceramics
Fine polymers	1981-86	To develop a new generation of synthetic polymers by taking as models the sophisticated functional capabilities of living organisms.
Perfect crystals	1981-86	To develop a new generation of semiconductors by combining perfect crystal growth technology with static induction transistor technology.
Bioholonics	1982-87	To study "holonic" systems in biological organisms in which molecules, cell tissues, and organs interact cooperatively at various levels of organization, and to build models of such systems.
Bio-information transfer	1983-88	To elucidate the mechanisms of action of neuroactive substances, such as prostaglandins and leukotrienes, which play a crucial role in intercellular information transfer The project aims to apply these mechanisms to medical problems and information technology
Superbugs	1984-89	To search for micro-organisms that grow under extreme environmental conditions such as high acidity, temperature, salinity, and pressure, and to analyze their tolerance mechanisms and metabolic pathways. A possible result may be new bioreactors that can operate at higher temperatures.
Solid-state surface	1985-90	Understand the behavior of atoms and molecules on the surface of solids, to investigate methods for the chemical processing of surfaces at the molecular level, to synthesize and separate matters, and to explore the possibilities for the composition of surfaces having information and energy conversion functions
Nanomechanism	1985-90	Review the mechanisms and dynamics of matter in the nanometer (billionth of a meter) order from a physical standpoint, and to search for clues for basic research and technology for measurement, processing, fabrication, etc
Quantum magneto flux logic	1986-91	To research the basic structure and characteristics of elements and circuits which handle quantum magneto fluxes, the method of environmental control such as complete magnetic shielding, and the simulation of circuit operation, the method of constructing an information processing system, etc.
Molecular dynamic assemblies	1986-91	Analyze fundamental dynamics by directly observing the motions of supramolecules and by measuring inputs and outputs; search for methods of reconstituting supramolecules in vitro and exploring the possibility of using them as biomolecular devices, and search for the principle of constructing sophisticated systems that can sense, process, and judge external information
Biophotons	1986-91	Examine methods that can become the basis for the measurement and analysis technology of biophotons; analyze the substances that emit biophotons and study the photo-emission mechanism, measure and analyze biophysical information on biophotons under various conditions, and explore the possibility of applying the results to the measurement of biological organisms

[1]ERATO stands for Exploratory Research for Advanced Technology the program is directed by the Research Development Corporation of Japan, a public corporation affiliated with the Science and Technology Agency

SOURCES Government of Japan Science and Technology Agency, and the Tokyo Office of the U S National Science Foundation

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Table C-2. Agency of Industrial Science and Technology (AIST) projects

Program/project	Period	Purpose
I Basic Technologies for Future Industries	Varies per project	To develop revolutionary basic technologies essential for establishing new industries Three fields, with 13 subfields, are covered in the program, R&D in these categories are conducted until the materials involved are ready for practical application
A. New materials	1981-93	The seven projects are high-performance ceramics, synthetic membranes for new separation technology, synthetic metals, high-performance plastics, advanced alloys with controlled crystalline structures, advanced composite materials, and photoactive materials
B. Biotechnology	1981-90	The three projects in this category are bioreactor systems, large-scale cell cultivation, and utilization of recombinant DNA
C. New electronic devices	1981-95	The three projects in this category are superlattice devices, three-dimensional integrated circuits, and bioelectronic dev''
II. The Large-Scale Project	1966+	Under this program, AIST cond. D projects of particular importance to the nation. Funds are contracted to participat .ompanies, which work closely with national laboratories and universities Since 1966, 24 projects have been undertaken; 16 have been completed, and 8 are in progress
A. Manganese nodule mining	1981-91	R&D on a commercial scale hydraulic mining system
B. High-speed computing system for scientific and technological uses	1981-89	R&D on high-speed computing systems for applications that existing computers cannot handle with adequate speed (e g , processing satellite information, simulation of nuclear fusion).
C. Advanced robot technology	1982-90	R&D on advanced robot technology to support people working under dangerous conditions (e.g , in nuclear power plants, disaster prevention)
D. Interoperable data base system	1985-91	R&D on technology for interoperable information systems with such features as distributed data bases and multi-media technology
E. Advanced material processing and machining system	1986-93	R&D on advanced surface processing using laser and/or ion beams for ultra-precision mechanical processing for the energy, precision machining, and electronics industries
III. The Sunshine Project	1974+	Ongoing R&D projects to develop alternative energy-generating te. nologies including solar, geothermal, coal, hydrogen, wind, and ocean thermal energy
IV. The Moonlight Project	1978-95	R&D on energy conservation technology including energy storage and discharge (e g , advanced battery storage, superheat pump energy accumulation system) and ultra-efficient energy generation (e g , advanced gas turbine, fuel cell power generation, and high-efficiency Stirling engines)

SOURCE Ministry of International Trade and Industry, *AIST 1987* (Tokyo Japan 1987)

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appendix d

awards under the specially promoted distinguished research program of the ministry of education

Year	Project title	Institution	Field
1982	Studies on New Digital Integrated Circuits Using Bridge-Type Josephson Junction Devices	University of Tokyo	Engineering
1982	Relationship between Polymorphism of DNA Double Helix and Base Configuration	University of Tokyo	Pharmaceutics
1982	Synthesis and Physical Properties of Artificial Lattice All	Kyoto University	Chemistry
1982	Studies on the Mechanism of Secretory Production of Useful Proteins by Molecular Breeding of Bacillus subtilis	University of Tokyo	Agriculture
1982	Restructuring of Antibody Genes and Information Transfer Mechanism in the Lymphocyte Differentiation Process	Osaka University	Medicine
1982	Studies on the Molecular Abnormalities of Blood Coagulation and Fibrinolysis Factors	Kyushu University	Science
1983	Elucidation of Social Interactive Processes by "Cognizance Theory"	Hokkaido University	Social Psychology
1983	Studies on Artificial Cleavages for the Exploitation of Deep Earth Crystal Energy	Tohoku University	Mechanical Engineering
1983	Studies on Communication and Instrumentation by Heterodyne Coherent Type Optical Fibers	University of Tokyo	Electrical Engineering
1983	Studies on the Origin and Evolution of Various Substances on the Earth by Lanthanum Geologic Clocks, Rare Earth, and Radioisotopic Tracers	University of Tokyo	Chemistry
1983	Direct Observation of Beauty Particles, and Detailed Studies on Charm Particles by Automatic Particle Tracing Systems	Nagoya University	Physics
1983	Studies on Clustered Ion Beam Processes (for Vapor Deposition and Crystallinity Control)	Kyoto University	Electrical Engineering
1983	Studies on Behaviors of Microstructures of Magnetic Walls, and their Application for Super-High Density Solid Memory Devices	Kyushu University	Electrical Engineering
1983	Nervous Processes for Memory in Cerebellum and Mechanism for Learning of Motion	University of Tokyo	Medicine

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Year	Project title	Institution	Field
1983	Molecular Genetic Studies on the Mechanism of Development of Hypertension	Kyoto University	Immunology
1983	Studies on the Structure and Function of Acetylcholine Receptors and Mechanism of Manifestation of Their Genes	Kyoto University	Medical Chemistry
1983	Biochemical and Genetic Studies on the Molecular Diversity of Cytochrome P-450 Enzymes	Osaka University	Protein Physiology
1983	Systematic Search and Biochemical Studies of New Peptides with Physiological Activity in Brain and Nervous Systems	Miyazaki Medical College	Biochemistry
1984	Systematic Studies on Dense Kondo State Materials	University of Tokyo	Physics
1984	Rare Gas Geoscience For Clarification of Evolution Processes of the Earth Atmosphere, Ocean, and Mantle	University of Tokyo	Geophysics
1984	Determination of Physical Factors of Galaxy Structure by Newly-Developed Quantitative Methods	University of Tokyo	Astronomy
1984	Investigation of Electronic Behaviors in Lattice-semi-matched Heterostructures, and their Application to Low Power and Very High Speed Devices	Tokyo Institute of Technology	Electronic System
1984	Analysis of the Total Structure of Chloroplast DNA	Nagoya University	Biology
1984	Organization of Ionic Solutes in Solution and Their Fluctuation	Kyoto University	Polymer Chemistry
1984	Clarification of Molecular Mechanisms of Calmodulin, the Intra-cellular Ionic Calcium-Receptor Protein	Osaka University	Higher Nervous Activity
1984	Studies on Expression of Genes by Chemically-synthesized Nucleic Acid and on their Molecular Structural Recognition	Osaka University	Pharmaceutical Chemistry
1984	The Structure, Function and Medical Significance of the Inhibitor Proteins Specific to Lysosomal-thiol-protease	Tokushima University	Enzyme Medicine
1985	Theoretical and Corroboratory Studies on Universality and Individuality of Japanese Language	Tsuda College	Linguistics
1985	Establishment of Methodology for Archaeohistorical Studies Based on Analyses of Data of Chronological Variation Patterns of Old Tree Growth Rings	Nara National Cultural Properties Research Institute	Archaeology
1985	Development of New Systems for Observation of Surface Atomic Configurational Structure, and Studies on Semiconductor Surface Superlattice Structures	University of Tokyo	Solid State Physics
1985	Search for Magnetic Monopoles and Other New Super Heavy Particles	University of Tokyo	Elementary Physics
1985	Quantum Hall Effects & Localization of Valence Electrons Quantum Effects in Electrical Conduction	Gakushuin University	Physics
1985	Studies on Physical Characteristics of Interfaces Between Chemical Compound Semiconductors and Insulators, and on Their Applications	Hokkaido University	Electrical Engineering
1985	Dynamic Structure and Functional Regulation of Protein Synthesis Systems	University of Tokyo	Biophysics

Year	Project title	Institution	Field
1985	Control Mechanisms in Biosynthesis of Blood-sugar-reducing and Blood-pressure-lowering Peptides	Tohoku University	Medicine
1985	Elucidation of B-Lymphocyte Hyperplasia and Differentiation Mechanisms and Studies on Their Anomaly Control	Osaka University	Cellular Engineering
1985	Studies on Animal Cell Division Mechanisms	University of Tokyo	Cell Physiology
1985	Molecular Biological Studies on Functions and Regulatory Mechanisms of Enzymes in Higher Animals	Kumamoto University	Biochemistry
1986	Integrated Historical and Demographic Studies on Pre-Modern Society in Japan: An Analysis of Religious Denomination Conversion Records and Development of A Computerized Database Thereof	Keio University	Economic History
1986	Studies on Methodologies for International Comparison of Human Perceptions	Institute of Statistical Mathematics	Statistical Mathematics
1986	Studies on Microstructural Semiconductor Lasers and Two-Dimensional Parallel Multi-layered Optical Integrated Circuits	Tokyo Institute of Technology	Laser Engineering
1986	Studies on Neutrino by Double Beta and Gamma Nuclear Spectroscopy	Osaka University	Nuclear Physics
1986	Optical Properties of Quantum Wells Under Electrical Field and their Applications to Ultra High Speed Optical Devices	Hiroshima University	Electronics
1986	Studies on Very Highly Ordered Molecular Systems to Achieve Ultimate Functions	Kyoto University	Organic Chemistry
1986	Studies on Muscle Contraction Mechanism by Cryoelectron Microscopy Utilizing Molecular and Heavy Atomic Labels	University of Tokyo	Biophysics
1986	Mechanism of Protein Permeation and Secretion through Membranes	Nagoya University	Agricultural Chemistry
1986	Molecular Genetic Studies of Multiformity Expression in Immunological Systems	Kyoto University	Medical Chemistry
1986	Genetic Information Retention Mechanism and Mutation Control Mechanism	Kyushu University	Molecular Genetics

SOURCE Government of Japan Ministry of Education, Science and Culture