Scie
Indicat
19

Science Indicators 1974

Report of the National Science Board 1975

National Science Board
National Science Foundation

Letter of Transmittal

December 10, 1975

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Seventh Annual Report of the National Science Board. The Report is submitted in accordance with Section 4(g) of the National Science Foundation Act of 1950, as amended.

In this Report, *Science Indicators—1974*, the Board presents the second step in the process begun with *Science Indicators—1972* of developing indicators of the state of science in the United States. Our goal is a periodical series of indices of the strengths and weaknesses of science and technology in the United States and the changing character of that activity. We hope that by contributing to the understanding of science itself we will strengthen its forward thrust, illuminate its significance, and assist in the examination of its problems.

The indicators in this Report deal primarily with resources—human and financial—for research and development. Progress has been made in developing measures of the outcomes or impacts of research and development and the contributions made thereby to the welfare of the Nation. We are continuing as a high priority our study of indicators of the characteristics of science and technology and will describe our progress in successive Science Indicator reports.

Respectfully yours,

Norman Hackerman
Chairman, National Science Board

The Honorable
The President of the United States

Contents

Introduction

The National Science Board is charged by the Congress with providing an annual report of the status of science in the United States.[1] In this, its seventh report, the Board continues the development of a series of indicators assessing the condition of the Nation's scientific endeavor. These indicators are intended to measure and to reflect U.S. science—to demonstrate its strengths and weaknesses and to follow its changing character.

Indicators such as these, updated regularly, can provide early warnings of events and trends which might impair the capability of science—and its related technology—to meet the needs of the Nation. The indicators can also assist those who set priorities for the enterprise, allocate resources for its functions, and guide it toward change and new opportunities. In these ways, communication about the issues of science is facilitated and considerations of new areas of public policy can be explored.

The internal characteristics of science provide the most readily available data for indicators, including the human and financial resources involved, the education of research scientists, changes in the institutional structures which support research and development, advances in the fundamental understanding of science and the transfer of technology. Of equal importance are measures of the external impact of science, often called "output indicators". These indicators are difficult to devise because the translation of science into technology and the genesis of science in technological advances are both deeply embedded among complex economic and social variables. In addition, many of the applications of science are not immediately realized, occurring long after and often appearing unrelated to their origins in research. However, the present report represents an advancement in the development of indicators of the outputs of the research and development enterprise.

The establishment of a comprehensive system of science indicators involves the investigation of potential indices, expansion of the underlying data base, improvement of methods for measuring the impacts of science and technology, development of analytic approaches for interpreting the measures, and demonstration of their utility across several audiences.

The effort to develop a system of effective indicators should be regarded as a long-term process. A central concept of the effort is, therefore, an evolving set of indicators derived from continuing exploration, testing, and design. The set will be evaluated, expanded, refined, and updated regularly as new data become available, as our understanding of their nature improves, and as the science enterprise itself changes.

Quantitative indicators are not a substitute for the experience and judgment of the scientific community. Indices, at their best, can only serve as supplements. The interpretation of indicators themselves—what they mean for the present and the future of the enterprise—requires the participation of the scientific community.

The Report

Indicators in this report include measures of basic research activity and industrial R&D, indices of scientific and engineering personnel and institutional capabilities, indicators of productivity and the U.S. balance of trade in high-technology products, and other aspects of the Nation's science and engineering activities.

Compared to the first Science Indicators report of the National Science Board,[2] the present report contains substantially more indicators, expanded to fill some of the major gaps and reorganized to present a more current and integrated coverage of science and related technology. A new chapter discusses industrial R&D in the United States, and includes the results of a survey on the innovative process. Additions to other portions of the report provide new information on the role of basic science in advancing technology, international aspects of technological innovation, and changing attitudes of the public toward science.

These indicators of the scientific enterprise are presented in six chapters, generally with a time span beginning in the early 1960's and

[1] Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

[2] *Science Indicators—1972*, National Science Board (NSB 73-1).

International Indicators of Science and Technology

exceeded that of the other major R&D-performing nations between 1960-74, although gains in productivity were larger in the latter countries; by 1974, the productivity of France and West Germany was some 75-80 percent of the U.S. level, while Japan, with the largest gains in productivity, reached a level which was approximately 55 percent as high as U.S. productivity.

- The United States has a large, favorable balance of trade in commodities produced by R&D-intensive industries, in contrast to the increasingly negative balance in non-R&D-intensive products; the 1974 balance in R&D-intensive products was large enough to offset petroleum imports for the same year.
- The favorable U.S. trade balance in R&D-intensive products depends primarily upon exports to developing nations and to Western Europe; a deficit balance developed with Japan in the mid-1960's and continued through 1973, due largely to imports in the areas of electrical machinery, professional and scientific instruments, and nonelectrical machinery.

This chapter presents indicators of science and technology in an international context. The focus is on the United States and how it compares with other major developed nations in several aspects of science and technology.

The indicators are directed primarily to four general aspects. The first of these relates to the absolute and relative levels of national resources utilized for research and development (R&D); this includes both human and financial resources, as well as the areas of application to which the R&D is aimed. The second topic centers around scientific research; the indicators here deal principally with the quantity and quality of scientific research in individual countries and the international dimensions of science. The third facet concerns the output from applied R&D and technological efforts; indices in this group include trends in invention and innovation, and international transactions in technology. Finally, the fourth aspect deals with productivity, economic competitiveness, and international trade; indicators in this area provide measures of the level and change in the productivity of nations and of the role of R&D in the U.S. trade balance.

International indicators of science and technology suffer from several general deficiencies. There is usually a paucity of data; the reliability of the data which are available is often unknown or less than desired; and information is frequently based upon concepts and methods which may differ substantially among countries. These place restrictions on both the aspects of science and technology which can be measured and the accuracy of the measurements themselves. For these reasons, the indicators and international comparisons presented in this chapter should be interpreted with considerable caution.

RESOURCES FOR R&D

The international comparisons presented here are based upon indicators of the human and financial resources directed to R&D by the major R&D-performing countries. These indicators are limited to measures of the magnitude of the national resources for R&D, and the general areas to which they are directed (e.g., defense, space, and health).

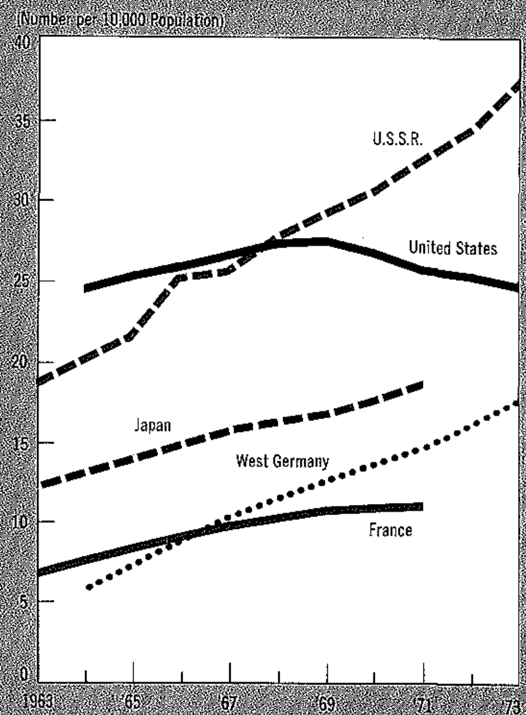
Expenditures for R&D

R&D expenditures as percentages of the Gross National Product (GNP) are shown in figure 1-1 for the six countries with the largest R&D expenditures.[2] This indicator expresses the proportion of a country's economic output which is directed to R&D and is a measure of the R&D intensiveness of a nation.[3] But because of differences among countries in the composition,

[2] Expenditures reported for the U.S. and the U.S.S.R. are for the performance of R&D alone, while those for other countries include associated capital expenditures.

[3] For the classification of various countries according to their R&D intensiveness, see "A Comparative Study of Science Advisory Approaches of Selected Developed Countries" in *Federal Policy, Plans, and Organization for Science and Technology, Part II*, U.S. Congress, House Committee on Science and Astronautics, 93rd Congress, 2nd Session, 1974.

Figure 1-2
Scientists and Engineers[1] Engaged in R&D per 10,000 Population, by Country, 1963-73



[1] Includes all scientists and engineers (full-time equivalent basis). Data for the United Kingdom are not available.
SOURCE: Organisation for Economic Co-operation and Development; U.S.S.R. estimates by Robert W. Campbell, Indiana University.

and engineers in R&D per 10,000 population is shown in figure 1-2 for the United States, the U.S.S.R., Japan, West Germany, and France. (Data for the United Kingdom are not available.) This indicator should be treated only as an approximate measure of the level and intensity of R&D because it fails to account fully for certain factors, such as national variations in the designation of scientists and engineers and their productivity.

The United States is the only major R&D-performing nation in which this indicator declined over the period studied.[6] For each of the other countries, the number of scientists and engineers engaged in R&D increased at a faster rate than the population. The United States is also unique among these nations in that a decline occurred in the number of scientists and engineers involved in R&D; this number fell from 558,000 in 1969 to 523,000 in 1973.[7] By comparison, the estimated number of such personnel in the U.S.S.R. increased from approximately 700,000 in 1969 to more than 900,000 in 1973. (See Appendix table 1-2.)

Government-funded R&D

Governments provide funds for R&D in a variety of areas such as national defense, space exploration, public health, and economic development. The distribution of funds among these areas indicates the relative emphases of the R&D programs of different countries.

Government expenditures for R&D are classified by the Organisation for Economic Co-operation and Development (OECD) into the following categories:

National Defense, encompassing all R&D directly related to military purposes, including space and nuclear energy activities of a military character;

Space, including all civilian space R&D such as manned space flight programs and scientific investigations in space;

Nuclear Energy, consisting of all civilian R&D primarily concerned with nuclear sciences and technology;

Economic Development, which covers R&D in a wide range of fields including: agriculture, forestry, and fisheries; mining and manufacturing; transportation, communications, construction, and utilities;

Health, encompassing R&D in all of the medical sciences, and in health service management;

Community Services, which includes R&D for such purposes as pollution control, education, social services, disaster prevention, planning and statistics; and

Advancement of Science, consisting of funds for fundamental research in government and private laboratories, and for research and science instruction in universities.

[6] The U.S. decline is due in large part to decreases in the employment of scientists and engineers in space and defense-related R&D. See the "Industrial R&D and Innovation" chapter of this report for further details.

[7] For more current data, see the chapter in this report entitled "Resources for R&D".

The percentage of total government funds going to each of these areas is shown in figure 1-3.[8] The United States differs principally from other nations in the relatively large percentage of R&D funds channeled to defense and space exploration (71 percent in 1971-72, the latest years for which such data are available for international comparisons), and the small percentages for the advancement of science and economic development.[9] In general, government R&D funds in other countries (except the United Kingdom) were concentrated in the latter two areas; this applied particularly to Japan and West Germany.

Changes in the distribution of government-funded R&D over the 1961-71 period were similar for each country. Defense-related R&D decreased as a proportion of the total R&D expenditures, whereas the fraction for the advancement of science and economic development generally increased, as did the percentage for health and community services. Overall trends suggest a relative shift from military R&D to areas of domestic concern and the advancement of science. (The magnitude of R&D expenditures for national defense, however, increased in absolute terms in all countries other than Japan.)

Differences between countries in the distribution of their R&D efforts arise from a variety of factors, such as the extent of a nation's military commitments and variations in the roles of government and the private sector. The pattern of R&D expenditures shown in figure 1-3 is based upon funding by governments only and does not include the large expenditures by the private sector, due to the lack of comparable data.

SCIENTIFIC RESEARCH

This section presents indicators of the international character of science and various measures of the magnitude and quality of scientific research in major nations. Indicators of magnitude are based upon the number of research publications from each nation in several fields of science. Quality indicators are developed from the international pattern of citations associated with these publications, as well as from the distribution of Nobel Prizes among nations and scientific fields.

The internationalism of science

Science by its very nature is international. The phenomena studied, the methods of investigation, and the validity of research findings are independent of national boundaries. Researchers from all countries can contribute to the body of scientific knowledge, with contributions assessed on their scientific merit, not the country of their origin.

The internationalism of science is based upon and fostered by a wide variety of formal and informal arrangements. Foremost among these are the publication of research findings in widely circulated journals and books, international meetings, joint research efforts, and informal correspondence among scientists. In addition to these, governments frequently sponsor international travel for scientists to consult and collaborate on research, and enter into formal bilateral agreements for scientific cooperation and exchange among nations. The international scientific community is also served by the International Council of Scientific Unions, which encompasses an array of associations for the advancement of science and the exchange of information. Finally, the United Nations has created specialized scientific agencies nearly global in scope, which foster international cooperation in science and which in turn provide models for similar regional organizations.

International scientific literature. The international dimension of science may be seen in one of its more fundamental forms in the performance of research and the publication of its results. Current research builds upon the extant body of scientific knowledge, which is the combined product of researchers from all countries. The dependence upon research performed in other nations is expressed, approximately, by a large sample of the citations in published research reports to scientific literature of foreign origin.

This indicator is shown in figure 1-4 for eight major fields of science and engineering, as well as for all the fields combined.[10] The indicator is based upon data from the six major R&D-performing nations identified in previous sec-

[8] Data are not available for the U.S.S.R.

[9] For current information on the distribution of U.S. Government expenditures for R&D, see the chapter in this report entitled "Resources for R&D"

[10] *Indicators of the Quantity and Quality of the Scientific Literature*, Computer Horizons, Inc., 1975 (A study commissioned specifically for this report).

tion helps to ensure that the reports have some degree of scientific or technical significance.

Indicators based on research reports, however, have several limitations when used for international comparisons: the quantity of such reports may be influenced substantially by the journals selected for examination,[12] by national customs regarding the publishing of research papers, by the availability of funds for preparing and printing papers, by journal refereeing and publishing policies, etc. These and other limitations provide good reason for caution in interpreting such indicators.

The indicators presented in this section provide measures of: (1) the proportion of the world's research literature in selected scientific areas produced by the United States and other major research-performing countries; (2) the distribution of research literature among fields of science in each country; and (3) the influence of the literature produced in each field by each country.

National origins of scientific literature. Estimates of the literature produced by researchers in each country were based upon counts of articles, letters, and notes published in some 500 journals covered by the *Science Citation Index (S.C.I.)*[13] over the period 1965-73, supplemented by data from various abstracting services.[14] The journals included in the set were those which were most highly cited in the total 1965 literature, regardless of field. The national origin of the literature was determined by the country of the first author of each scientific paper. The results are presented in figure 1-6.[15]

The United States produced a larger proportion of the 1973 scientific literature in this sample of 492 journals than any other country in these fields: physics, engineering, psychology, molecular biology, and systematic biology. In the fields of chemistry and mathematics, however, the U.S.S.R. led all countries, with the United States following as the second largest producer.[16] The overall position of the United States, relative to the other countries, has changed little since 1965, the initial year of this indicator. For the seven fields as a whole, U.S. scientists and engineers published more than did those of any other country, followed by Soviet scientists and engineers. The United Kingdom, in these terms, ranks a distant third, while France, West Germany, and Japan cluster at a somewhat lower level.

The international position of the United States may be declining in the fields of chemistry, engineering, and physics. The U.S. share of the literature in each of these fields declined slightly in both 1972 and 1973, as shown in figure 1-6. Furthermore, the absolute number of publications in these areas was lower in 1973 than in some previous years.[17] (These declines may be related to trends in the funding of research in the three fields, as presented in the "Basic Research" chapter of this report).

Although attention was focused above on the six countries producing the largest number of scientific publications, several other nations contribute significantly to the world literature.[18] The largest contributors among these in 1973 were:

Australia	Italy
Canada	Netherlands
Czechoslovakia	Poland
India	Sweden
Israel	Switzerland

Each of these countries ranked among the first 10 nations in the number of 1973 research publications of at least one of the eight fields of science.

National research profiles. Countries differ in the emphasis they place on various fields of scientific research. The relative number of

[12] The representativeness of a journal set only approximates the representativeness of the articles themselves because of the varying sizes of journals and other reasons. The next *Science Indicators* report will examine this representiveness in detail.

[13] Published by the Institute for Scientific Information, Philadelphia, Pennsylvania.

[14] For details of the sample and methodology employed, see *Indicators of the Quantity and Quality of the Scientific Literature,* Computer Horizons, Inc., 1975. (A study commissioned specifically for this report).

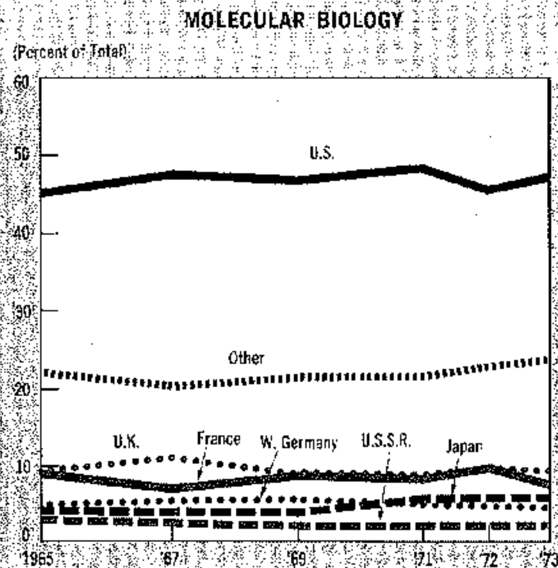
[15] An analysis of 2,121 journals included in the *Science Citation Index* for 1973 yields similar results in the ranking of nations within fields, but comparable data for the larger set of journals are not available for earlier years.

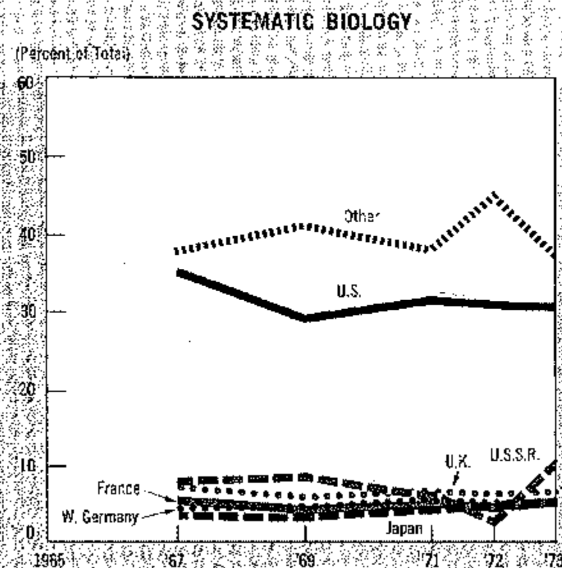
[16] The *Science Citation Index* for 1973 and earlier years did not include a number of important U.S.S.R. chemistry journals; the U.S.S.R. share of the chemistry literature, therefore, may be underestimated.

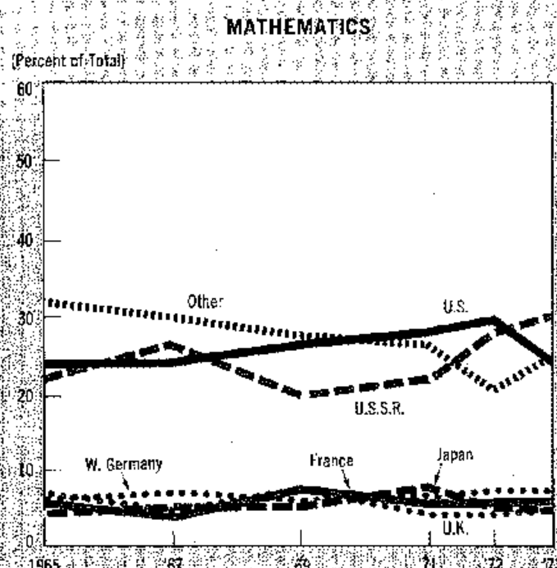
[17] Similar publication trends in these fields, found in another study, are presented in the "Basic Research" chapter of this report.

[18] These and all subsequent data on scientific literature were developed from an analysis of 2,121 of the journals in the 1973 *Science Citation Index,* as described in *Indicators of the Quantity and Quality of the Scientific Literature,* Computer Horizons, Inc., 1975 (A study commissioned specifically for this report).

Figure 1-6 continued







SOURCE: Computer Horizons, Inc.

Citation indices of selected scientific literature[22] by selected fields and countries, 1973

Field	Country	Citation indices
Clinical medicine	United States	1.3
	United Kingdom	1.3
	Japan	.6
	West Germany	.5
	France	.5
	U.S.S.R.	.2
Biology and biomedical research	United States	1.3
	United Kingdom	1.2
	Japan	.8
	West Germany	.8
	France	.6
	U.S.S.R.	.3
Chemistry	United States	1.5
	West Germany	1.5
	United Kingdom	1.4
	Japan	.7
	France	.7
	U.S.S.R.	.4
Physics	United States	1.4
	West Germany	1.0
	United Kingdom	.9
	France	.8
	Japan	.7
	U.S.S.R.	.6
Engineering	France	1.1
	United States	1.1
	United Kingdom	1.0
	U.S.S.R.	1.0
	West Germany	.9
	Japan	.8
Earth and space sciences	United States	1.3
	United Kingdom	1.0
	Japan	.7
	West Germany	.7
	France	.6
	U.S.S.R.	.3

The United States ranks first or ties for first place on this measure in each of the eight fields. The U.S. lead is greatest in physics, followed by the earth and space sciences.

Each country tends to have higher citation indices for its own scientific literature than it has for the literature of other countries (see Appendix table 1-7b). This is particularly true for the U.S.S.R. and France. The United States, on the other hand, cites its own literature less than other countries cite theirs, except in the fields of chemistry and physics where its domestic citation indices are higher than those of the other five countries.

[22] The relatively high citation ratios associated with the United States and the United Kingdom may reflect, in part, the growing use of English as the language of scientific publication. Nevertheless, when citations made by U.S. and U.K. authors were excluded from these indices, the United States still had the highest citation ratios for chemistry, physics, mathematics, and the earth and space sciences.

Nobel Prizes in science

International prizes for scientific achievement, although awarded to individuals rather than countries, provide a gross indication of the relative position of nations in scientific research. Foremost among such awards are the Nobel Prizes. These prizes were established by a bequest of Alfred Bernhard Nobel, and give international recognition to achievements in the fields of physics, chemistry, and physiology/medicine.[23]

The Nobel Prizes from the first year awarded, 1901, are shown in figure 1-8 in terms of the number awarded to scientists in each of five countries which together account for a majority of the awards, and in relationship to the population of these countries.[24] Data are presented by year of award which, on the average, is some 15 years after the time of the research itself.

Scientists in the United States have received the largest number of awards over the 1901-74 period as a whole, surpassing all other countries since the 1931-40 decade. Prizes going to the U.S. scientists, however, declined after the 1951-60 decade, primarily as a result of a smaller number of prizes in the field of physics. In relationship to population, however, U.S. scientists received a smaller fraction of prizes than the United Kingdom over the last three decades.[25]

[23] *Nobel, the Man and His Prizes.* (Stockholm: Nobel Foundation, 1962). Nobel also established prizes in the fields of literature and peace. Later, in 1969, the Nobel Foundation instituted the prize in economics and since then, 4 prizes have been awarded to U.S. economists, and single prizes to economists in Austria, the Netherlands, Norway, Sweden, and the United Kingdom. In some other areas of science which are not within the scope of the Nobel Prizes, there are similar international distinctions awarded for eminent accomplishments; for example, the Fields Medal for Mathematics was established in 1936 and since that time, U.S. mathematicians have received 35 percent of the quadrennial awards, largely after 1958.

[24] The apparent decline in 1971-74 is partially explained by the shorter time interval covered in this period.

[25] Other countries, such as the Netherlands and Switzerland, have received a greater number of Nobel Prizes in respect to population size than either the United Kingdom or the United States.

Figure 1-8 a

Nobel Prizes Awarded in Science, for Selected Countries, 1901-1974

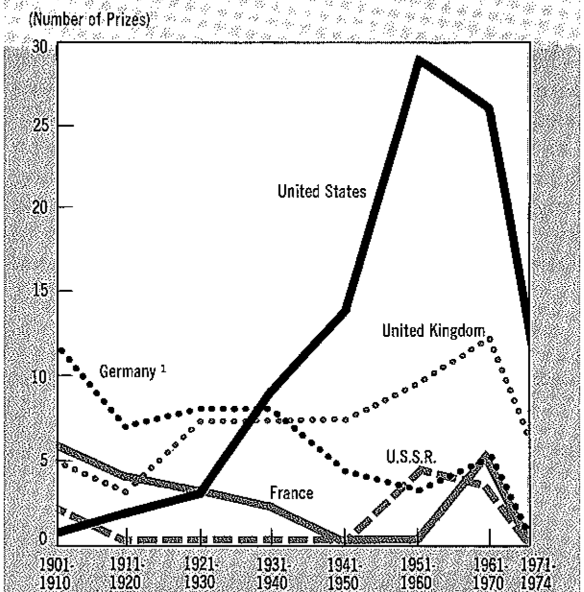
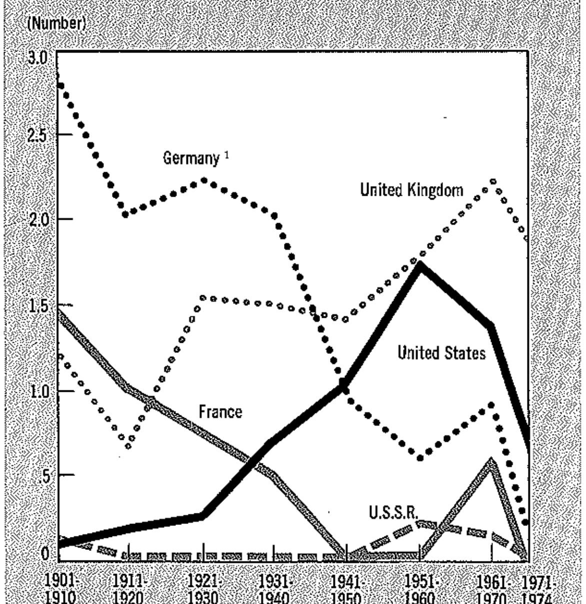


Figure 1-8 b

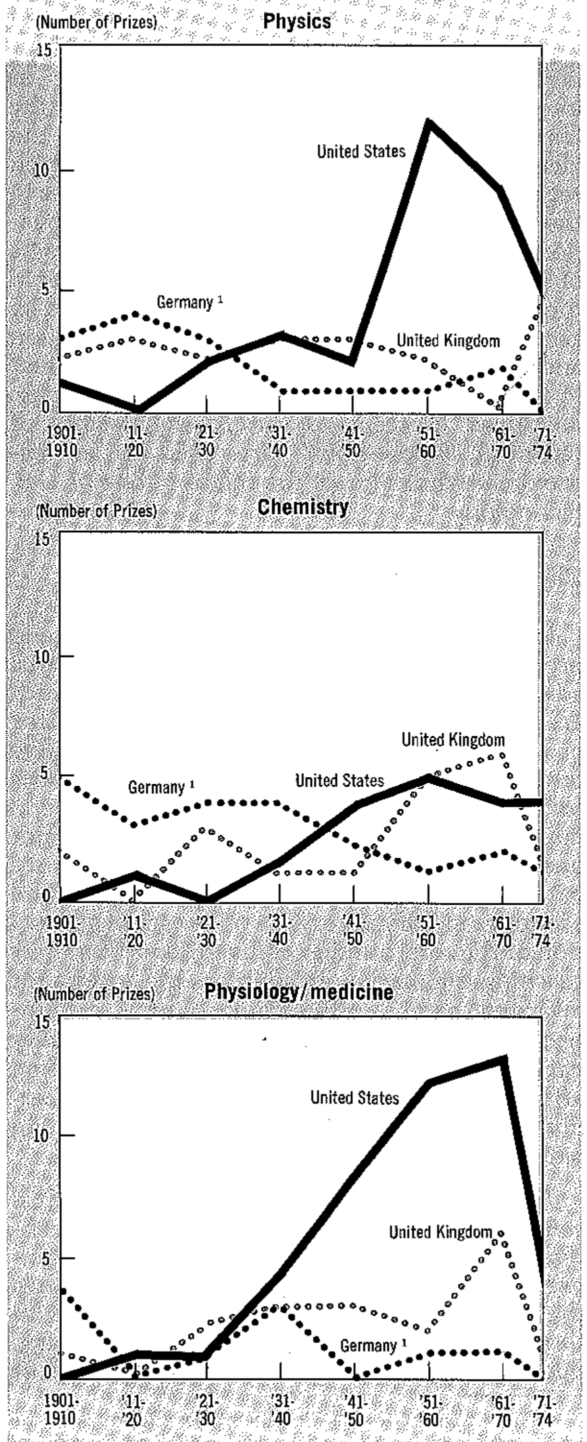
Nobel Prizes in Science per 10 Million Population for Selected Countries, 1960-1974



[1] After 1945, excludes the German Democratic Republic.
SOURCE: The Nobel Foundation.

Figure 1-9

Nobel Prizes Awarded by Field for Selected Countries, 1901-74



[1] After 1945, excludes the German Democratic Republic.
SOURCE: The Nobel Foundation.

States; and the resulting U.S. balance. These 10 countries were responsible for nearly 70 percent of all foreign patent transactions with the United States during 1966-73. (Data are not available for Italy, and are not reliable for France for use in this report).

The "patent balance" of the United States fell by about 30 percent between 1966 and 1973, as shown in figure 1-10. The decline was due both to an increasing number of U.S. patents awarded to foreign countries and a decline (in 1973) in the number of foreign patents awarded to U.S. citizens. Overall, foreign patenting increased in the United States during the period by over 65 percent, and by 1973 represented more than 30 percent of all U.S. patents granted. This suggests that the number of patentable ideas of international merit has been growing at a greater rate in other countries than in the United States.

The United States has a favorable but declining patent balance with each country except West Germany and the U.S.S.R.[27] (figure 1-11). The favorable balance with Japan has declined steadily since 1968, as its patenting of inventions in the United States increased some threefold. The U.S. balance with Canada dropped sharply after 1972 as a result of a 30 percent reduction in the number of patents granted by Canada to U.S. inventors.

Foreign origin patents by product area. The rapid growth of foreign patenting in the United States has occurred in a broad spectrum of product areas and technologies. The number of such foreign patents granted in these areas can be used to identify the products and technologies in which the foreign impact is greatest.

For this purpose, all U.S. patents granted during 1963-73 were assigned to 15 major product areas according to the probable areas of application of the invention.[28] The percentage of foreign origin patents within each of these areas in 1973 is presented in the table below.

In 1963, the proportion of foreign origin patents in 12 of the 15 areas was less than 20 percent; only one area—petroleum refining and extraction—had less than 20 percent foreign patents in 1973.

In studies of more specific fields and technologies, the U.S. Patent Office has identified a number of areas in which the foreign share of U.S. patents is particularly high and increasing rapidly.[29] Listed below are some of these areas and the corresponding foreign share of patents during 1972:

Areas	Percent of U.S. patents to foreign countries
Piezoelectric compositions	78
Magnetic field responsive resistors	72
Automatic transmissions	69
Superconductors	60
Vinyl halide polymers	56
Ground effect machines	54
Semiconductor internal structures	52
Magnetic sound recording and reproducing structures	52
Magneto-hydrodynamic generators	49
Ignition timing controls	49

Japan, West Germany, and the United Kingdom received the greatest proportion of foreign patents awarded by the United States in these areas.

Percent of total U.S. patents granted to foreign countries by major product area, 1973

Product area	Percent	Product area	Percent	Product area	Percent
Drugs and medicines	44	Food and kindred products	33	Motor vehicles and other transportation equipment	28
Aircraft and parts	39	Machinery, except electrical	30	Rubber and miscellaneous plastics products	28
Textile mill products	37	Electrical equipment, except communications	29	Stone, clay and glass products	27
Chemicals, except drugs	35	Professional and scientific instruments	29	Fabricated metal products	25
Primary metals	34	Communication equipment and electronic components	28	Petroleum refining and extraction	17

[27] The U.S.S.R. accounted for only one percent of all the patent transactions considered.

[28] *Indicators of the Patent Output of U.S. Industry*, Office of Technology Assessment and Forecast, U.S. Patent Office, 1974 (A study commissioned specifically for this report).

[29] This information was taken from a series of reports of the Office of Technology Assessment and Forecast, U.S. Patent Office, April 1973-January 1975.

creased energy consumption—which may be associated with the innovations.

The innovations included in the study represent a wide range of product areas and industrial sectors. Examples of the innovations are listed below:

Nuclear reactors	Automatic optical readers
Oral contraceptives	High speed electric trains
Urethane foams	Integrated circuits
Electron beam welding	Lasers
High voltage electric cables	Weather satellites

The innovations were classified according to the type of market which the innovating company intended for the innovation[34]: producer goods, consumer goods, or the government (viewed as both a producer and a consumer market). The innovations in total were aimed principally at the producer-goods market (65 percent of all innovations), followed by the government (19 percent), and the consumer-goods market (16 percent). The following table shows the distribution of innovations among the three types of markets for each of the five countries:[35]

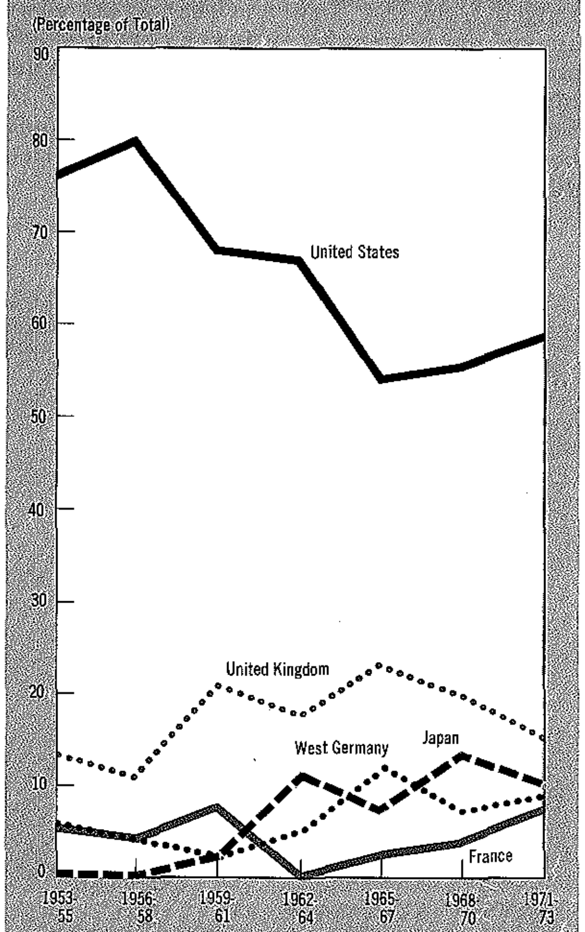
Percent distribution of innovations by type of market and country, 1953-73

Country	Type of market: Producer goods	Government	Consumer goods
United States ...	62	19	19
United Kingdom .	89	2	9
Japan	77	16	7
West Germany ..	69	7	24
France	45	10	45

Major innovations by selected countries. The proportion of the 492 innovations produced by each of the five countries is shown in figure 1-12. The United States leads each of the other nations by a wide margin in the percentage of major innovations produced. The U.S. lead, however, declined steadily from the late 1950's to the mid-1960's, falling from 82 to 55 percent of the innovations. The slight upturn in later years represents a relative rather than an absolute gain, and results primarily from a decline in the proportion of innovations produced in the United Kingdom, rather than an increase in the number of U.S. innovations. The largest actual gains were recorded by Japan, although its share of the innovations reached only some 10 percent by the early 1970's.

The innovations as a whole covered a wide range of product areas, but U.S. innovations were concentrated primarily in the most R&D-intensive industries, particularly: electrical equipment and communications, chemicals and

Figure 1-12
Major Technological Innovations, by Selected Countries, 1953-73



SOURCE: Gellman Research Associates, Inc.

[34] The innovation may have been introduced subsequently into other markets; e.g., innovations initially directed to the government may have been introduced later into another market.

[35] Innovations originating in Canada were omitted from this report because they are small in number and therefore cannot be analyzed in detail.

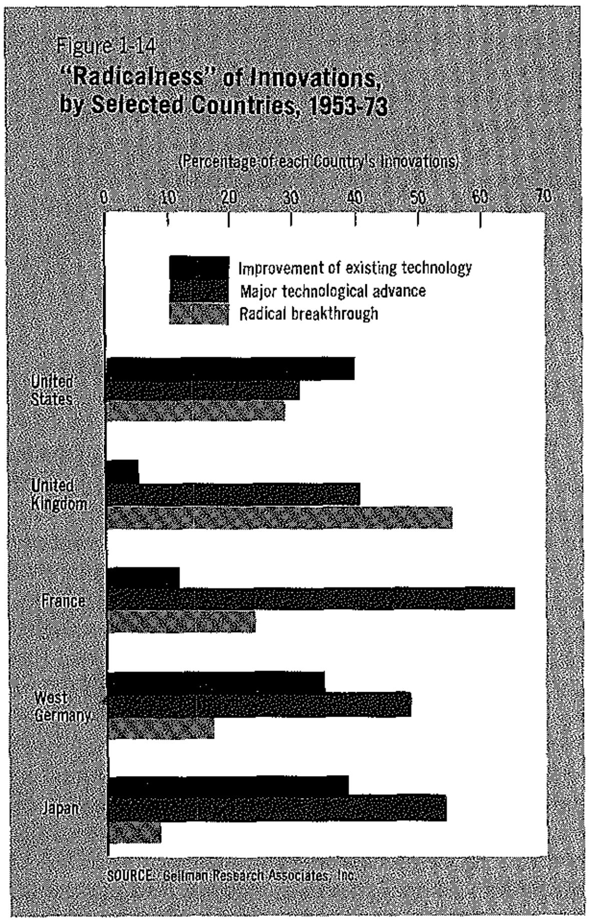


Figure 1-14
"Radicalness" of Innovations, by Selected Countries, 1953-73
(Percentage of each Country's Innovations)
SOURCE: Gellman Research Associates, Inc.

and manufacturing rights) of a country is one indicator of the technological position of that country *vis-a-vis* other nations. Several other factors, however, may influence the volume of such purchases, such as the economic development policies of the nations involved and the trading arrangements among them.

Information on payments and receipts for technical "know-how" is available for transactions between multinational companies and their foreign affiliates as well as between independent organizations. The latter information was selected for use primarily on the assumption that purchases by independent enterprises are more likely to be based on the technical merit of all available "know-how". The omission of transactions between corporations and their foreign affiliates, however, results in a substantial understatement of the extent of technology transferred. In addition, a significant amount of "know-how" is transferred through the exchange of technical and management personnel, and through informal agreements which are not reflected in the financial data presented here.

The dollar value of U.S. receipts, payments, and the resulting balance (i.e., receipts minus payments) for exchange of technical "know-how" is shown in figure 1-15. Over the 1960-74 period, U.S. receipts from the sale of "know-how" grew exponentially while its payments grew more linearly, resulting in an increasingly large positive balance of payments in this area. Increases in the U.S. balance are due principally to purchases of U.S. "know-how" by Western Europe and Japan (accompanied by relatively small purchases of Japanese "know-how" by the U.S.). From 1970 onward, for example, nearly 45 percent of U.S. net receipts were associated with Japan, and 30 percent with Western Europe (including the United Kingdom). The developing countries are increasingly important purchasers of U.S. "know-how", accounting for 15 percent of the U.S. balance in 1974.

U.S. purchases of foreign "know-how" are primarily from Western Europe. Approximately 80 percent of U.S. payments in 1974 went to these countries, with nearly 35 percent going to the United Kingdom alone.

Although considerably more technical "know-how" appears to flow from the United States than to it, the volume of foreign technology acquired by the United States is substantial and expanding in various areas. Machine tools is one such area in which the advanced "know-how" of foreign countries has been acquired for use in the United States. In plastics, the European developments in polyethylene have impacted significantly on American industry. Imported technology and "know-how" have also had substantial influence in the optical equipment area.[36]

PRODUCTIVITY AND BALANCE OF TRADE

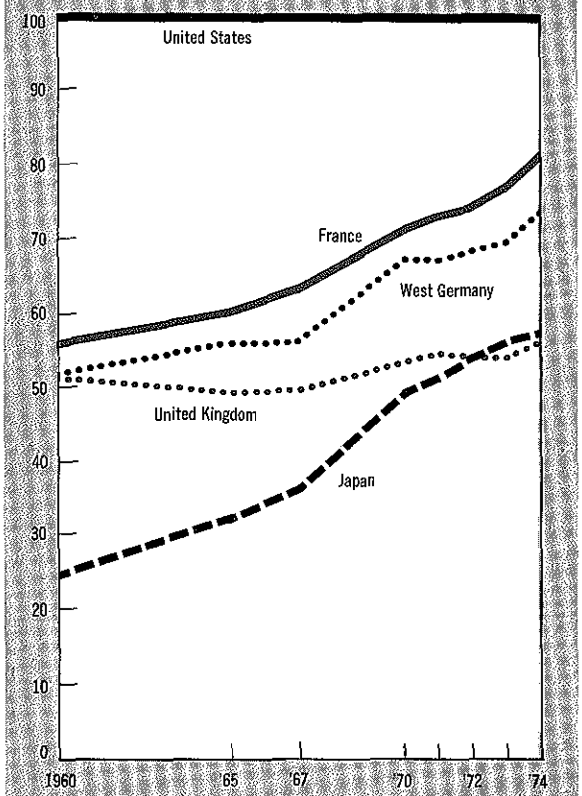
This section presents indicators of international trends in productivity, as well as measures of the contribution of R&D to the U.S. balance of trade. Trends in the level of national

[36] *International Economic Report of the President,* Council on International Economic Policy, 1975.

Figure 1-16

Real Gross Domestic Product per Employed Civilian, for Selected Countries Compared with the United States, 1960-74

(Indexes, United States = 100)



SOURCE: U.S. Department of Labor.

Product per employed civilian". Measured in these terms, the level of U.S. productivity exceeded that of France, Japan, West Germany, and the United Kingdom throughout the 1960-74 period (figure 1-16). Gains in productivity, however, were larger in the four other countries, with the result that the U.S. lead diminished significantly. By 1974, the productivity levels of France and West Germany were only 20-25 percent lower than the United States. Japan gained the most in productivity, but was still some 40-45 percent below the U.S. level in 1974.

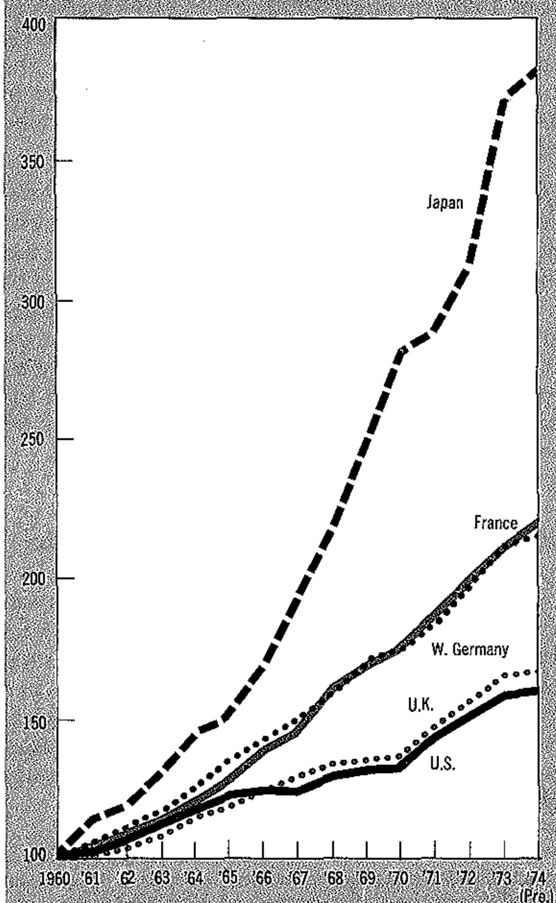
Trends in productivity are more commonly measured in terms of output per man-hour. The use of this index does not imply that labor alone is responsible for productivity growth; output per man-hour may also be influenced by factors such as technological advances, scale of production, and management effectiveness. This index is developed for each country separately, and is used to measure the change in productivity over time in that country; it does not permit comparisons of the actual productivity levels of different countries.

This indicator is presented in figure 1-17 for manufacturing industries in the five countries. The U.S. productivity gain between 1960-74 is the smallest of these five countries (60 percent)

Figure 1-17

Productivity[1] in Manufacturing Industries, by Selected Countries, 1960-74

(Index 1960 = 100)



[1] Output per man-hour.

SOURCE: U.S. Department of Labor.

engineers engaged in R&D per 1,000 employees and (b) company-funded R&D amounting to at least 3 percent of their net sales, were regarded as "R&D-intensive" products.[42] Based on these criteria, the product areas identified as R&D-intensive are (1) chemicals, (2) nonelectrical machinery, (3) electrical machinery, (4) aircraft and parts, and (5) professional and scientific instruments. All other manufactured products were regarded as non-R&D-intensive.

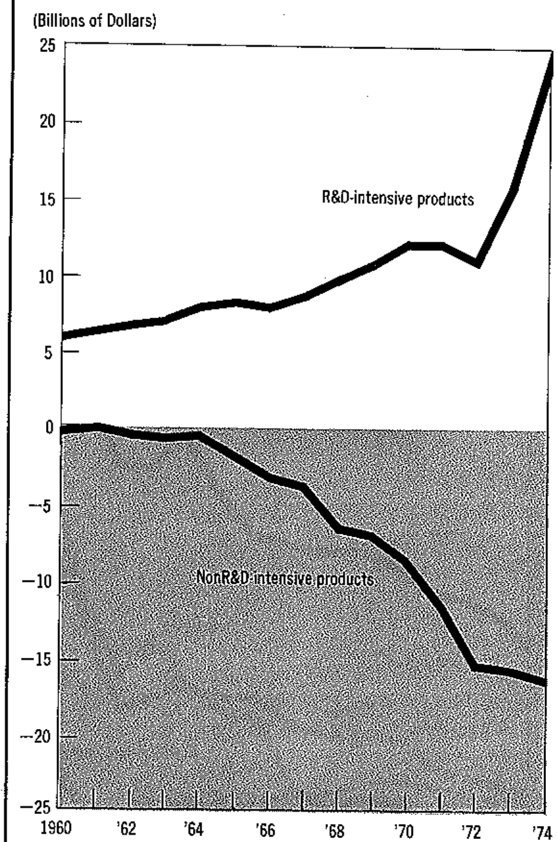
The U.S. trade balance (exports minus imports) associated with these two categories of products is shown in figure 1-19.[43] The favorable balance in R&D-intensive products is clearly indicated; the balance increased fourfold over the 1960-74 period and doubled between 1970-74 alone. In contrast, the United States had a large and increasing trade deficit in non-R&D-intensive products. The principal products in this area which accounted for the deficit were motor vehicles, textiles, and metals.[44]

The favorable U.S. trade balance in products from R&D-intensive industries is shown in figure 1-20.

Nonelectrical machinery accounted for nearly one-half of the favorable balance in R&D-intensive products. The recent growth in the balance for this area was largely the result of increased export of electronic computers, construction equipment, and mining and well-drilling machinery.

Aircraft and parts contributed approximately one-fifth of the positive balance in R&D-intensive products in 1974. This is the only one of the five areas in which imports decreased between 1973 and 1974.

Figure 1-19
U.S. Trade Balance in R&D-intensive and NonR&D-intensive Manufactured Products, 1960-74



SOURCE: U.S. Department of Commerce.

Chemicals accounted for an additional one-fifth of the positive balance in R&D-intensive products. The recent increase in net exports of chemicals was due largely to growth in the exports of plastics, medicinal and pharmaceutical products, and manufactured fertilizers.

Electrical machinery had the smallest margin of exports over imports, as a result of large and increasing imports in telecommunications apparatus, without comparable increases in exports of other types of electrical machinery.

---

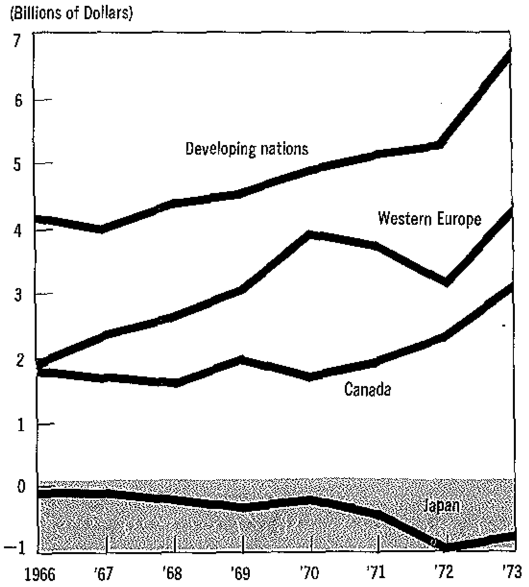
[42] This grouping, of course, is an approximate one. Products and industries, although highly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry can be considered R&D-intensive.

[43] The export statistics presented here include all merchandise shipped from the U.S. customs area, with the exception of supplies destined for U.S. Armed Forces abroad for their own use; shipments for relief purposes or under military assistance programs are included. The import statistics cover foreign merchandise received in the U.S. customs area.

[44] The trends in U.S. foreign trade presented here were influenced by recent adjustments in the international monetary system. In December 1971, the United States reduced the par value of the dollar; in March 1974, all of the major world currencies converted to a system of floating exchange rates. The precise impact of these changes on the U.S. trade position is not known, but in general they are thought to enhance the competitiveness of U.S. exports. A detailed discussion of this topic is presented in the *Economic Report of the President*, Council of Economic Advisers, 1975.

Figure 1-21

U.S. Trade Balance with Selected Nations in R&D-intensive Manufactured Products, 1966-73



SOURCE: U.S. Department of Commerce.

United States have a significant net export position with respect to Japan. (It might be noted that the United States also has a negative trade balance with Japan in non-R&D-intensive products).

The importance of the positive trade balance in R&D-intensive products is illustrated by the fact that the net exports of such products in 1974 ($23.6 billion) were large enough to offset the negative balance in petroleum products ($23.4 billion) for that same year.[47]

Agriculture is an additional component of foreign trade which is significantly affected by the position of U.S. technology. The leading role of U.S. agriculture is due at least in part to the contributions of science and technology in such areas as the development of new hybrids; the utilization of irrigation techniques; the improvement of fertilizers, pesticides, and herbicides; and the widespread mechanization of production.[48] In 1974, the United States exported $22.3 billion of agricultural commodities (with especially high volume in wheat, soybeans, and corn), and had a positive trade balance of $11.9 billion in agricultural commodities as a whole.[47]

The preceding examination of foreign trade was restricted, for the purposes of this report, to those aspects which provide relatively direct indices of the position and performance of U.S. technology. As a result, such topics as foreign direct investment, sales of U.S. subsidiaries abroad, and the impact of multinational corporations were not discussed.[49]

[47] *Overseas Business Reports,* Department of Commerce, Domestic and International Business Administration (OBR 75-22).

[48] *Agricultural Production Efficiency,* National Academy of Sciences, Washington, D.C., 1975.

[49] For further treatment of these topics see the *International Economic Report of the President,* Council on International Economic Policy, 1975.

Resources for Research and Development

- for defense remained at slightly more than 50 percent throughout 1969-74, whereas the fraction for civilian areas rose steadily from 24 to 34 percent while the share for space R&D declined from 24 to 14 percent.
- Funds from the Federal Government for civilian R&D increased 70 percent in current dollars and 28 percent in constant dollars between 1969 and 1974; the civilian fields accounting for most of the growth were health (39 percent of the total growth) and the environment (17 percent).
- Federal funds for civilian R&D are concentrated on research (applied and basic) rather than development—in contrast to defense and space R&D; in 1974, 72 percent of the funds went for research, with 45 percent going for applied research and 27 percent for basic research.
- Federal funds for laboratory equipment provided through research grants declined as a fraction of total grant funds, decreasing from 11 percent in 1966 to 5 percent in 1974.[4]
- Federal support for major fixed equipment and R&D facilities in 1974 was well below the years of highest funding in the mid-1960's even though such support has increased considerably since 1972.
- Expenditures by the Federal Government for the dissemination of the results of R&D increased in current dollars each year from 1960 through 1974, but changed little in constant dollars after 1968; the ratio of these obligations to total Federal obligations for R&D has remained at approximately .025 since 1970.

Substantial resources are committed to research and development in the United States. The largest fraction of these resources goes for R&D in a broad spectrum of national concerns, such as national defense, space exploration, health, energy, and the environment. A large and nearly comparable portion of the R&D resources is used to develop new and improved industrial products and processes. A small part of the resources is allocated for basic research to advance the understanding of nature.

"Research and development" in this report comprises basic and applied research and development activities. "Basic research" has the purpose of acquiring scientific knowledge of natural phenomena, where the primary aim is fuller understanding of the subject of study, rather than specific application of the resulting knowledge. "Applied research" has a similar although often less general purpose, but where the prime aim is the potential application of the acquired knowledge. The scientific fields encompassed in basic and applied research consist of the life sciences (including the medical sciences), physical sciences, mathematical sciences, and engineering, as well as the psychological and social sciences.[5] "Development" consists of the use of knowledge gained from research, in conjunction with technical "know-how", for the design and prototype construction of materials, devices, processes, products, systems, and methods.

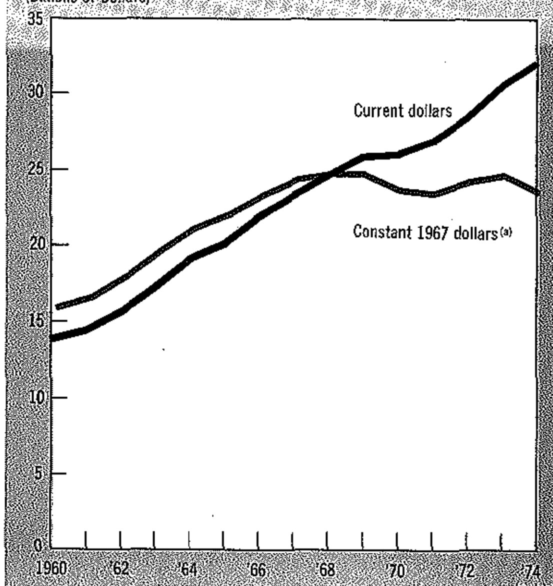
Indicators presented in this chapter are intended to portray general trends in the allocation and use of financial and human resources in the Nation's overall R&D effort. These include several measures of the absolute and relative magnitude of these resources, as well as the sectors which supply and utilize them. Indicators are provided also of the financial resources which are directed to basic research, to applied research, and to development. In addition, trends in Federal funds for R&D are presented in relationship to the total Federal budget and in respect to broad areas of R&D activity. The chapter also contains indicators of the resources for research equipment and facilities, and trends in the Federal support of efforts to disseminate the results of R&D. More detailed examination of particular areas of R&D activity, and measures of output, are presented in subsequent chapters.

---

[4] Based upon research grants of the National Science Foundation and the major National Institutes of Health.

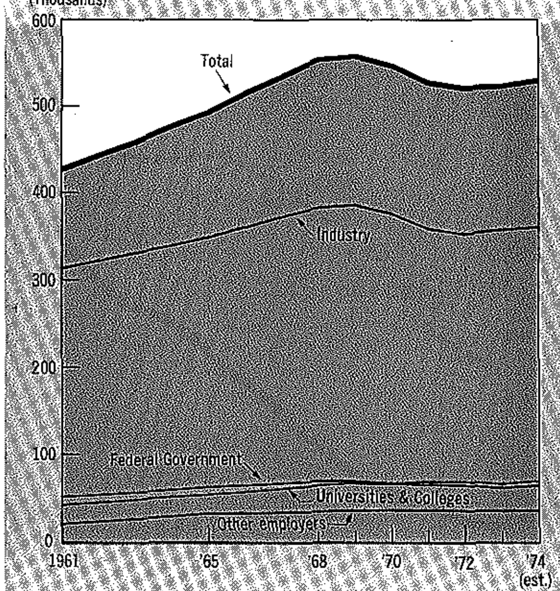
[5] Data are not available on industry resources for research in the psychological and social sciences.

Figure 2-1
National R&D Expenditures, 1960-74



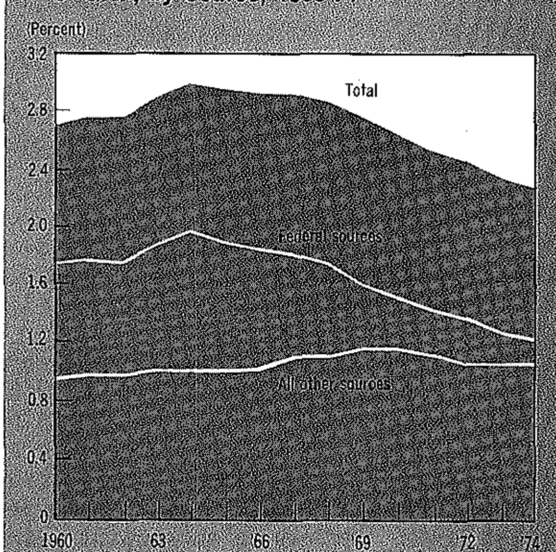
(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 2-2
Scientists and Engineers[a] Employed in R&D by Sector, 1961-74



(a) Full-time-equivalent basis, excluding those employed in state and local agencies, calculated as the yearly average.
SOURCE: National Science Foundation.

Figure 2-3
National R&D Expenditures as a Percent of GNP, by Source, 1960-74



SOURCE: National Science Foundation.

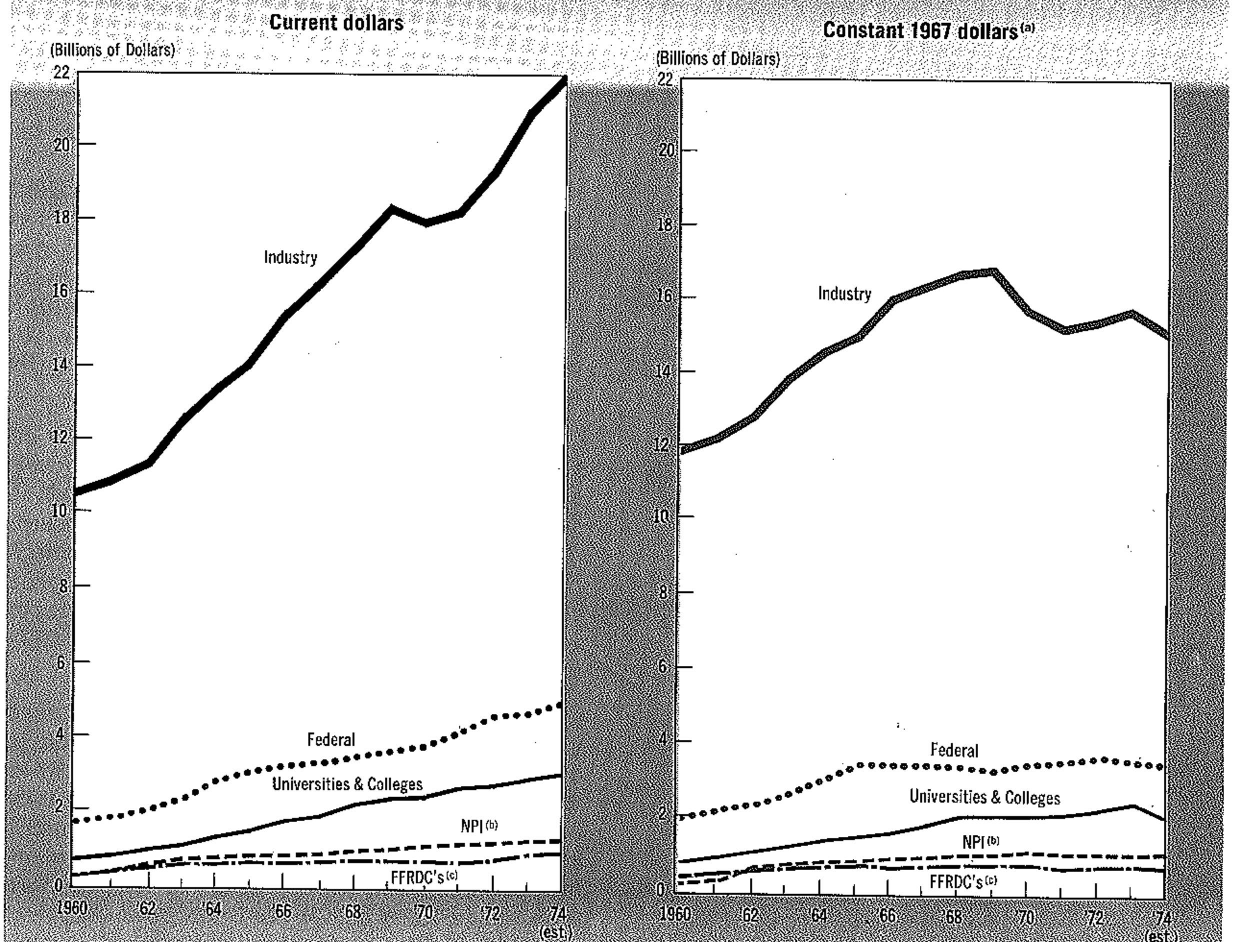
The share of total support of R&D expenditures borne by the Federal Government stood at 53 percent in 1974 (figure 2-4) compared with 65 percent in 1965. The industry proportion increased from 33 percent in 1965 to 43 percent in 1974. The combined share contributed by universities, colleges, and other nonprofit institutions has ranged between 2 and 4 percent from 1960 to 1974.

Even though the universities and colleges represent a small source of R&D expenditures, their contribution increased considerably during the period, rising from $168 million in constant dollars in 1960 to a high of $472 million in 1974.[6] This reflects, in part, the increased support provided to public institutions by state and local governments.

Other nonprofit institutions increased their spending also, growing from $160 million in constant dollar expenditures in 1960 to a high of $359 million in 1973.

[6] Data in this report for universities and colleges include only separately-organized R&D; expenditures for the usual teaching/research assignments of the faculty are excluded.

Figure 2-5
National Expenditures for R&D, by Performer, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
(b) Nonprofit institutions.
(c) Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

was 26,000 fewer than in 1968. This sector, as well as Federal laboratories and universities and colleges, had a small increase in the number of R&D scientists and engineers between 1973 and 1974.

The distribution of R&D scientists and engineers[7] among performing sectors has remained nearly the same for many years (figure 2-3). Over two-thirds are employed in industry, while the Federal government and academic shares are nearly equal to one another—approximately 12-13 percent each.

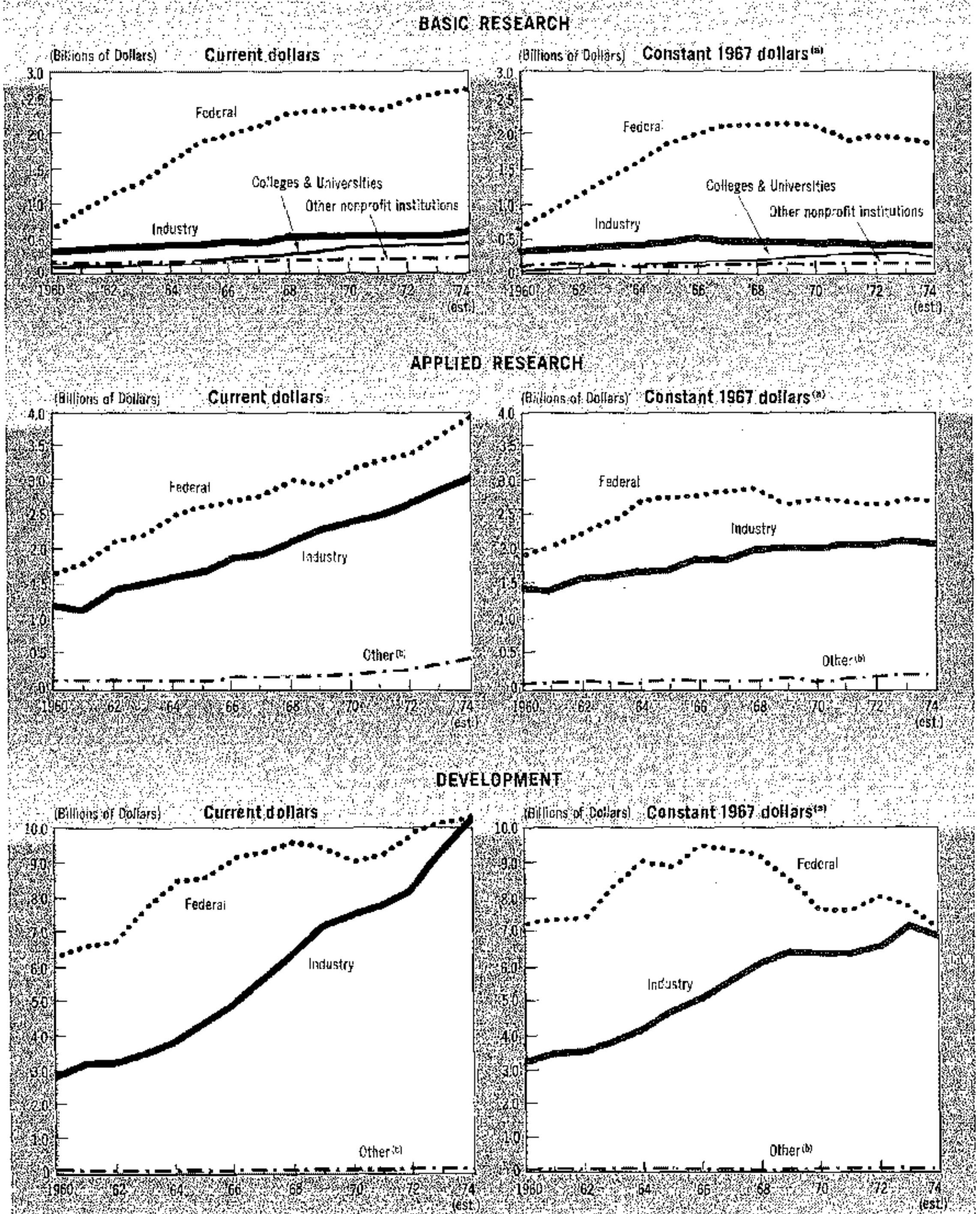
[7] Full-time equivalent basis.

Basic research, applied research, and development

Trends in expenditures for the three categories of R&D are presented in figure 2-6. Development efforts accounted for almost two-thirds of the total R&D expenditures each year during the 1960-74 period, applied research approximately 22 percent, and basic research, over 12 percent.

Current dollar expenditures increased nearly every year for each of the three components. In constant dollars, however, development expenditures leveled off in the late 1960's, and were 7

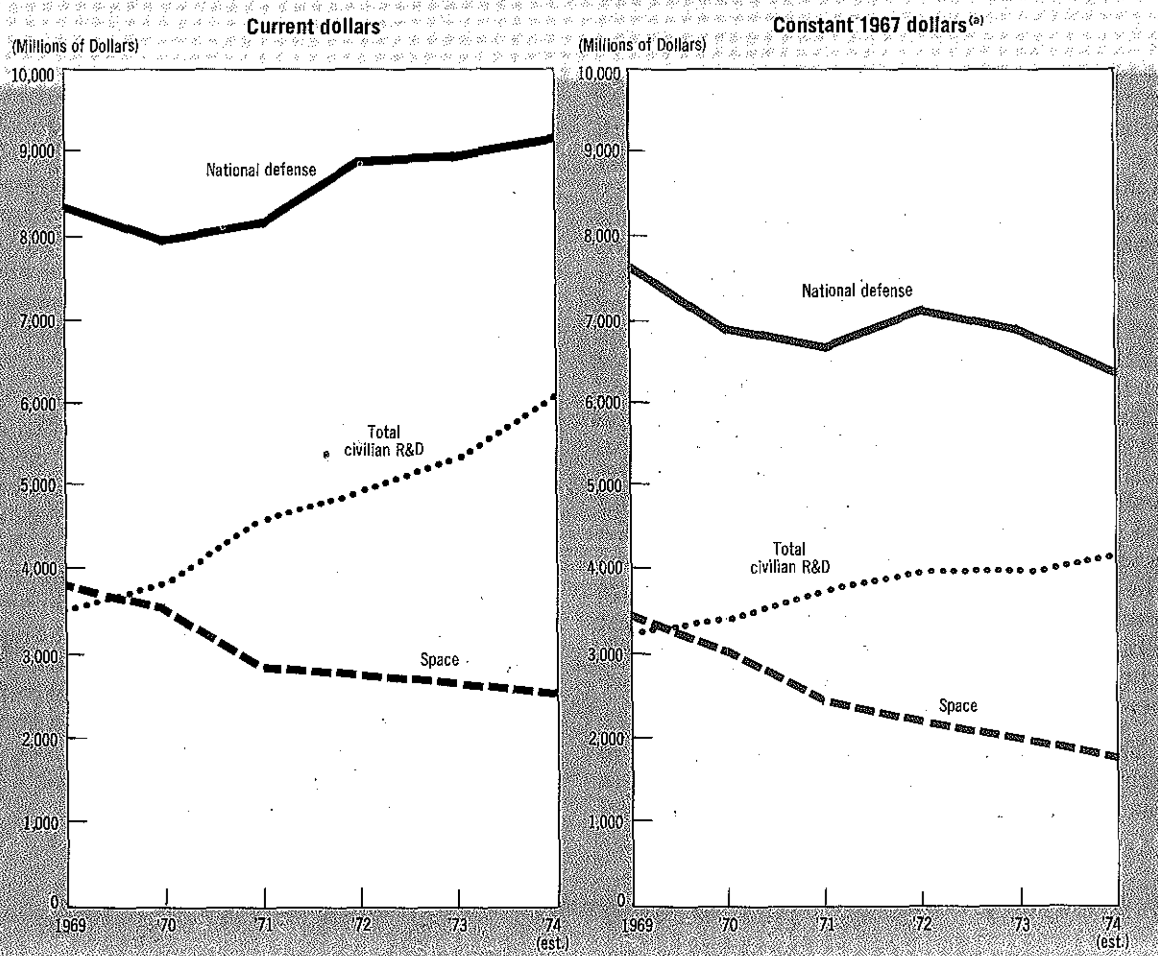
Figure 2-7
National R&D Expenditures, by Character of Work, and Source of Funds, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
(b) Universities, colleges and other nonprofit institutions combined.
SOURCE: National Science Foundation.

Figure 2-9

Federal Obligations for R&D, by Major Function, 1969-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

1974); and (c) the continuing decline of space R&D (down from 24 percent of total R&D obligations in 1969 to 14 percent in 1974). In the defense area, current dollar obligations for R&D in 1974 were the highest of the period, up 13 percent over their 1969 level; in constant dollars, however, obligations were 17 percent lower in 1974 than in 1969. Civilian R&D, on the other hand, increased in both current and constant dollars, rising 70 percent and 28 percent, respectively. Obligations for space R&D declined 33 percent in current dollars and 49 percent in constant dollars between 1969 and 1974.

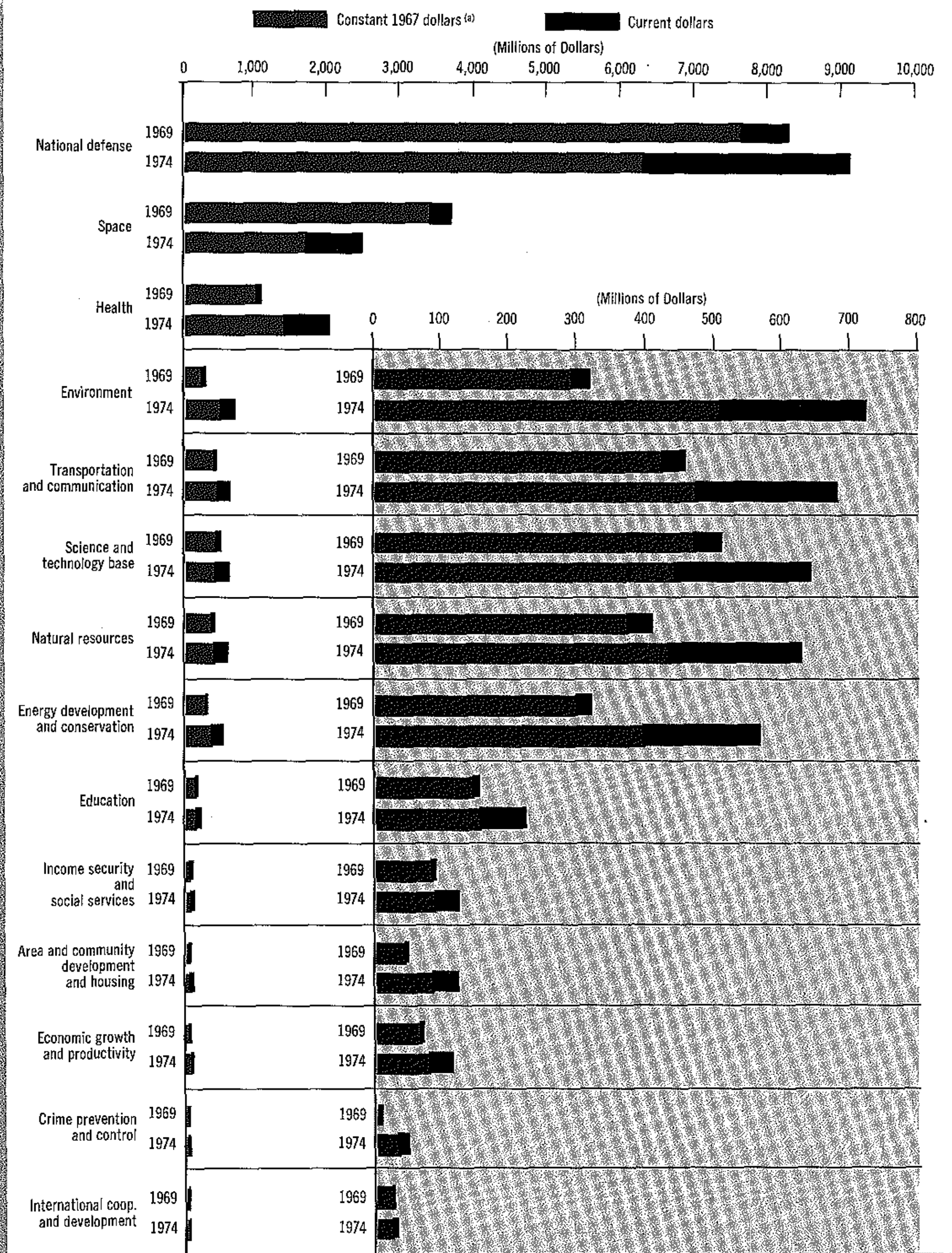
The 1974 R&D programs within these three broad categories are described briefly below, first national defense, then space, and finally the civilian category—each in terms of its major components.[12]

National Defense. The 1974 obligations were directed in the main to the development of *missiles, aircraft, defense-related atomic energy, ships and*

[12] For more detailed information, see *An Analysis of Federal R&D Funding by Function*, National Science Foundation, (NSF 74-313).

Figure 2-10

Federal Obligations for R&D, by Function, 1969 and 1974



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

SOURCE: National Science Foundation.

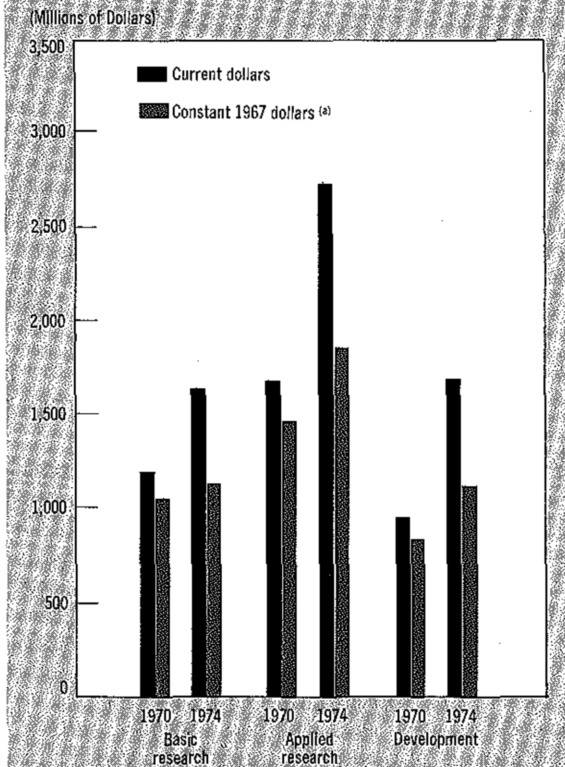
and sport fisheries resources management. This Natural Resources function also includes a *multi-resource* R&D effort which is defined as the earth observation program of NASA and the sea grant program of NOAA.

(6) **Energy Development and Conversion,** which consists of subfunctions related to four sources of energy—*nuclear, fossil fuels, solar and geothermal*—and to one category for *other* energy R&D. *Nuclear* energy activities are concentrated in the AEC programs related to reactor development and safety, controlled thermonuclear research, and nuclear materials production. *Fossil fuel* research is composed of coal, petroleum, and oil shale R&D efforts supported by the Department of the Interior. Both *solar* and *geothermal* energy subfunctions are represented by the NSF projects in these areas. The *other* energy development and conversion subfunction is made up of 13 programs including AEC's applied energy technology program, the NSF's energy research and technology program, and Interior's energy conservation and analysis program.

(7) **Education,** is composed of several HEW programs including the National Institutes of Education, the Office of Education, and the Office of Human Development; and the NSF programs of Scientific Education Improvement and Institutional Improvement. Educational R&D is spread among a wide range of efforts, including the development of improved curricula and individualized instructional materials, better understanding of the learning process, and the motivation of disadvantaged children.[13]

Figure 2-11

Federal Obligations for Civilian R&D, by Character of Work, 1970 and 1974



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

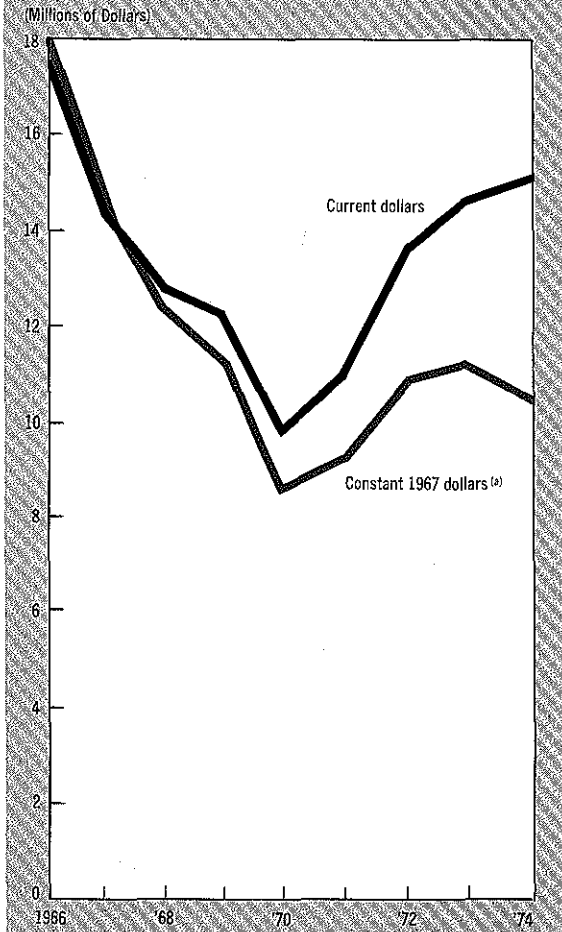
Basic research, applied research, and development in civilian R&D

Federal obligations for R&D in civilian areas are directed primarily to basic and applied research rather than to development (figure 2-11), a distribution pattern quite different from the defense and space sectors described below and from the overall national R&D effort (figure 2-6). In 1974, funds for research accounted for 72 percent of all civilian R&D obligations by the Federal Government, with 45 percent going for applied research and 27 percent for basic research. A comparison of 1970 obligations with those of 1974 indicates, however, a shift toward greater emphasis on development and applied research and relatively less on basic research. Between 1970-74, Federal obligations in current dollars for development and applied research rose by 72 percent and 64 percent, respectively, compared with a 36 percent increase for basic research (figure 2-11).

Federal obligations for civilian basic research are concentrated in a few functional areas; 83 percent of these obligations in 1974 were in the areas of health, natural resources, and the science and technology base. Of these three areas, only one—health—had funding increases between 1970-74 for basic research which were

[13] For information on the R&D programs in the other five areas of the civilian sector, see *An Analysis of Federal R&D Funding by Function, 1969-75*, National Science Foundation, (NSF 74-313).

Figure 2-13
NSF Obligations for Permanent Laboratory Equipment, 1966-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

There are other sources of support for research equipment within the Federal Government as well as the private sector, but information on the extent and other characteristics of such support is not available. General concern, however, has been expressed by the scientific community that funds for laboratory equipment have been deficient in recent years, with the result that the quality of research instrumentation is declining. Information appearing to substantiate this concern was obtained in a 1971 study of equipment needs in universities. The study concluded that research equipment was inadequate in each of the 10 scientific fields surveyed, and estimated the amount required to fill immediate needs to be some $275 million in these fields.[16]

R&D plant

Resources in this area go for the acquisition, construction, and major repair of R&D facilities, as well as for the purchase of large fixed equipment such as reactors, wind tunnels, and radio telescopes. Data are available for only one source of support for R&D plant—the Federal Government. Funds from this source, however, are believed to represent a large part of the total investment in this area, although the relative size of the Federal role may vary among different sectors.

Federal expenditures for R&D plant are shown in figure 2-14. The rapid growth of expenditures during the early 1960's was due almost entirely to the expansion of intramural facilities of the National Aeronautics and Space Administration (NASA); the decline in later years reflects, largely, the completion of these facilities. The up-turn in expenditures after 1972 was produced by increased spending on the part of the Atomic Energy Commission, NASA, and the Department of Health, Education, and Welfare; funds from these agencies were directed in the main to industry and Federal intramural facilities.

In recent years, over three-fourths of the Federal support for R&D plant has been allocated to two sectors—Federal intramural laboratories and industry (figure 2-15). The intramural laboratories received 42 percent of the funds in 1974, industry 35 percent, Federally Funded Research and Development Centers (FFRDC's) administered by universities 14 percent, universities and colleges 5 percent, and other nonprofit institutions 4 percent.

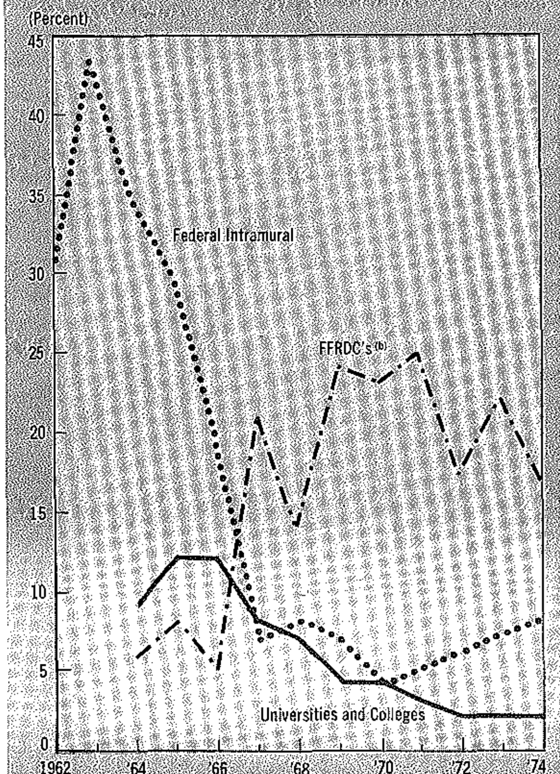
Federal support for R&D plant has not kept pace with funds for total R&D, as is shown in figure 2-16, which presents the relationship between Federal funds for R&D plant as a percent of total Federal obligations for R&D. The early rise and latter decline in this ratio for

[16] *Survey of Research Equipment Needs in Ten Academic Disciplines,* National Science Foundation and National Academy of Sciences, 1972.

[17] Data for those FFRDC's administered by industry and other nonprofit institutions are not separately available.

Figure 2-16

Federal Obligations for R&D Plant as a Percent of Federal Obligations for Total R&D, by Selected Performers, 1962-74[a]



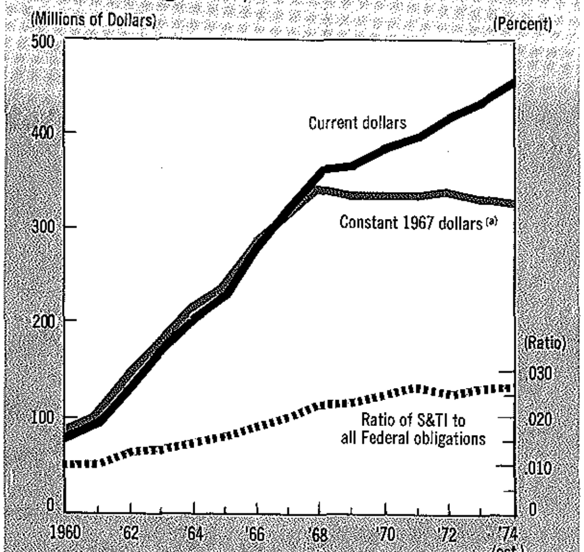
[a] Data for specific performers are not available for earlier years.
[b] Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

Scientific and technical information (S&TI) activities consist of: (1) documentation, reference, and information services; (2) publication and distribution; (3) symposia and audio visual media; (4) R&D in information sciences; and (5) information systems, techniques, and devices. Federal support for these activities increased six fold over the 1960-74 period[19] (figure 2-17); in terms of constant dollars, however, 1968 was the year of highest funding followed by a leveling off through 1974. The ratio of total S&TI obligations to Federal R&D grew from .010 in 1960 to .025 in 1970, and remained approximately at that level through 1974 (figure 2-17).

Several agencies support programs in this area. Those which account for most of the Federal support are indicated in figure 2-18, which presents the obligated funds from each. The Department of Defense, through such programs as the Defense Documentation Center, supplied one-third of all Federal funds for S&TI in 1974. The Department of Commerce provided 20 percent of the total, much of which is accounted for by the National Technical Information Service. A similar amount comes from a variety of programs in the Department of Health, Education, and Welfare, a major one being the National Library of Medicine.

Figure 2-17

Federal Obligations for Scientific and Technical Information Activities, Compared with Total Federal R&D Obligations, 1960-74



[a] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[19] Available data reflect only a portion of the Federal support for all S&TI activities, in that they include only the direct obligations for S&TI and not the support provided through R&D grants and contracts.

Basic Research

ditures in 1974 to approximately the same level as 1961.

- The number of research publications from major fields of science increased generally throughout the 1960's, but leveled off in several fields in the early 1970's; publication output in chemistry, engineering, and physics, for example, has remained at a nearly constant level in recent years.
- Universities are by far the largest producers of published research reports with some 75 percent of the total in 1973, followed by the Federal Government and private industry with approximately 10 percent each, and other nonprofit institutions with 5 percent.
- Basic research contributes increasingly to technological innovation, as reflected by the growing number of citations to research in patents associated with major advances in technology; the frequency of such citations increased 17 percent between the 1950's and 1960's, while citations to other patents declined by almost 25 percent.
- Research performed in universities is most frequently cited as the origin of patented technological advances, accounting for almost 55 percent of the cited research in recent years and replacing industry as the prime sector in which such research is performed.

Basic research is the quest for fundamental understanding of man and nature, in terms of scientific observations, concepts, and theories. Such research is generally motivated by curiosity and the desire to advance scientific knowledge, with the opportunities for its advancement determined primarily by the existing state of scientific understanding itself, rather than by practical need or potential application. As an activity, this research ranges from efforts of teams of scientists working with large facilities such as particle accelerators to the efforts of individual scientists using little or no research equipment. And basic research, being international in its nature, joins the activities of scientists from many countries.[1]

Although curiosity is frequently the prime motive of the individual scientist for performing research, potential applications often underlie the private and public support of basic research. There is as yet, however, no method for correlating the cost of such research with its total returns—intellectual, economic, and social. But the many and varied uses of basic research suggest that the benefits may be substantial, particularly in comparison with the relatively small investment involved. The findings of basic research represent much of the objective knowledge of the physical and social world which forms a major part of the educational curriculum of the general population, while both the results and the conduct of such research constitute the core of advanced education in the sciences and engineering. Basic research provides the fundamental knowledge on which modern technology increasingly depends. This research, in addition, supplies indispensable knowledge for planning and directing the rest of the R&D effort. Finally, the maintenance of a wide spectrum of basic research can provide the new knowledge needed for responding to challenges in the future—challenges which may not be foreseen at present.

Indicators of the state of basic research presented in this chapter consist largely of the financial resources committed to research and preliminary measures of outputs and their application in industrial technology. The "input" indicators provide information on national expenditures for basic research, the extent of research performed in universities and other sectors, and trends in expenditures for basic research in the various fields of science. "Output" indicators include publications of scientific research produced by different sectors in major fields of science, and measures of the extent to which such research underlies advances in technology.

The present set of indicators are deficient in a number of major aspects. They do not encompass substantive aspects of basic research, such as advances in knowledge achieved in the various scientific disciplines. The indicators, further-

[1] For further discussion of international aspects of science, see the chapter entitled, "International Indicators of Science and Technology" in this report.

collection. For all but the industry sector, the definition of basic research stresses that such activity be directed toward increases of knowledge in science with the primary aim of the investigator being ". . .a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."[4] For the industrial sector, to take account of an individual company's commercial goals, basic research is defined as ". . .original investigations for the advancement of scientific knowledge . . .which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."[4]

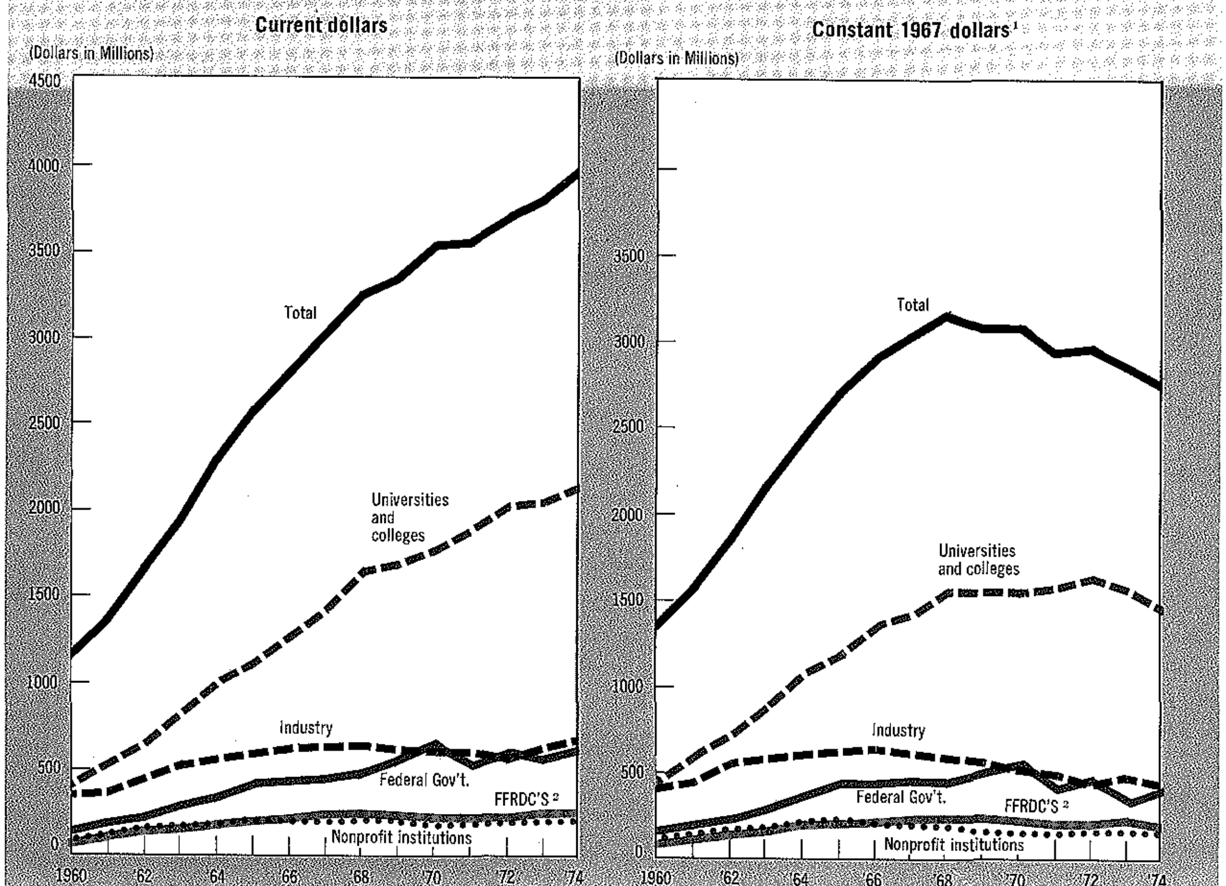
[4] *Ibid.*

The varying levels of basic research expenditures from 1960 to 1974 are shown in figure 3-2 for the R&D-performing sectors. It should be noted that the growth in current dollar expenditures between 1968-74 was not sufficient to compensate for inflation in any of these major sectors.

Constant dollar expenditures for basic research leveled off in the late 1960's for most sectors, and fluctuated around that level in subsequent years. The largest proportional declines between the year of peak funding and 1974 were in industry (31 percent), whereas the smallest percentage decline (9 percent) occurred in universities and colleges.

Figure 3-2

Basic Research Expenditures, by Performer, 1960-74



1 GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
2 Federally Funded Research and Development Centers administered by universities.
SOURCE: National Science Foundation.

the 1960-74 period, although the annual increments were smaller after the late 1960's—the same years in which inflation grew fastest. As a result of these trends, funding by all sources except nonprofit institutions declined in constant dollars with the largest absolute reductions occurring in Federal Government support. Funds from this source in 1974 were down 16 percent in comparison with the peak funding year of 1968. Funds supplied by universities[5] continued to outpace inflation through 1972, but declined more than 13 percent between then and 1974. Industry's funding for basic research peaked in 1966 in constant dollars, then fluctuated around a somewhat lower level through 1974. Universities, on the other hand, raised their share of support from 6 percent in 1960 to 11 percent by 1974. Federal support, as a percentage of the total national expenditures, increased from 59 percent in 1960 to a high of 72 percent in 1967 before declining to 68 percent of the total in 1974.

Federal support of basic research

The Federal Government assumed prime responsibility for support of basic research after World War II. This policy recognized the decisive role played by scientific knowledge in the war effort, and sought to strengthen the Nation's basic research capability for peacetime pursuits. Over the past 30 years, the policy has come to be predicated on the broad and varied role of basic research in advancing the country's defense, economy, health, and technology, as well as upon its general cultural value, in education and in the intellectual life of the Nation. During this period, many Federal agencies came to support basic research as an instrument in fulfilling their missions, and a new agency—the National Science Foundation—was created for the express purpose of supporting scientific research and strengthening such capability.

Six of these agencies accounted for 95 percent of all Federal obligations[6] for basic research in Fiscal Year 1974.[7]

Percent of total Federal obligations for basic research, by agency, 1974

Federal agency	Percent basic
National Aeronautics and Space Administration (NASA)[8]	29
Department of Health, Education, and Welfare (HEW)	23
National Science Foundation (NSF) .	16
Atomic Energy Commission (AEC) ..	11
Department of Defense (DOD)	10
Department of Agriculture (USDA) .	6

Basic research and total R&D. Basic research funded by each of these Federal agencies, and performed intramurally or by other sectors, is a part of the overall R&D effort of that agency. The magnitude of the basic research component, in relationship of the total R&D program, suggests the relative importance assigned to basic research by the agency. This ratio is shown in figure 3-4 for each of the six agencies.

For all agencies as a whole, the ratio has increased slowly, reaching 15 percent of all R&D obligations in 1974. Obligations for basic research increased 20 percent between 1971-74, compared with a 14 percent increase for all R&D obligations.

The NSF has the largest ratio by far, as would be expected in view of its designated role in the support of basic research. Recent declines in this agency's concentration on basic research—down from just over 90 percent of its total R&D obligations in the mid-1960's to approximately 80 percent in 1974—are due to initiation of such new and largely applied research programs as "Research Applied to National Needs."

Two other agencies—NASA and HEW—show sizable changes in recent years in the fraction of their total R&D expenditures which is directed to basic research. The fraction for NASA has

---

[5] Includes funds from State and local governments, as well as the universities and colleges themselves.

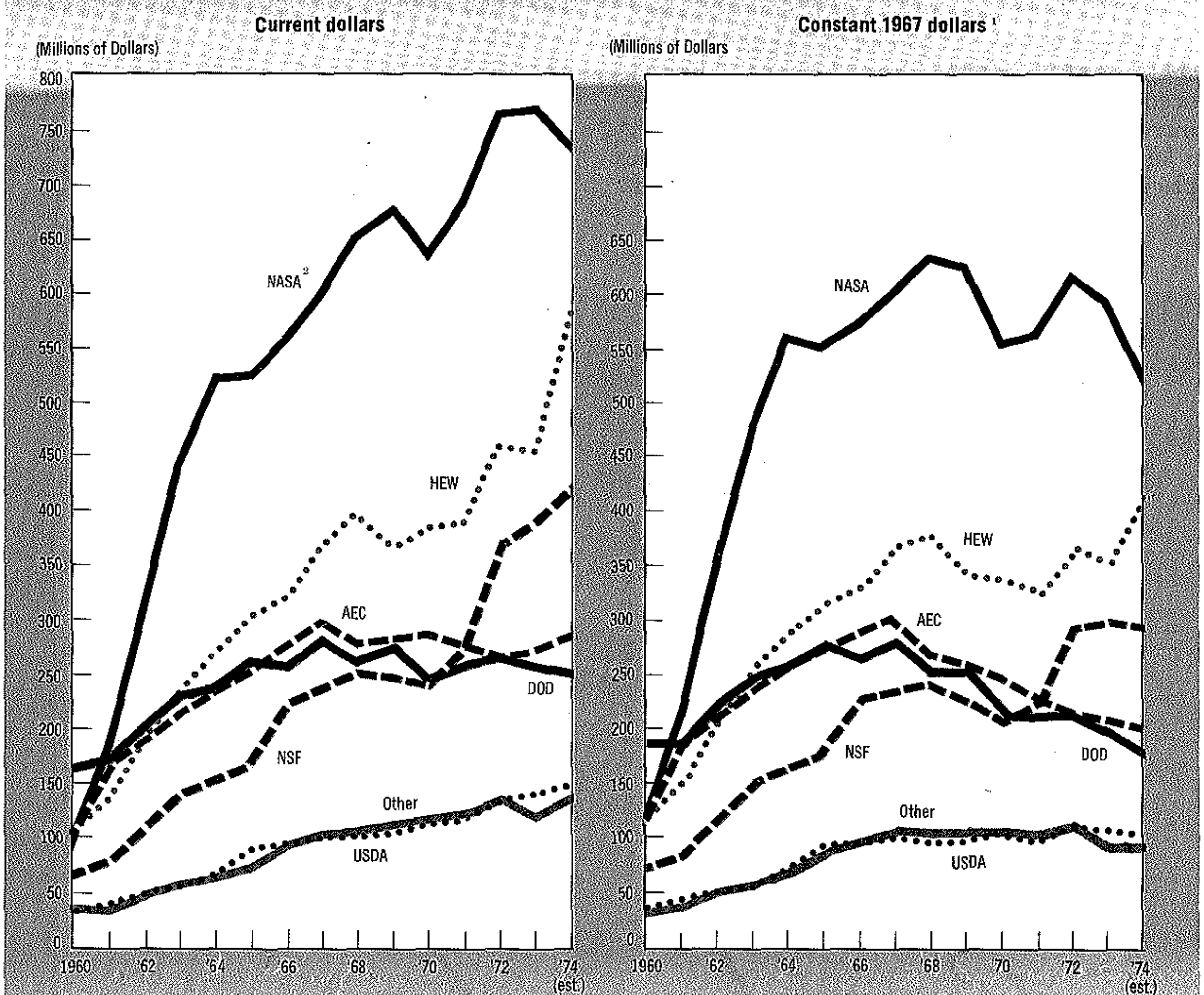
[6] Federal obligations for basic research may differ from federally provided expenditures in the same year for a number of reasons. A sector which performs research, for example, may report expenditures for research projects which it regards as "basic research," whereas the Federal agency providing the support may report the same projects as consisting of "applied research." In addition, obligations made in a given year may actually extend over several later years in terms of the availability of the funds for expenditure. Moreover, the withholding of obligated funds may produce discrepancies between obligations and reported expenditures.

[7] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII, National Science Foundation (NSF 74-320-A).

[8] NASA considers all of its activities to be R&D, or in support of R&D. The agency's obligations for basic research (as well as for applied research and development) include the related costs of spacecraft, launch vehicles, tracking and data acquisition, and the *pro rata* costs of ground operations and agency administration.

Figure 3-5

Federal Obligations for Basic Research, by Agency, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

[2] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical proration of costs for tracking and data acquisition.

SOURCE: National Science Foundation.

percent of all USDA's basic research obligations, as a part of the agency's R&D aimed at improving animal and plant productivity and enhancing the use of natural resources related to agriculture.

The proportion of total Federal obligations for basic research provided by each of these agencies shifted considerably in the period 1960-74. The Department of Defense provided 28 percent of the total basic research obligations in 1960, compared to 10 percent in 1974. This decline may be due, in part, to the "Mansfield amendment" which restricted the DOD to the funding of research related directly to its mission. The proportion supplied by NASA declined from a high of 33 percent in 1964 to 29 percent in 1974, reflecting both changes in the mission of this agency and the faster growth of basic research obligations in some other agencies.

Federal obligations for basic research in Fiscal Year 1974. Three of the areas—life, physical, and social sciences—had reached their highest level of current dollar obligations in 1974, whereas obligations for the environmental sciences and engineering declined after 1972. In constant dollars, basic research obligations for all areas other than the life sciences were lower in 1974 than in some previous year. The largest decline occurred in the physical sciences, where constant dollar obligations decreased by 24 percent between 1969 and 1974.

A major and rapid shift in the distribution of basic research obligations among these areas of science occurred in the life and physical sciences. The proportion of obligations for the life sciences increased from 27 percent of the total obligations in 1969 to 34 percent in 1974. Over the same period, the fraction of total basic research obligations for the physical sciences dropped from 39 percent in 1969 to 32 percent in 1974. This shift from the physical to the life sciences is due to reductions or relatively slow growth in basic research obligations from DOD, NASA, and the AEC—the major sources of funding for the physical sciences—coupled with substantial increases in HEW's obligations for the life sciences (figure 3-5).

Within these broad areas, large changes have occurred in individual fields in recent years (Appendix table 3-6). In the area of physical sciences, for example, Federal obligations for basic research in physics were at their highest level in 1967 in constant dollars before declining 28 percent by 1974 when obligations were approximately at a pre-1963 level. In the life sciences, basic research obligations for the biological sciences grew steadily, whereas clinical medical sciences declined 58 percent in constant dollars between the peak funding year of 1967 and 1974.

BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

Universities and colleges perform the bulk of the Nation's basic research. They accounted for 54 percent of the total national expenditures for such research in 1974 (figure 3-2). The presently dominant position of these institutions in fundamental research is the culmination of a long-term trend. In 1953, universities and colleges accounted for only 26 percent of the total expenditures for basic research, compared with 35 percent for industry and 24 percent for intramural research by the Federal Government. As funding of basic research rose over the years—primarily as the result of increasing Federal support—the fraction of the total going to universities and colleges grew rapidly, much more rapidly than funding in the industry and Federal intramural sectors. In consequence, the percentage of the total funds for basic research accounted for by these two sectors had declined to 16 percent each in 1974. There was little change in the share of basic research expenditures accounted for by the nonprofit institutions and the university FFRDC's, with each accounting for some 7 percent of basic research expenditures throughout the last decade (Appendix table 3-2).

The significant role of universities and colleges in basic research is reflected also in the fact that scientists and engineers employed by these institutions are responsible for a large proportion of all U.S. scientific research reports—approximately three-fourths of the total in 1973 (Appendix table 3-21). The research performed by these institutions, moreover, is increasingly the basis for advances in technology (figure 3-25).

Basic research in universities and colleges ranges from the efforts of individual scientists and engineers to those of large research teams which often are organized around the use of unique equipment and facilities. Most of the research takes place in universities which have graduate-level programs offering doctorate degrees; these institutions reported 98 percent of all academic basic research expenditures in 1974.[11] This concentration reflects, in part, the close relationship between research and graduate education in science and engineering. Research is an integral part of graduate education in these areas and, indeed, students are involved in performing much of the research. Graduate students in chemistry, for example, were coauthors of 56 percent of the research reports published in 1971 by institutions awarding doctorate degrees in that field.[12]

Expenditures by universities and colleges for basic research (from all funding sources combined) increased continuously from 1960 to 1974

[11] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1973*, National Science Foundation (NSF 75-316-A).

[12] *Directory of Graduate Research*, American Chemical Society, 1971.

dollars, Federal funding for basic research reached a maximum in 1968 and declined a total of 13 percent by 1974. In spite of the slowed growth in current dollars, the Federal Government provided 70 percent of all funds expended by the academic sector for basic research in 1974—down, however, from the high of 77 percent which prevailed between 1964-67.

Funds provided by "All other sources"[14] for basic research in figure 3-7 increased in both current and constant dollars until 1972—thus replacing some of the reduced Federal support—before declining 11 percent in constant dollars by 1974. These sources of support accounted for 27 percent of the total support for basic research in these institutions in 1974.

Basic research in fields of science

Estimates of total academic expenditures for basic research in selected fields of science are presented in figure 3-8.[15] These estimates are based upon a survey conducted by the National Science Foundation in which universities and colleges report their total research and development expenditures for each of several fields of science, as well as the percentages of the total R&D expenditures (over all fields combined) which are given to basic research, applied research, and development. This information is correlated with other factors—such as the source of the research support and the type of academic institution which performed the research—in deriving the estimates of expenditures for basic research in the individual scientific fields. Because these data are estimates, and may differ from actual expenditures, they should be regarded only as approximations.[16]

The six broad areas of scientific research indicated in figure 3-8 received almost 90 percent of all expenditures for basic research in universities and colleges in 1974.[15] Expenditures for fundamental research in these institutions are concentrated in the life science fields of clinical medicine and the biological sciences; 51 percent of all basic research expenditures in 1974 was in these fields. About one-fourth of the total expenditures was divided almost equally between engineering and the physical sciences (principally physics and chemistry), while the social sciences received 8 percent and environmental sciences 7 percent of the total (Appendix table 3-8).

In current dollars, basic research expenditures increased between 1973 and 1974 in all areas except engineering. In constant dollars, however, a reduction in basic research spending was recorded in all fields other than the environmental sciences and clinical medicine, with the largest declines occurring in engineering and the biological sciences.

Federal Government support of basic research

Current dollar expenditures from Federal Government sources for basic research in universities and colleges increased throughout most of the 1964-74 period for each of the six broad fields of science and engineering, except for a 14 percent decline in engineering expenditures from 1973 to 1974 (figure 3-9).[17] Increases in the level of support after 1968, however, were less than increases in inflation in all fields other than the environmental and biological sciences. As a result, the magnitude of the federally funded research effort—as measured by constant dollar expenditures—was lower in 1974 than in some previous year in each of the six fields. The fields with the largest reductions were engineering, the physical sciences, and clinical medicine, which recorded declines of 26, 30, and 10 percent, respectively, between 1968 and 1974 (see Appendix table 3-9).

The Federal Government, as noted earlier, provided 70 percent of all funds expended by universities and colleges for basic research in 1974. The dependence on this source of support, while varying from field to field, declined over the last decade in all fields other than the biological sciences, as shown below:

---

[14] This includes universities and colleges, State and local governments, and other nonprofit institutions.

[15] See Appendix table 3-8a for a listing of the scientific disciplines encompassed by these broad fields and Appendix table 3-8 for more detailed data for certain disciplines.

[16] The feasibility of obtaining data directly on basic research expenditures in individual fields of science is being investigated and may be attempted in future NSF surveys.

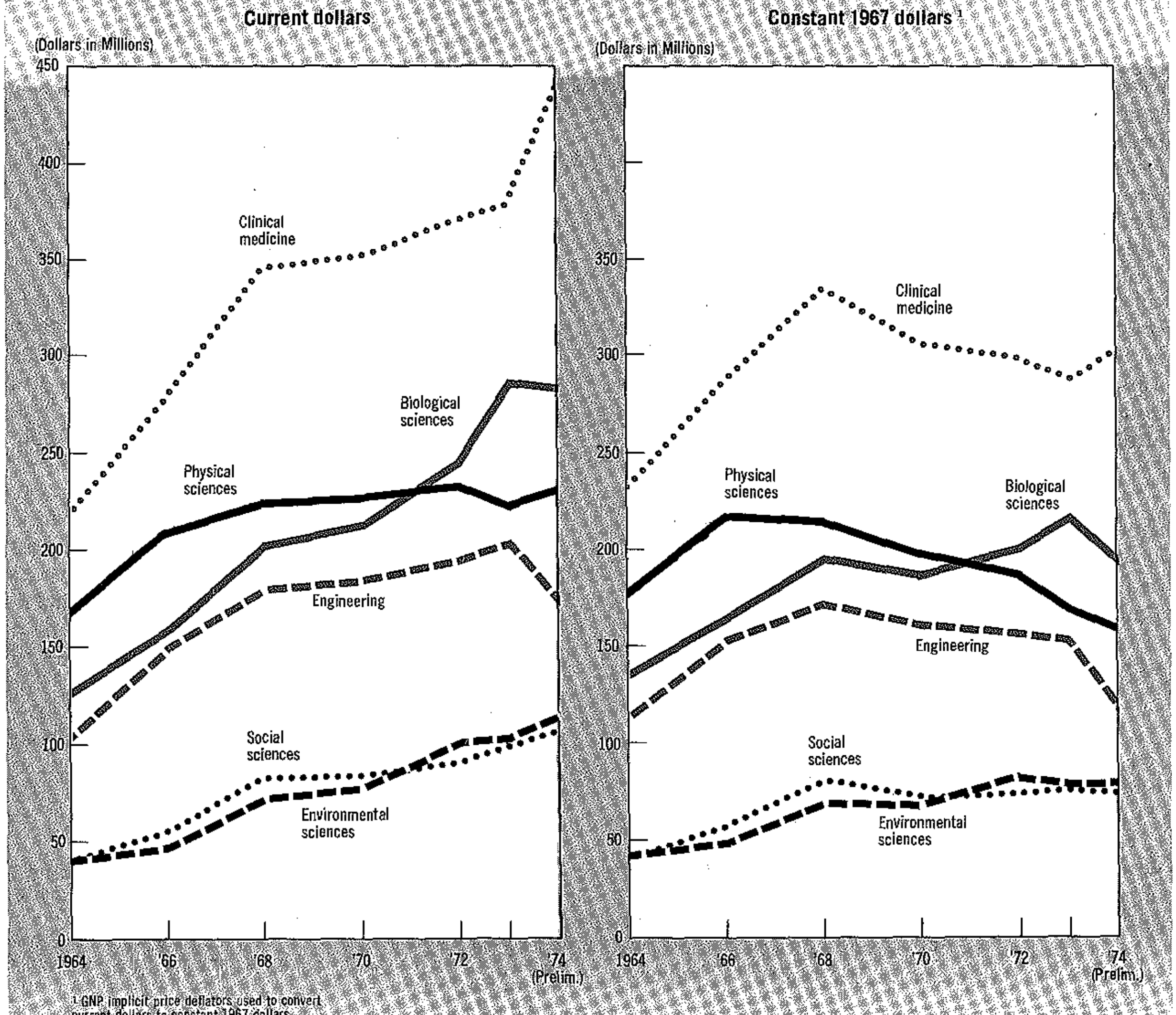
[17] These data are estimates based on the same NSF survey as the total expenditures for basic research in academic institutions presented in figure 3-8.

six agencies noted earlier, NSF and HEW allocated the largest fraction of their total basic research obligations to educational institutions in 1974 (84 and 70 percent, respectively), followed by DOD (44 percent), USDA (24 percent), AEC (21 percent), and NASA (6 percent).

Comparably large variations exist among the agencies in respect to the allocation of basic research obligations for broad fields of science and engineering at universities and colleges, as shown in the following table.

Figure 3-9

Estimated Federal Basic Research Expenditures in Universities and Colleges, by Field of Science, 1964-74

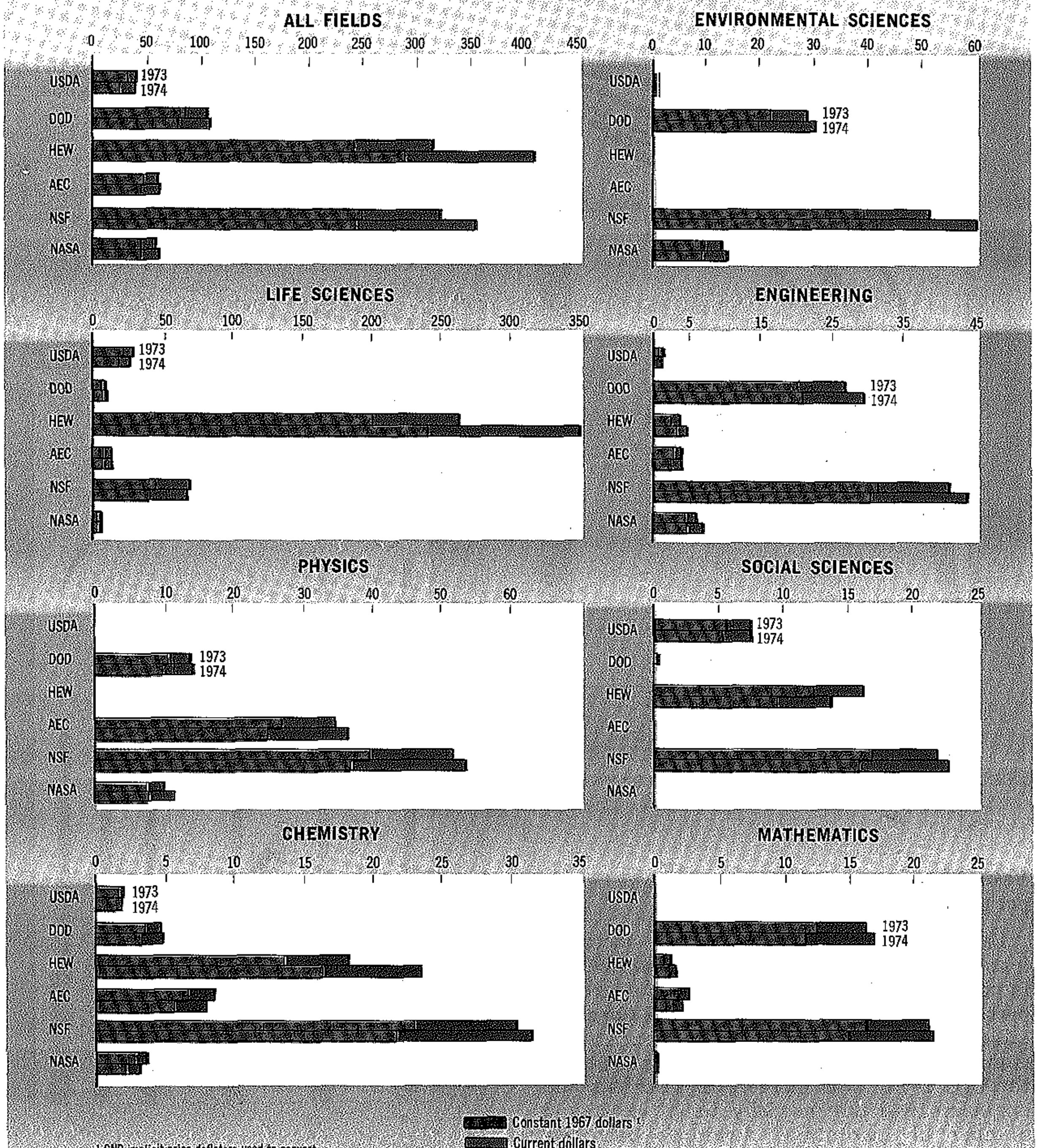


[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 3-10

Federal Obligations for Basic Research in Universities and Colleges, by Selected Supporting Agencies and by Selected Fields, 1973-74

(Dollars in Millions)



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

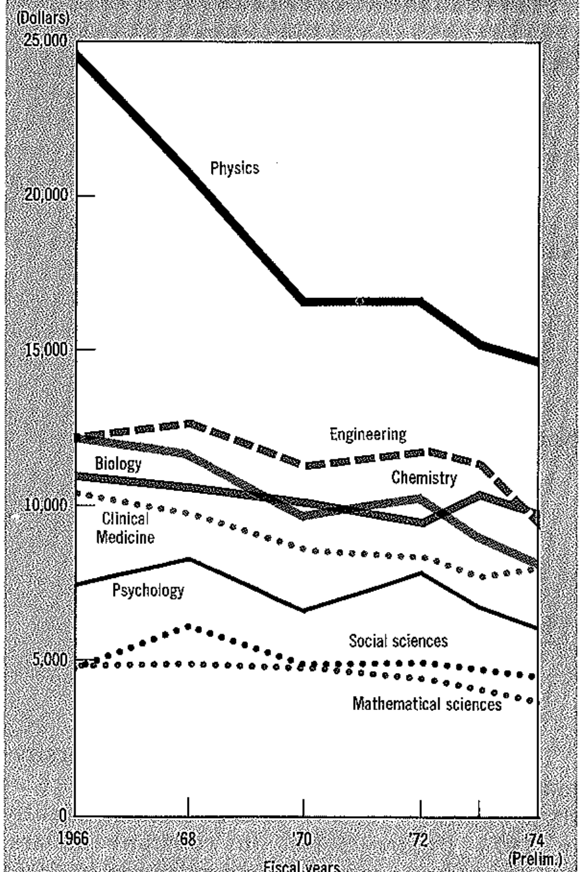
doctorate institutions since 1968 (figure 3-12). A slight shift from expenditures for basic to applied research occurred after 1972 and is one reason for this decline, the inclusion of scientists and engineers from the new doctorate institutions is another, and the reduction in constant dollar expenditures, particularly those supported by the Federal Government, is a third factor. Federal funds for basic research per scientist and engineer declined almost 30 percent between 1968 and 1974. Funds from other sources decreased by a similar percentage after 1972, but the reduction in absolute terms was much less than the Federal declines.

The reductions in real expenditures for basic research per scientist and engineer have occurred in several fields,[24] as shown in figure 3-13. The largest decline was recorded in physics, where such expenditures dropped almost 40 percent between 1966 and 1974. Decreases in this field were due primarily to declines in funding, rather than to increases in the number of physicists.

Figure 3-13

Estimated Basic Research Expenditures in Doctorate-granting Institutions per Scientist or Engineer[1] by Selected Fields, 1966-74

(in constant 1967 dollars)[2]



[1] Full-time equivalent basis.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

BASIC RESEARCH IN FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS ADMINISTERED BY UNIVERSITIES

Federally Funded Research and Development Centers (FFRDC's) are organizations financed exclusively or primarily by the Federal Government to perform R&D in relatively specific areas, or in some instances to provide facilities at universities for research and associated training purposes. The Centers usually have a direct and long-term relationship with their funding agency, making it possible for them to maintain instrumentation, facilities, and operational support beyond the capabilities of single educational or research institutions. Non-Federal organizations—academic, industrial, or nonprofit—administer the FFRDC's.

In 1974, FFRDC's administered by universities accounted for 7 percent of the Nation's total basic research expenditures,[25] and 86 percent of the Federal obligations for all FFRDC's.[26] These Centers and their sponsoring agencies are:

Atomic Energy Commission

Ames Laboratory
Argonne National Laboratory
Brookhaven National Laboratory

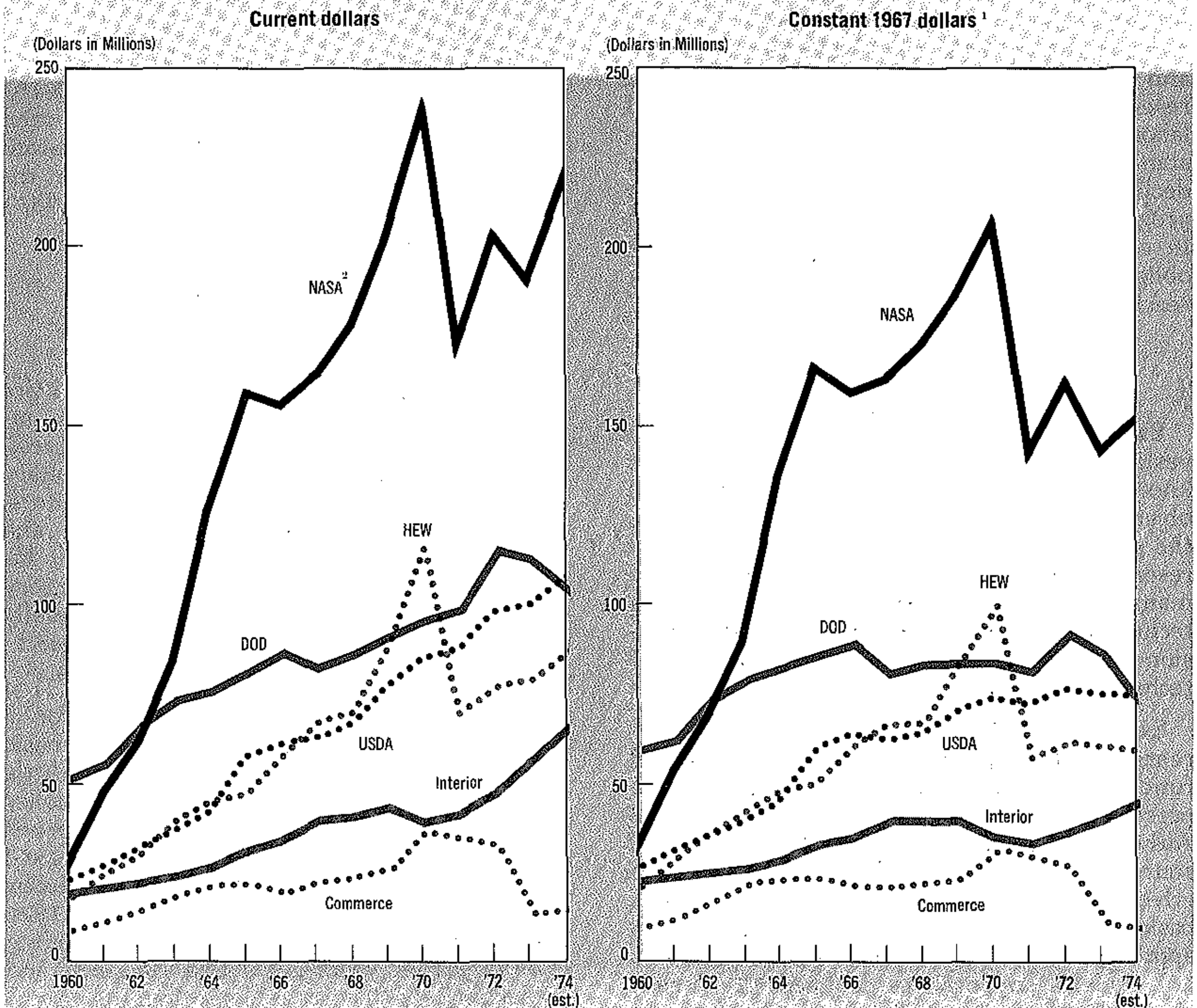
[24] The actual cost of conducting research differs substantially from field to field, reflecting in part the extent to which research depends upon special equipment, facilities, and technical support staff.

[25] *National Patterns of R&D Resources, 1953-75*, National Science Foundation, (NSF 75-307).

[26] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975*, Vol. XXIII, National Science Foundation (NSF 74-320-A).

Figure 3-15

Federal Obligations for Intramural Basic Research, by Selected Agencies, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[2] The large amounts reported by NASA for basic research are due to the substantial cost of support equipment such as spacecraft and launch vehicles peculiar to space exploration, and the statistical proration of costs for tracking and data acquisition.

SOURCE: National Science Foundation.

and the R&D Institute at the National Cancer Institute of HEW.[28]

Current dollar funding for basic research in these laboratories increased steadily from 1960 to 1970, and then after a slight decline in 1971 had risen again by 1974.[29] In constant dollars, however, 1974 funding was approximately equal to that of 1965, and down 22 percent from the peak year of 1970.

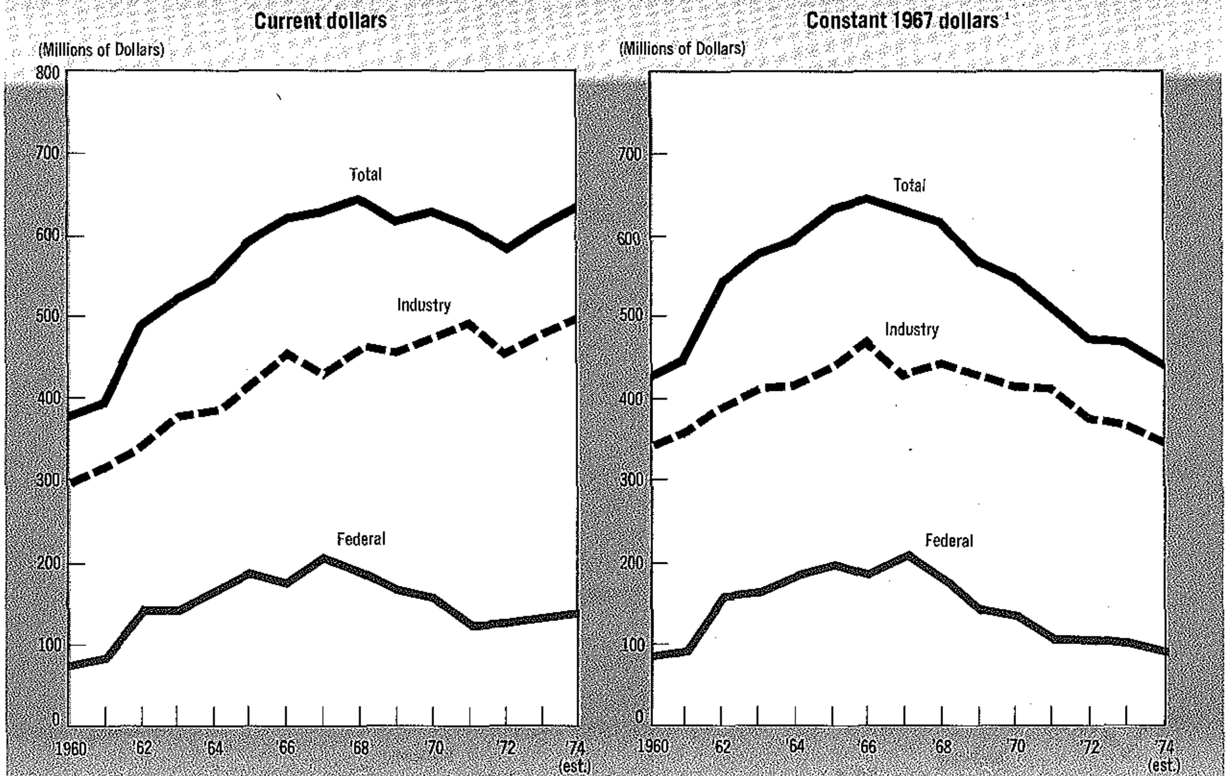
The constant dollar decline in intramural basic research funding is evident in all major agencies

[28] For further information on the utilization of intramural Federal laboratories see: U.S. Congress, House Committee on Appropriations, Agriculture-Environmental and Consumer Protection Appropriations for 1975; Part 7, *Investigative Report on the Utilization of Federal Laboratories* - 93rd Cong., 2nd Sess., 1974.

[29] See Appendix table 3-15.

Figure 3-16

Industrial Basic Research Expenditures, by Source, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

RESEARCH OUTPUTS AND APPLICATIONS

Subsequent sections of this chapter present the results of experimental studies aimed at measuring a part of the output of research and a portion of its applications. The studies represent, at best, small steps in these directions.

Output of scientific research literature

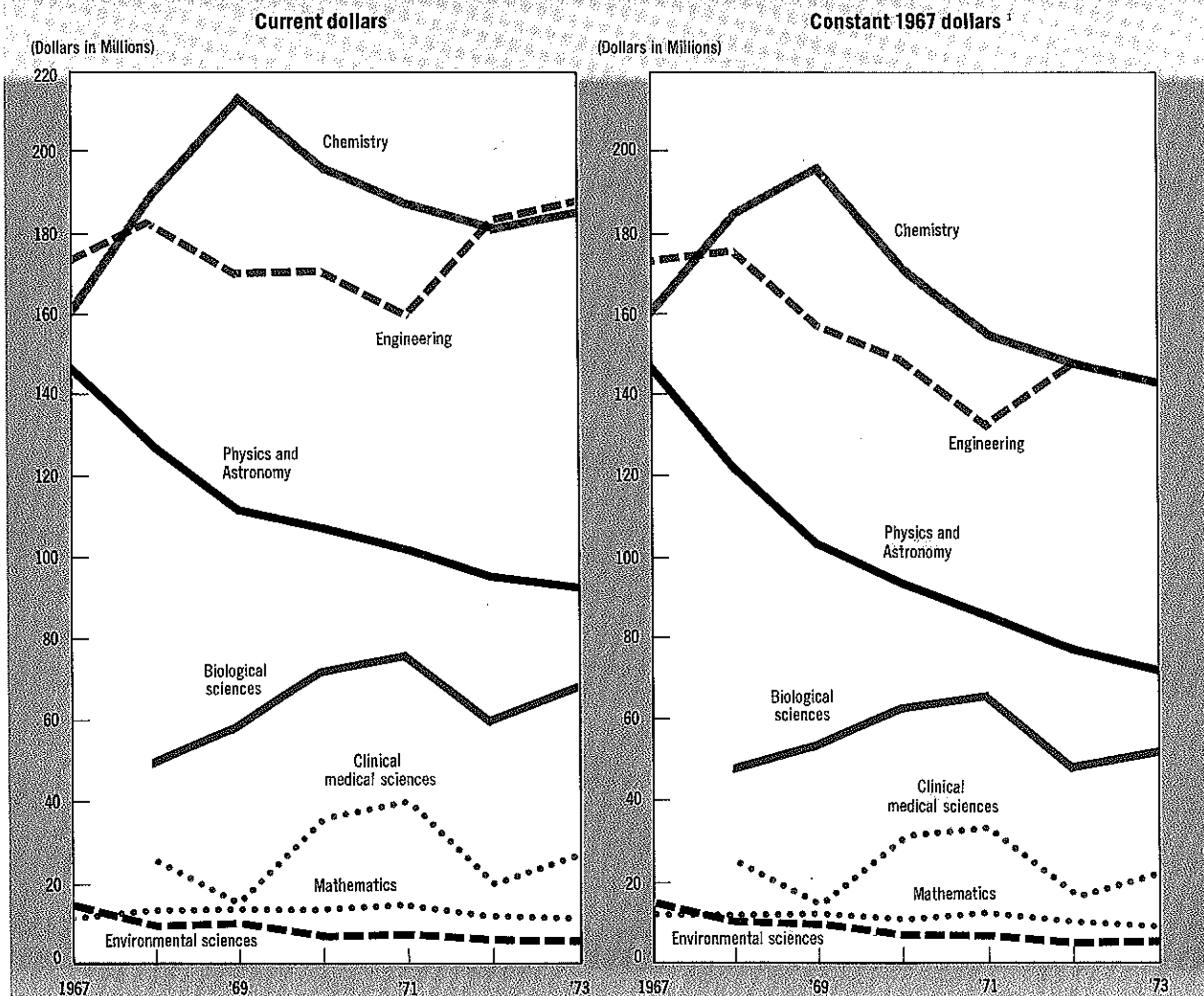
Information on the quantity and sectoral origin of published research reports from several fields of science was obtained from a study conducted by the National Federation of Abstracting and Indexing Services.[32] The study, in brief, involved the selection of a set of scientific and engineering journals which was representative of the total literature in each field. This was accomplished largely through the guidance of the Federation's member services and by advice from experts active in the fields. On a sampling basis, individual reports in the journals were examined to determine the first author's institutional affiliation: academic, government, industry, or other nonprofit organization. The sample of reports was restricted to those whose first authors were affiliated with U.S. institutions.

The data obtained from the study were used to develop preliminary measures of the relative growth of several fields of science and engineering in terms of their publication output, the roles of the different sectors in the overall research effort of each field, and the relationship between the research output and financial inputs.

[32] *Indicators of the Output of Scientific Research*, National Federation of Abstracting and Indexing Services, 1974 (A study commissioned specifically for this report, and funded largely by the Office of Science Information Service, National Science Foundation).

Figure 3-18

Expenditures for Basic Research in Industry, by Selected Fields, 1967-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

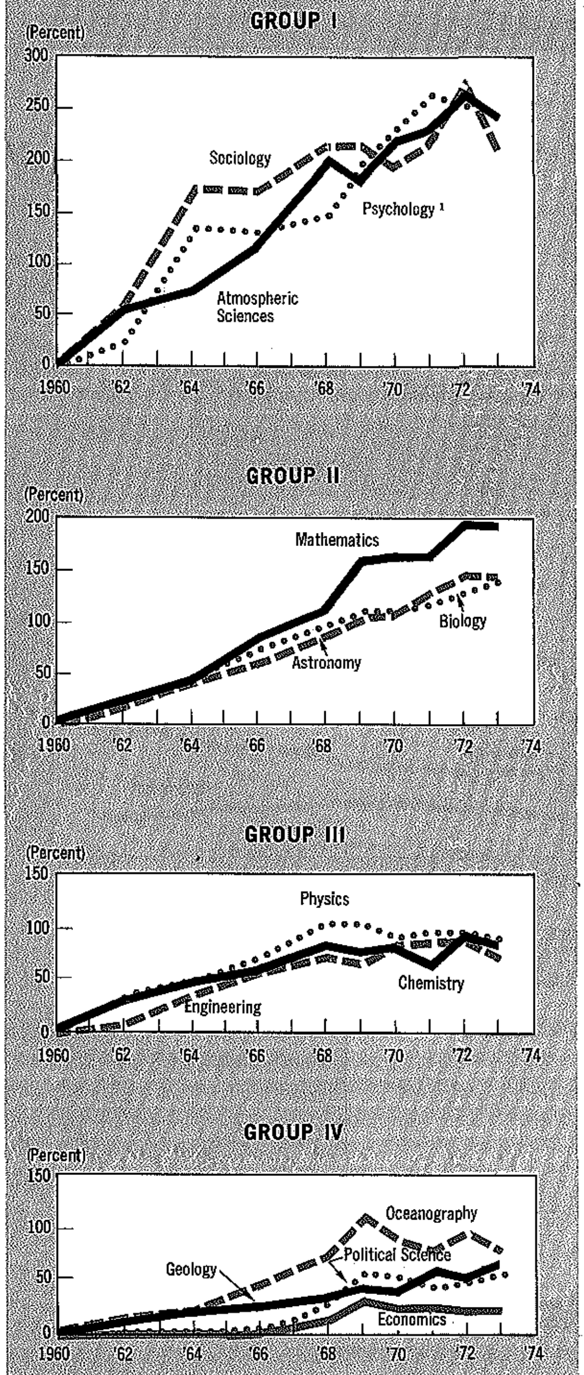
Research output by sectors. The research publications produced by each sector—university, government, industry, and other nonprofit organizations—are shown in figure 3-21 for five selected fields. (Data for each of the 13 fields are presented in Appendix table 3-21).

Universities were by far the largest producers of published research reports, followed by government, industry, and nonprofit organizations. The predominant role of academic institutions increased throughout the 1960-73 period covered by the study. By 1973, universities were responsible for an average of almost 75 percent of the publications in the 13 scientific fields, compared with some 60 percent of the total in 1960. The share of publications accounted for by the academic sector rose in all fields during the period, with the largest increases occurring in sociology, physics, chemistry, geology, and mathematics (including computer sciences).

Figure 3-20

Relative Growth in Scientific Research Publications, by Selected Fields of Science, 1960-73

(Percent growth after 1960)



¹ Data not available for 1973.
SOURCE: National Federation of Abstracting and Indexing Services.

of research publications, and that their role *vis-a-vis* other sectors is increasing. The extent of their publication output appears high in relationship to the fraction of total financial resources for research which is expended by these institutions. (See figure 3-2 for the research expenditures by this and other sectors.)

Research publications and research expenditures. Publications in the five fields shown in figure 3-21 which were produced by universities were compared with the reported R&D expenditures for these fields. Expenditures in constant dollars were used for this purpose, with a "lag time" of two years between the expenditures and publications. (The limited available data on expenditures restricted the correlation to a short period of time, and did not permit exploration of alternate "lag times").

The results are presented in figure 3-22. A relatively close fit between lagged expenditures and publication output was found for the fields of biology, engineering, and mathematics. On the other hand, relatively large deviations between input and output were obtained in chemistry and physics, particularly in later years.

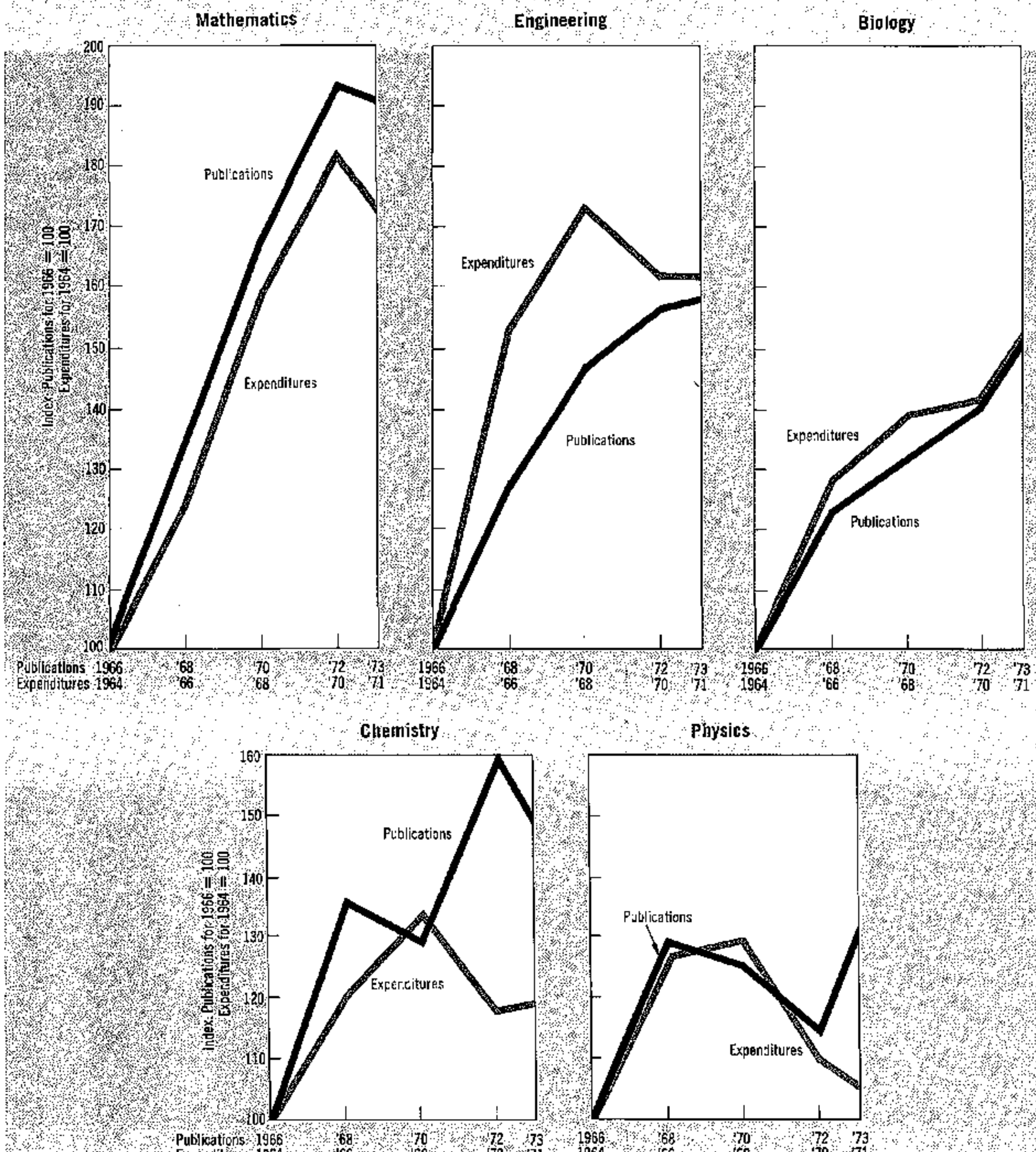
Basic research and technology

The relationships between basic research and eventual applications in modern technology are complex and difficult to trace. Certain aspects of these relationships were the subject of a special study upon which the data presented here are based. The study centered around 179 major advances in technology which occurred in the United States during the 1950-73 period. The patent documentation associated with each of the advances was examined to determine characteristics of the research which were cited as the origin of the invention.

The sample of 179 major advances covers ten broad areas of technology. These areas and examples of specific advances included in the study are shown below, on page 78

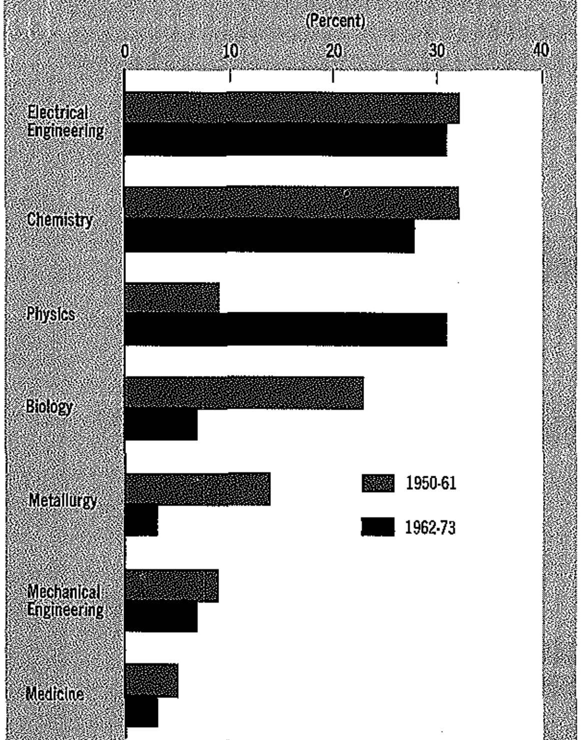
Figure 3-22

Research Publications and R&D Constant 1967 Dollar Expenditures[1] in Universities and Colleges, 1964-72



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation and National Federation of Abstracting and Indexing Services.

Figure 3-24
Percent of Basic Patents Citing Research Literature, by Field of Science and Engineering, 1950-61 and 1962-73



SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

chemistry and electrical engineering (29 and 31 percent) over the 1950-73 period. Following these were physics (22 percent), biology (14 percent), metallurgy (8 percent), mechanical engineering (8 percent), and medicine (4 percent).

Sectors producing cited research. For each research citation, the institutional sector in which the cited research was performed was identified (figure 3-25). In the 1950-61 period, most of the research cited in the sample was performed in corporate laboratories (57 percent). In the 1962-73 period, however, corporate research was cited least frequently, accounting for only 15 percent of the research citations. Universities, on the other hand, rose from second place (28 percent) in 1950-61 to first place in 1962-73, with 54 percent of the cited research being performed in this sector. Research in academic institutions also accounted for most of the basic research citations in both periods, and applied research in the second period. These results should be considered, however, in respect to the total literature output of each of the four sectors. While most academic research is published without restraint, it is generally believed that research reports of corporate and government-affiliated scientists may be published less frequently because of their proprietary or national security character.

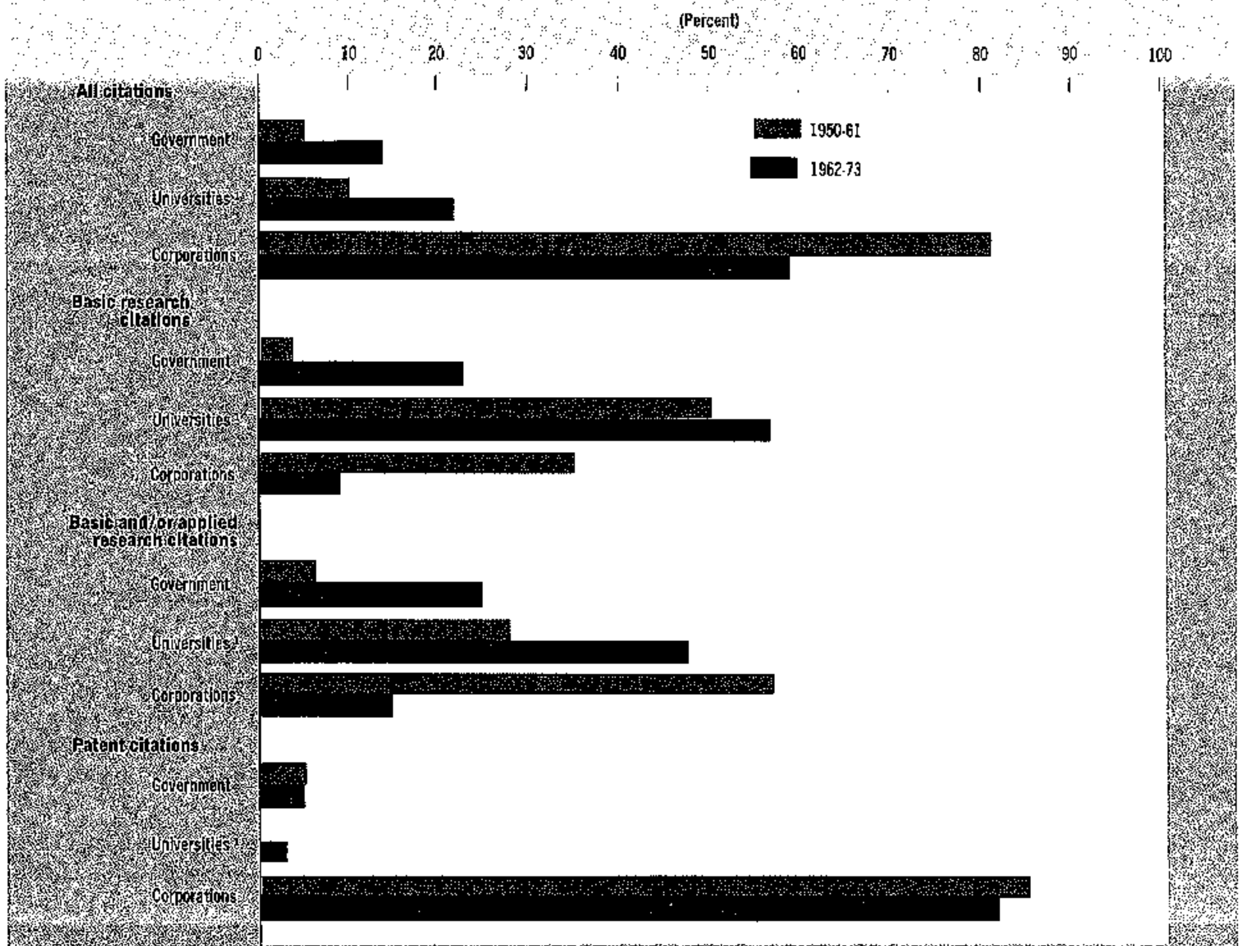
Time between research and application

Many of the results from basic research are not immediately incorporated into applied technologies. Often a long period of time is required to synthesize research results, or to await an economic or social need for a particular application in technology.

In the present study, the time between the research and its utilization in technology was defined as the interval between the publication date of the cited research and the date of patent application. The average time was found to decrease from seven to six years from the first to the second half of the 1950-73 period. The most recent period covered in the study (1970-73) has an average time interval of only three years, suggesting an increasingly rapid utilization of research results in modern technology.

Figure 3-25

Percent of Citations in Basic Patents, by Type of Citation and Source, 1950-61 and 1962-73



[1] Includes nonprofit institutions which account for less than 3 percent of all the citations.

SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

Technological areas	Number of advances
Chemicals	26
Electronic components	25
Nonelectrical machinery	22
Communication devices	20
Scientific, photographic & optical equipment	19
Computers & electronic data processors	17
Metals and alloys	16
Transportation systems & devices	16
Pharmaceuticals	12
Ceramics and other nonmetals	6
Total	179

Examples

Organo-phosphoric acids
Oral antidiabetic agent
Thermoelectric devices
Permutation decoder
Tunnel diode
Permanent magnetic materials
Wavefront reconstruction
Low energy electron sterilization
Processing of nuclear reactor fuel elements
Multiple speed transmission

Each technological advance is represented by a single "basic patent" in which the fundamental concept or idea embodied in the invention is presented for the first time in a patent application. The documentation provided with the application, as well as information added in the patent examination process, was reviewed in order to identify the research which was cited as the basis for the advance. Of the 179 examples, slightly more than 50 percent of the associated basic patents cited published research literature and/or other patents.[35] The data presented here are based on those patents in the sample which contained such citations.[36]

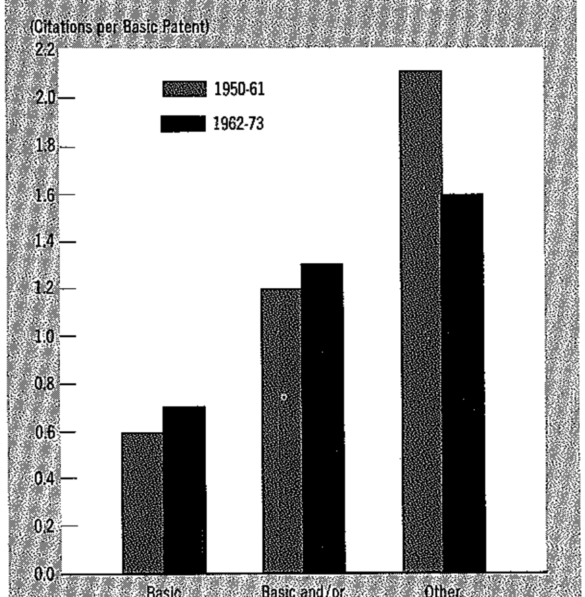
[35] The absence of citations in the remaining basic patents may have several causes, including the possible lack of candid disclosure by the patent applicant. Failure to make required disclosure has, in fact, resulted in a doubling of the number of patent invalidations over the past twnety years.

[36] For further information on the methodology of the study, see *Indicators of the Role of Science in Patented Technology*, Franklin Pierce College Law Center and the PTC Research Foundation, 1974 (A study commissioned specifically for this report).

Dependence on basic research. One important indicator of the relationship between basic research and technology is the extent to which new technologies or major advances in existing ones depend upon results from basic research. A measure of the incidence of such relationships is shown in figure 3-23. These findings show that other patents were cited more frequently than published research, but that differences between the two in citation frequency have narrowed considerably. The frequency of citation (number of citations per basic patent) increased by 17 percent for the basic and by 8 percent for the combined basic and applied research categories from the first to the second decade. On the other hand, the frequency of citation to other patents decreased almost 25 percent. These results suggest that more recent technological advances may depend increasingly on new scientific discoveries reported in the research literature.

Seven different fields of science and engineering were represented in citations to the research literature (figure 3-24). Almost an equal percentage of basic patents cited research in

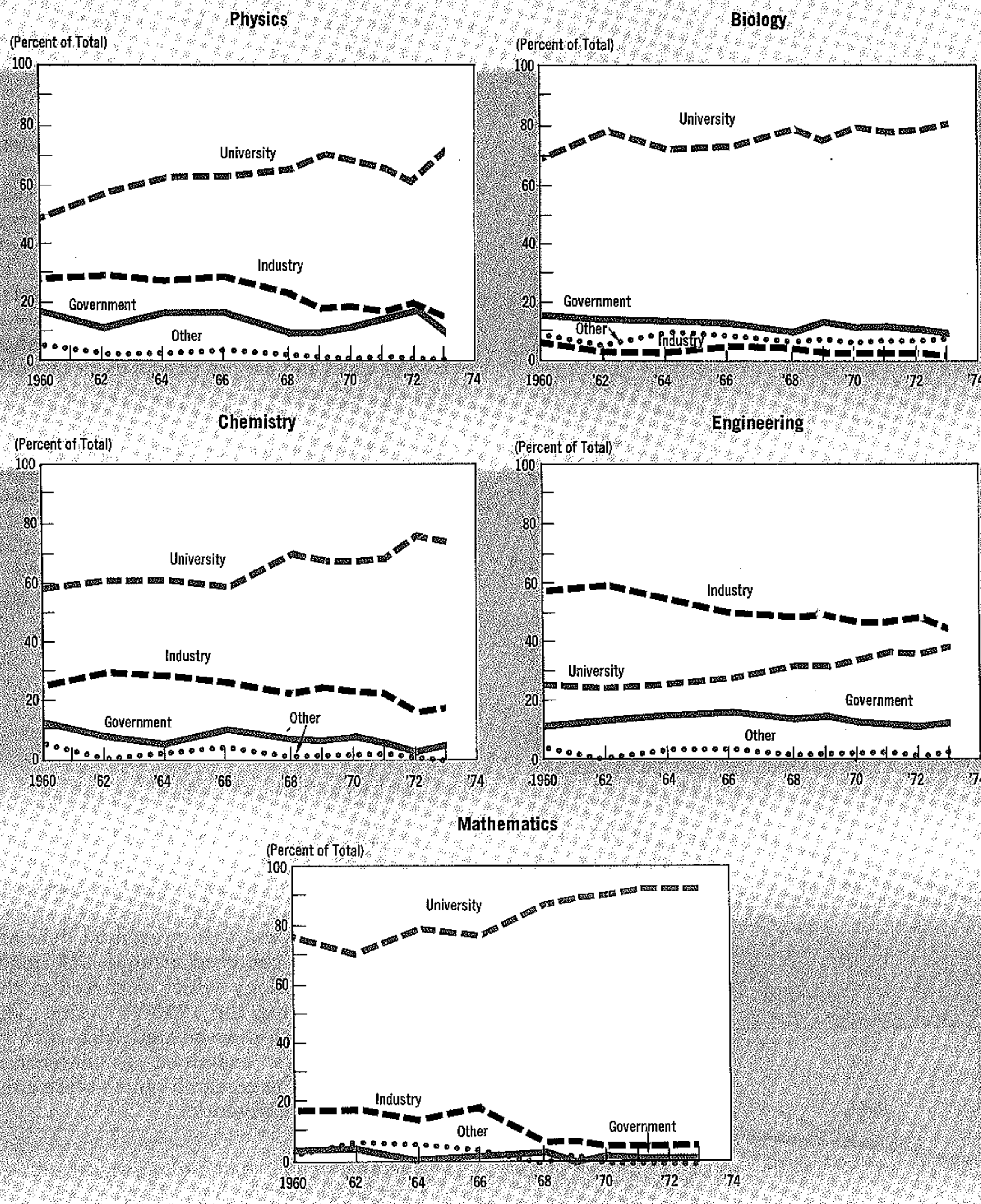
Figure 3-23
Citations per Basic Patent, by Type of Citation, 1950-61 and 1962-73



SOURCE: Franklin Pierce College Law Center and the PTC Research Foundation.

Figure 3-21

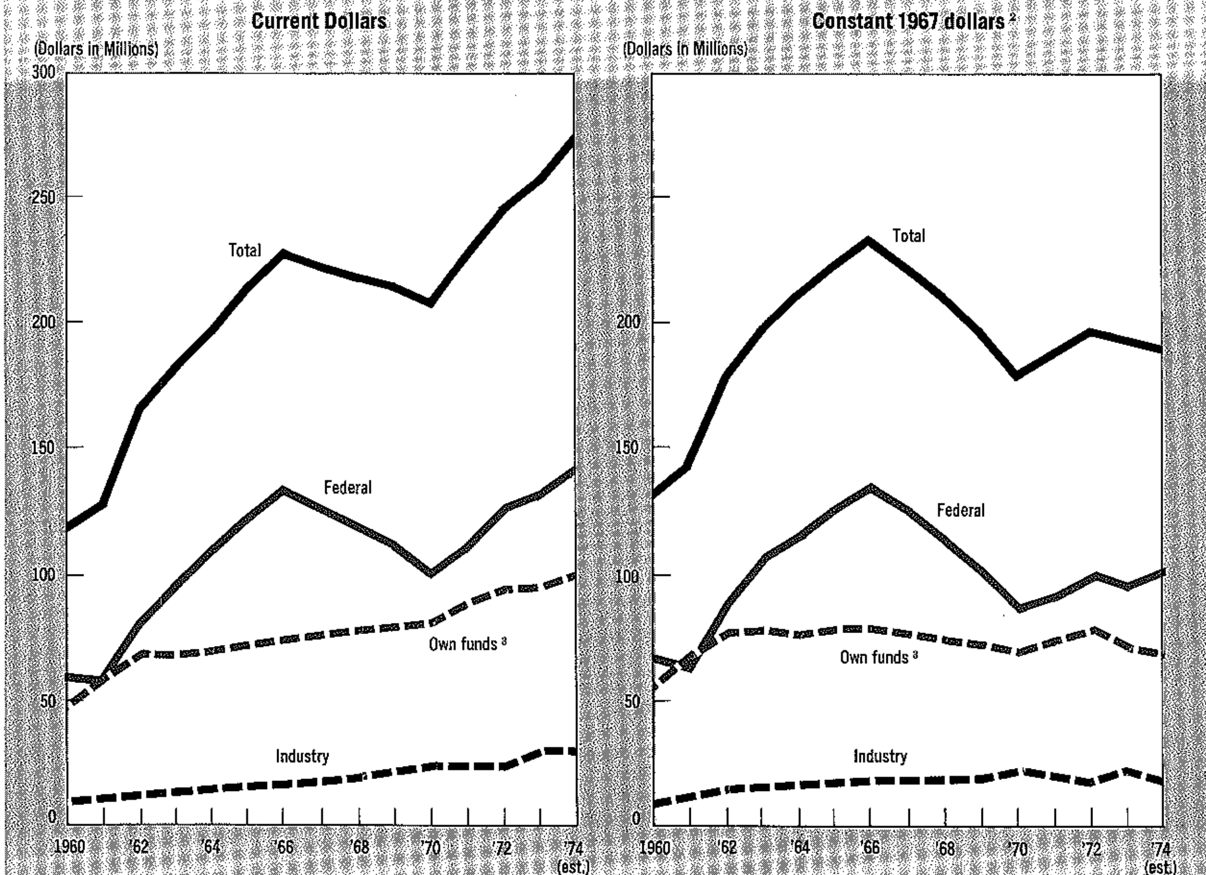
Publication Output for Selected Fields of Science, Percent of Yearly Totals by Sectors, 1960-73



SOURCE: National Federation of Abstracting and Indexing Services, 1974.

Figure 3-19

Basic Research Expenditures in Nonprofit Institutions,[1] by Source, 1960-74



[1] Includes State-administered hospitals.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[3] Includes State and local government funds.
SOURCE: National Science Foundation.

The Federal Government was the second largest producer of published research reports in 1973, with an average of 11 percent of the total reports from the 13 fields. The proportion of the total research publications produced by this sector declined, however, in all fields between 1960 and 1973, with the largest decreases occurring in oceanography, chemistry, and physics. In 1973, this sector accounted for a significant share of total research publications in the fields of astronomy (29 percent), oceanography (21 percent), geology (18 percent), and astronomy (16 percent).

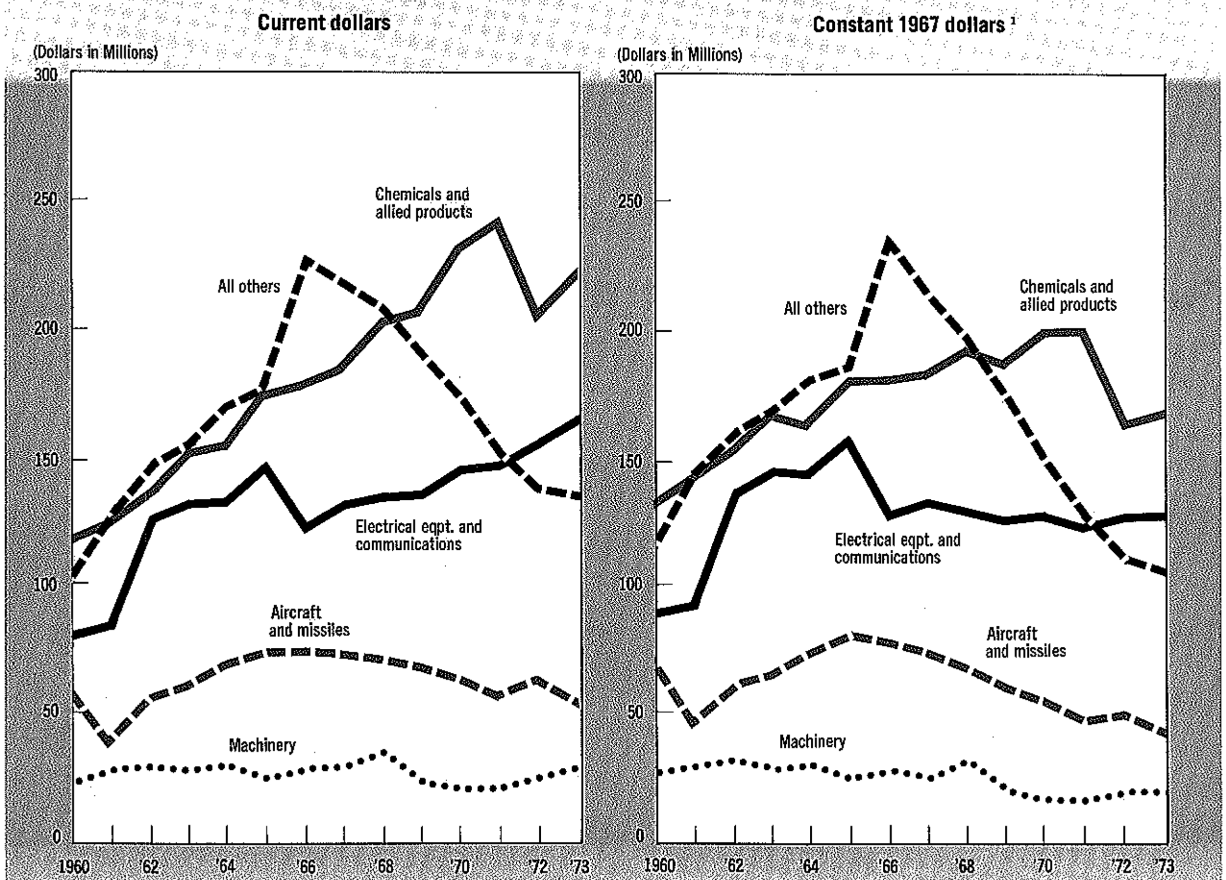
Private industry's share of research publications in 1973 averaged 10 percent among all fields as a whole, with the largest fractions in the fields of engineering (44 percent), chemistry (18 percent), and physics (16 percent). The proportion of total publications for which this sector was responsible declined in all fields—other than the atmospheric sciences and oceanography—between 1960 and 1973. The largest declines were recorded in engineering, physics, and chemistry.

Nonprofit organizations produced the remaining 5 percent of total publications in 1973, down from some 10 percent in 1963.

It is clear from these indicators that academic institutions are predominant in the production

Figure 3-17

Expenditures for Basic Research in Industry, by Major Performing Industries, 1960-73



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Growth in research output. The extent and pattern of the relative growth in research publications are shown in figure 3-20 for each of 13 fields of science and engineering. The fields listed in this figure are presented in descending order with respect to the magnitude of their relative growth in publications during the 1960-73 period. The fields included in the top part of the figure grew by more than 200 percent during the period, those in the second plot by more than 100 but less than 200 percent, those in the third by more than 75 but less than 100 percent, and those in the bottom plot by less than 75 percent.

The fields differ considerably in their pattern of growth. For example, research publications in physics, chemistry, and engineering[33] (third plot from top) have remained at nearly a constant level since the late 1960's, whereas astronomy and biology (second plot from top) grew continuously throughout the period. The field of oceanography exhibits one of the more complex and unusual growth patterns; research publications in that field rose rapidly until 1969, but declined in most subsequent years.[34]

---

[33] These fields, as noted later in this chapter, play a large role in technological innovation.

[34] For information on the U.S. output of scientific research in an international context, see the chapter entitled, "International Indicators of Science and Technology" in this report.

except the Department of the Interior (figure 3-15). In the case of NASA, HEW, and Commerce, the year of highest funding of intramural basic research support was 1970, after which funding decreased in each of the agencies. By 1974, NASA's funding had declined more than 25 percent over its 1970 level, HEW by 40 percent, and Commerce by almost 70 percent. Basic research in DOD and USDA intramural laboratories received the highest level of constant dollar support in 1972. The DOD program declined by just over 20 percent while the USDA program remained fairly constant through 1974. In contrast, the Department of the Interior obligations for intramural basic research reached their highest level in 1974.

BASIC RESEARCH IN INDUSTRY[30]

Basic research consists of original investigations for the advancement of scientific knowledge which has no specified commercial objective, although the research may be within the general area of a company's interest. Such research, which is conducted largely by manufacturing industries, may provide a technical basis for product improvement, expansion or new business, and a defense against technological obsolescence.

Expenditures for basic research in industry represented 16 percent of the total national funds spent for basic research in 1974, but only 3 percent of all R&D expenditures in industry.[31] Although the current dollar total from all sources has risen, particularly since 1972, the effect of inflation has been to reduce the 1974 basic research expenditures in industry to approximately the same level as 1961 (figure 3-16). Federal support has dropped 12 percent since 1971 in constant dollars compared to a 3 percent increase of non-Federal basic research expenditures. The proportion of basic research in industry which has had Federal support has been about 22 percent for the last three years, compared to 32 percent in 1967.

Over three-fourths (78 percent) of the 1973 basic research expenditures in industry were accounted for by only four industries (figure 3-17): chemicals and allied products (37 percent), electronic equipment and communications (28 percent), aircraft and missiles (9 percent), and machinery (4 percent).

For the most part, basic research in industry is concentrated in the physical sciences and engineering (some 80 percent in 1973). Expenditures in the physical sciences, however, have declined significantly since the late 1960's, in both current and constant dollars (figure 3-18), while engineering expenditures reached their highest level in 1973 in current dollars. Constant dollar expenditures in the life sciences, on the other hand, grew substantially in the late 1960's before peaking in 1971 and then declining.

BASIC RESEARCH IN NONPROFIT INSTITUTIONS

Independent nonprofit institutions are organizations other than educational institutions chartered to serve the public interest, and include research institutes, hospitals, private foundations, science exhibitors, professional societies, trade associations, and FFRDC's administered by such nonprofit institutions. Although the largest single category is the research institutes, the others generally perform other services in addition to research, such as patient care or charitable activities.

These institutions were responsible for 7 percent of the Nation's expenditures for basic research in 1974, a fraction which changed little during the 1960-74 period. Current dollar expenditures for basic research in nonprofit institutions reached their maximum in 1974 (figure 3-19). In terms of constant dollar expenditures, funds for basic research in 1974 were comparable in magnitude to the funding level of earlier years (1971 and 1962-63), and approximately 20 percent lower than the year of highest funding which was 1966.

Federal sources provide the greatest part of support for basic research in these institutions and have a large impact on the total level of funding in any given year. In 1974, Federal support accounted for 53 percent of all basic research expenditures in nonprofit institutions, compared to 58 percent in 1966 and 50 percent in 1960. In contrast to the fluctuating Federal funding, support from other sources rose comparatively steadily, although slowly.

Over the 1960-74 period, basic research as a proportion of total research and development expenditures by these institutions declined from 38 percent to 22 percent.

---

[30] A more comprehensive discussion of R&D in industry is found in a later chapter entitled, "Industrial R&D and Innovation."

[31] *National Patterns of R&D Resources, 1953-75,* National Science Foundation (NSF 75-307).

Cambridge Electron Accelerator
Fermi National Accelerator Laboratory
E.O. Lawrence Berkeley Laboratory
E.O. Lawrence Livermore Laboratory
Los Alamos Scientific Laboratory
Oak Ridge Associated Laboratory
Plasma Physics Laboratory
Stanford Linear Accelerator

Department of Defense

Applied Physics Laboratory
Applied Research Laboratory
Center for Naval Analyses
Lincoln Laboratory

National Aeronautics and Space Administration

Jet Propulsion Laboratory
Space Radiation Effects Laboratory

National Science Foundation

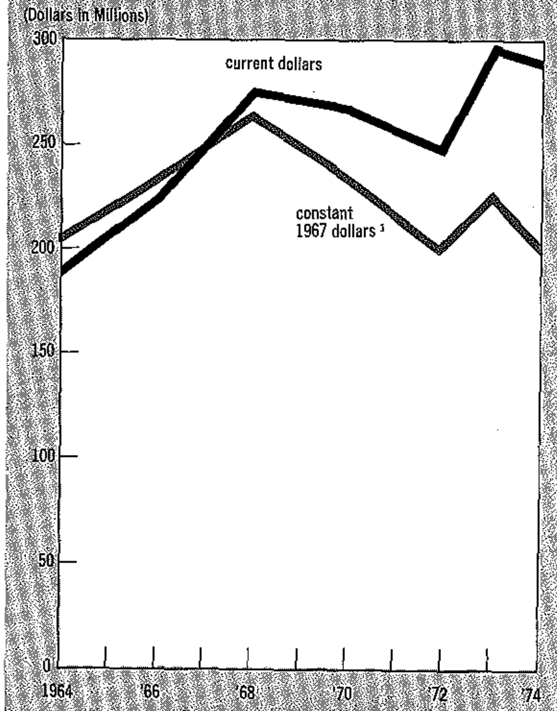
National Astronomy and Ionosphere Center
Cerro Tololo Inter-American Observatory
Kitt Peak National Observatory
National Center for Atmospheric Research
National Radio Astronomy Observatory

In current dollars, expenditures by university-managed FFRDC's for basic research were at their highest level in 1973 and declined slightly in 1974 (figure 3-14). In constant dollars, however, basic research expenditures in 1974 were almost 25 percent less than those of the 1968 peak year and approximately equal to expenditures in 1964. Data are not available on expenditures for specific scientific fields, but it is apparent from the above listing of the Centers, and the Federal agencies involved, that the basic research is predominantly in the physical sciences and engineering. The proportion of all R&D expenditures in FFRDC's reported as basic research has remained at nearly 35 percent in the last few years.[27]

Although some of the FFRDC's are permitted to receive support from sources other than the Federal Government, such funds amounted to less than 1 percent of their total funding in 1974.

[27] See Appendix table 3-14.

Figure 3-14
Basic Research Expenditures at Federally Funded Research and Development Centers Administered by Universities, 1964-74



1 GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

BASIC RESEARCH IN INTRAMURAL FEDERAL LABORATORIES

Several agencies of the Federal Government operate their own R&D laboratories as part of their effort to meet the research needs associated with their agency mission and program objectives. Intramural laboratories were responsible for 16 percent of the total basic research expenditures and 23 percent of all federally supported basic research in 1974. About 94 percent of all such research in 1974 was undertaken by the six agencies indicated in figure 3-15. Examples of such laboratories are the Goddard Space Flight Center of NASA, the National Animal Disease Laboratory of USDA,

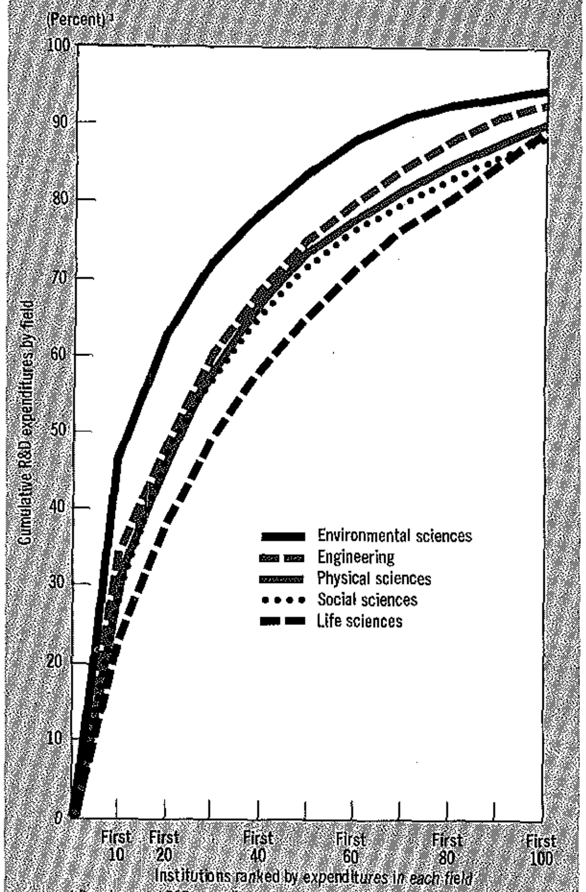


Figure 3-11
Concentration of R&D Expenditures at the 100 Universities and Colleges with the Greatest Expenditures in Selected Fields, 1974

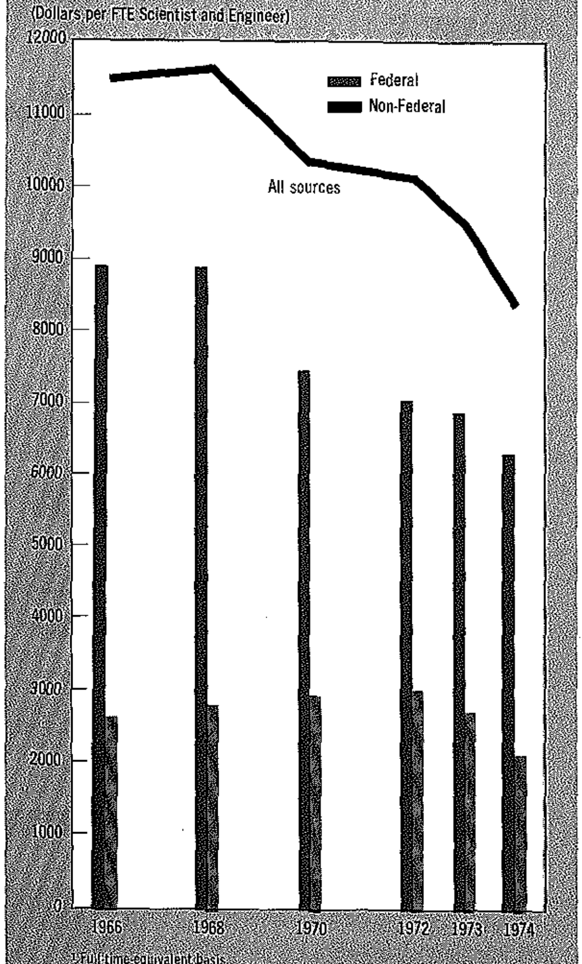
[1] Based on total R&D expenditures in individual fields.
SOURCE: National Science Foundation.

Basic research expenditures per scientist and engineer

Basic research expenditures in doctorate institutions[23] reached their highest level in 1972 in constant dollars and then dropped nearly 15 percent over the next two years (see Appendix table 3-12), while the number of scientists and engineers in these institutions rose continuously through 1974. This increase of scientists and engineers was due partially to an expanding number of institutions awarding doctorate degrees in a science or engineering field—224 such universities in 1969 compared with 280 in 1974—as well as increases in the number of such personnel at existing doctorate-level institutions.

These trends—an increase in the number of scientists and engineers and a drop in real expenditures for basic research—have produced a reduction of almost 30 percent in constant dollar expenditures per scientist and engineer in

Figure 3-12
Basic Research Expenditures per Scientist and Engineer[1], in Doctorate-granting Institutions, by Source, 1966-74
(in constant 1967 dollars[2])



[1] Full-time-equivalent basis.
[2] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

[23] Those granting doctorates in at least one science or engineering field.

Percentage of total basic research obligations directed to universities and colleges, by field, 1974[19]

Fields of science[20]	NSF	HEW	DOD	USDA	AEC	NASA
Life sciences	83	73	30	24	29	3
Physical sciences	82	84	36	8	19	11
Environmental sciences	63	—	54	22	—	6
Engineering	97	92	40	12	25	12
Social sciences	90	37	—	56	—	—

These fields of science and engineering are supported by various combinations of Federal agencies, as indicated in figure 3-10 which presents the proportion of Federal obligations provided by each of the six agencies to universities and colleges for basic research in each major field. The figure indicates that either one or two agencies alone provided at least 70 percent of all Federal obligations for basic research in each field. The NSF and HEW together, for example, provided nearly 90 percent of all federally obligated dollars for basic research in the life sciences in 1974, almost 83 percent of the obligations for psychology and the social sciences, and approximately 75 percent for chemistry. Similarly, two agencies (DOD and NSF) accounted for more than 85 percent of the six agencies' obligations for the environmental sciences and some 80 percent of those for engineering, while the AEC and NSF in combination provided nearly 80 percent of all obligations for physics research in universities and colleges.

The fact that the NSF in 1974 provided either the largest or next largest amount of basic research obligations in the several fields—and nearly 35 percent of all obligations from the six agencies—underscores the extent of dependency on that agency by universities and colleges for support of basic research.

Institutional concentration of basic research

Basic research is concentrated in institutions which award advanced degrees in science and engineering. The 280 universities which grant doctorate degrees in the sciences and engineering accounted for 98 percent of academic basic research expenditures in 1974, with 82 percent of the total expenditures concentrated in 100 such institutions.[21] Little change occurred in this pattern of institutional concentration during the 1964-74 period as shown in the table below, although there were considerable shifts in the positions of specific institutions.

Percentage of expenditures for basic research by groups of institutions ranked in order of expenditures, 1964 and 1974

Year	First 10	First 20	First 40	First 60	First 80	First 100
1964	25	41	60	72	NA	NA
1974	24	39	59	72	81	86

The institutional concentration of R&D expenditures varies among the five broad scientific areas (figure 3-11).[22] The life sciences exhibited the least concentration in 1974, and the environmental sciences the greatest. The social sciences, physical sciences, and engineering had similar patterns of distribution or concentration, although varying considerably among individual institutions. The ten academic institutions with the largest R&D expenditures in the life sciences, for example, reported 23 percent of the total for all universities in 1974, compared with a concentration of 47 percent of all environmental science R&D expenditures in the first ten institutions for that field. No university ranked among the first ten in all five fields, and only one university held this position in four of the fields—reflecting a diversity of field concentration patterns even within the major research universities.

[19] *Ibid.*, and special tabulations.

[20] See Appendix table 3-6a for descriptions of these fields.

[21] *Expenditures for Scientific and Engineering Activities at Universities and Colleges, FY 1973*, National Science Foundation (NSF 75-316-A), and special tabulations.

[22] Data on basic research expenditures alone are not available for separate fields of science and individual institutions. An approximation is available, however, in the form of total R&D expenditures by these institutions in scientific fields, the largest component of which is basic research.

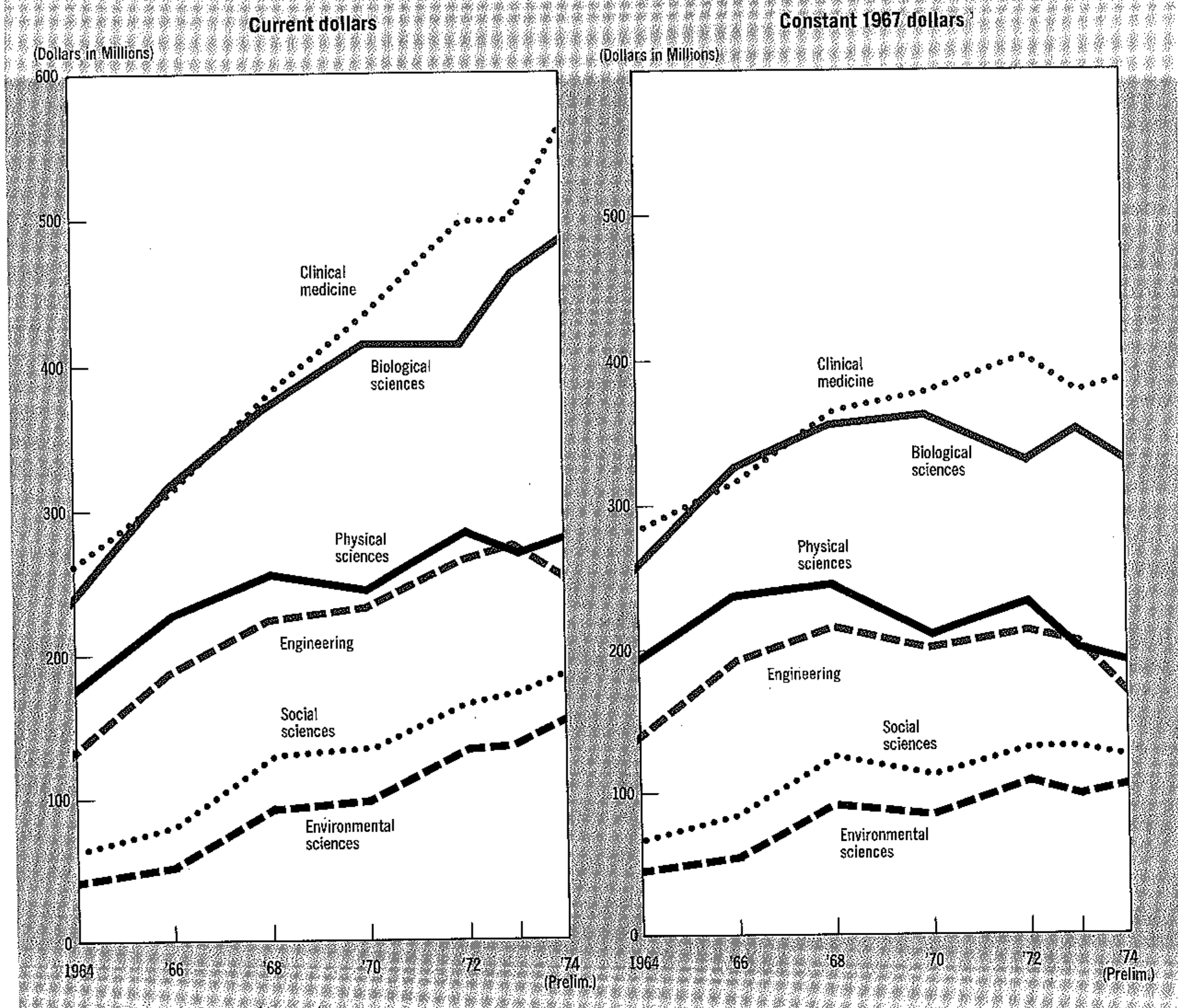
Selected fields	Federal support as a percent of all basic research expenditures	
	1964	1974
All fields	76	70
Physical sciences	93	82
Chemistry	89	78
Physics	97	87
Environmental sciences	91	74
Life sciences	69	69
Clinical medicine	84	77
Biological sciences	53	59
Engineering	82	69
Social sciences	61	58
Other fields	80	72

Support by Federal agencies. The six Federal agencies mentioned earlier accounted for 98 percent of total Federal obligations to universities and colleges for basic research in 1974, with the NSF and HEW alone providing 74 percent of all such obligations. The individual Federal agencies differ greatly in the proportion of their total obligations for basic research which they direct to universities and colleges.[18] Of the

[18] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975, Vol. XXIII* National Science Foundation (NSF 74-320-A), and earlier volumes in this report series.

Figure 3-8

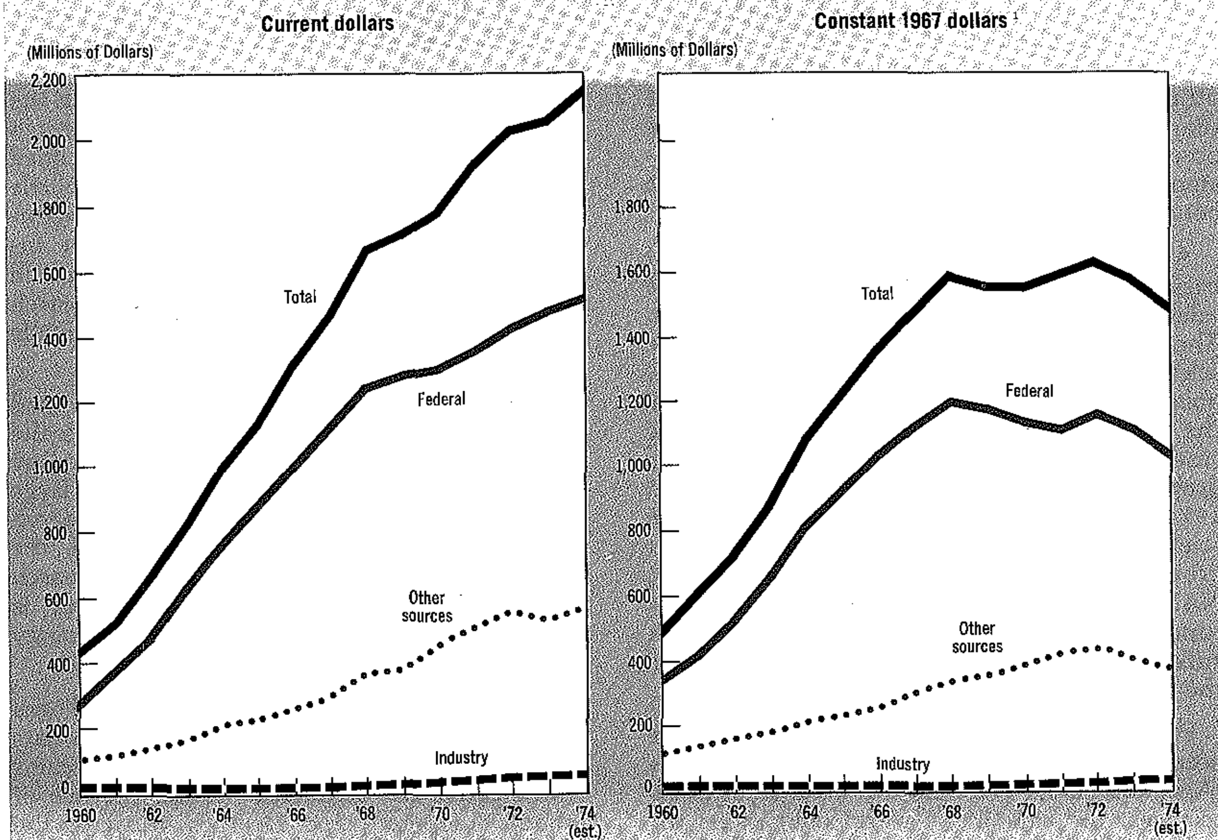
Estimated Basic Research Expenditures in Universities and Colleges, by Field of Science, 1964-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 3-7

Basic Research Expenditures in Universities and Colleges, by Source, 1960-74



¹ GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

in current dollars, although the annual rate of growth diminished after 1968 (figure 3-7).[13] This decline in the growth rate, coupled with rising inflation, produced a level of constant dollar expenditures which changed little during the 1968-72 period. Small constant dollar increases in 1971 and 1972 were succeeded by larger decreases in the two following years, with the result that basic research expenditures in 1974 were 9 percent lower than in 1972, the year of highest constant dollar funding.

[13] These expenditure data are for R&D which has been sponsored by other agencies and organizations, as well as R&D supported by an institution's own funds which it allocates to separately organized institutes, divisions, or specific R&D projects. They do not include the expenditures for research/teaching assignments of the faculty (departmental research). Expenditures associated with FFRDC's administered by universities are treated later in this chapter.

The leveling off and decline in constant dollar expenditures for basic research is due mainly to reduced growth of funding by the Federal Government (figure 3-7), in combination with inflation. The scientific fields most affected by these declines were the physical sciences (particularly physics) and clinical medicine (see figure 3-9 and Appendix table 3-9).

Sources of funds for basic research

The sources of financial support for basic research in universities and colleges are shown in figure 3-7. The largest of these—the Federal Government—provided substantial annual increases in current dollars between 1960-68, but reduced significantly the average annual increments in later years. Translated to constant

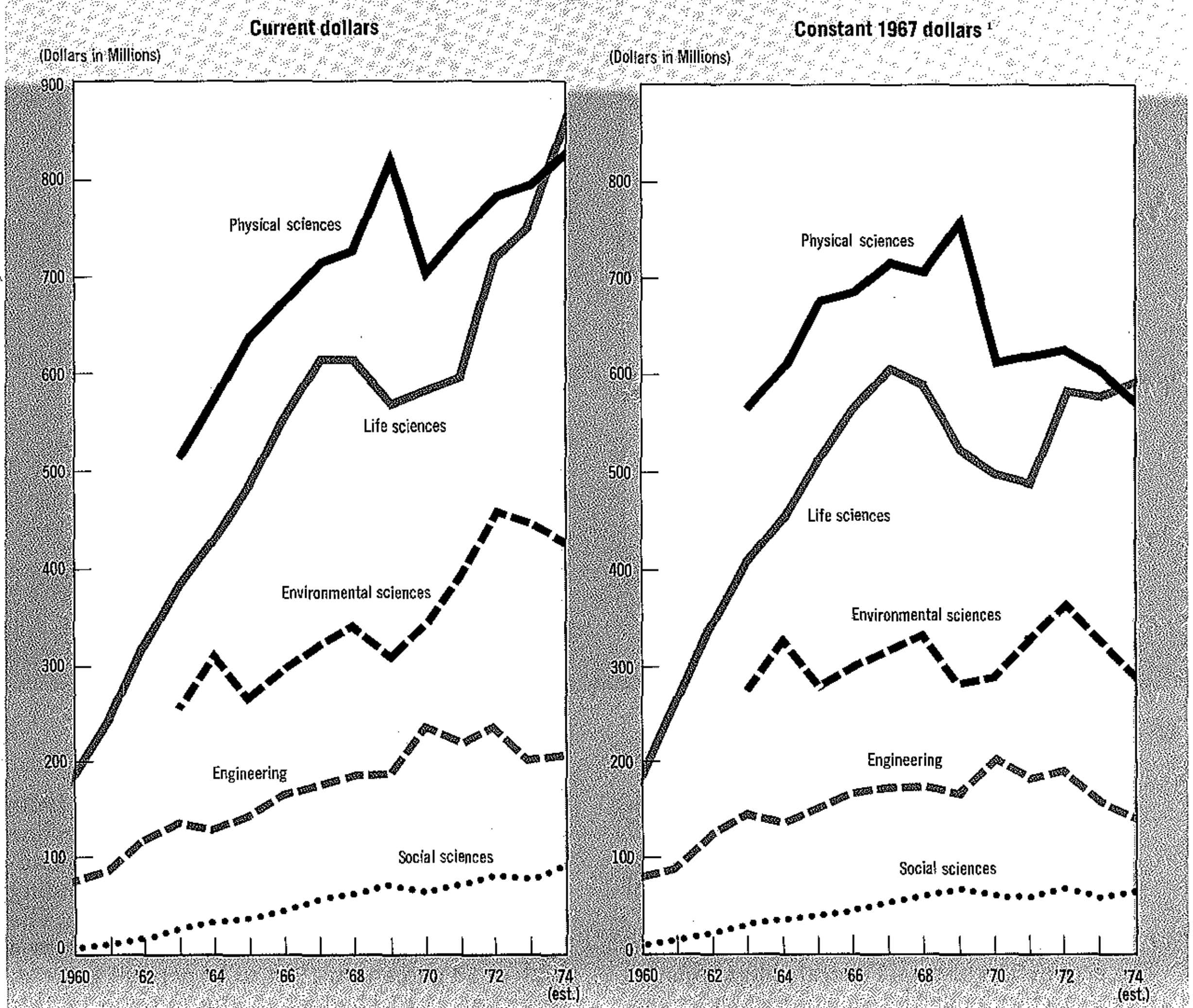
Accompanying the declines in DOD and NASA were recent increases in the fractions provided by HEW and NSF, with the former accounting for 23 percent of total obligations in 1974 (versus 17 percent in 1960), and the latter 16 percent (versus 11 percent in 1960). Much of the growth in HEW's share during the period occurred in 1973 and 1974 in connection with increased funding for cancer research; similarly, a large part of the growth in NSF's share took place in the years after 1970, as a result of increasing obligations for basic research in virtually all major scientific disciplines.

Basic research obligations in scientific areas. An overview of the distribution of Federal support for basic research by scientific area is presented in figure 3-6.[10] The five broad areas shown in the figure accounted for 95 percent of

[10] See Appendix table 3-6 for disaggregated data for certain disciplines and Appendix table 3-6a for a listing of the scientific disciplines encompassed in these broad fields.

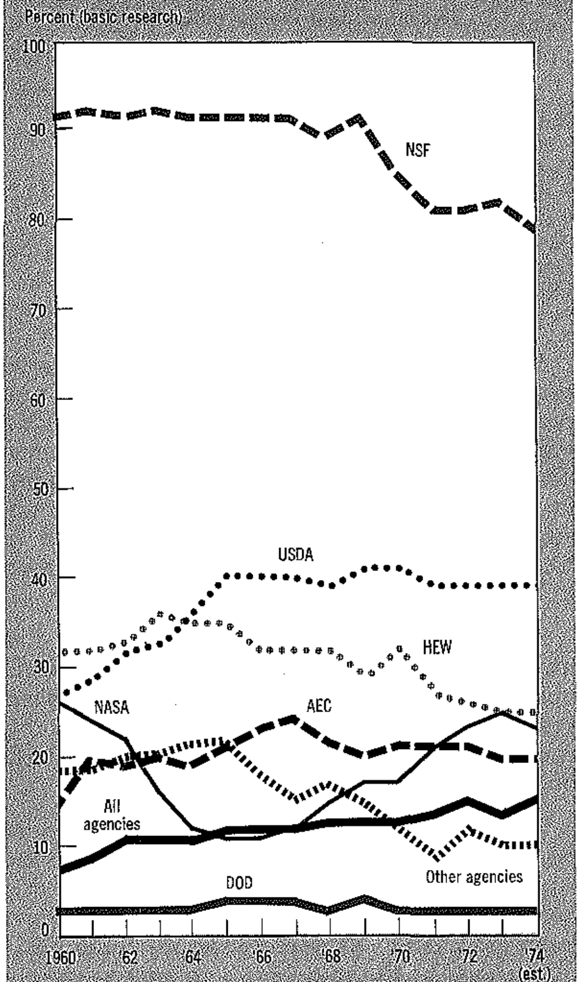
Figure 3-6

Federal Obligations for Basic Research, by Selected Fields of Science, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 3-4
Federal Obligations for Basic Research as a Percent of Each Agency's R&D Obligations, by Agency, 1960-74



SOURCE: National Science Foundation.

ranged from a low of 11 percent in the mid-1960's to some 25 percent in the 1972-74 period, with much of the latter growth coinciding with reduced obligations for the manned-space program. Basic research obligations by HEW show a long-term decline, as a percentage of the agency's obligations for all R&D; increase in life sciences research "targeted" toward specific disease areas accounts in part for the declining fraction of basic research obligated in recent years by this agency.

Basic research obligations. Obligations for basic research alone are shown in figure 3-5 for each of the six agencies, as well as for all other agencies combined. Current dollar obligations were higher in 1974 than 1973 in each of the six agencies other than DOD and NASA. In contrast, constant dollar obligations declined in all agencies other than HEW.

The principal scientific disciplines supported by each of these agencies[9] and the agency missions which generated the need for basic research in 1974 were:

NASA. The physical and environmental sciences receive some 75 percent of all NASA's basic research obligations, primarily in connection with lunar and space exploration.

HEW. Some 80 percent of HEW's obligations for basic research are directed to the life sciences, principally for biomedical research, and almost 6 percent to the social sciences for research in areas such as education and drug abuse.

NSF. Over 30 percent of this agency's basic research obligations are for the physical sciences, with 23 percent for the environmental sciences, 16 percent for the life sciences, and 11 percent for engineering. The broad purpose of the research is to advance the state of basic scientific knowledge.

AEC. The physical sciences receive almost 80 percent of AEC's basic research obligations and the life sciences nearly 13 percent—principally in high energy physics and in nuclear sciences. The purpose of this research is to generate the foundation for the development and utilization of atomic energy.

DOD. Engineering accounts for 29 percent of DOD's obligations for basic research, physical and environmental sciences 22 percent each, and the life sciences about 12 percent. The prime aim of the research is to provide the fundamental knowledge needed for developing future military systems and improved operations.

USDA. The life sciences receive some 70 percent and the physical sciences nearly 15

[9] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1973, 1974 and 1975,* Vol. XXIII, National Science Foundation (NSF 74-320-A).

The distribution of the total funds expended for basic research changed significantly among the sectors during the 1960-74 period. The fraction of the total accounted for by universities and colleges increased from 37 percent in 1960 to 54 percent in 1974, while industry's fraction fell from 32 to 16 percent. There was little change in the distribution of such expenditures among the other sectors.

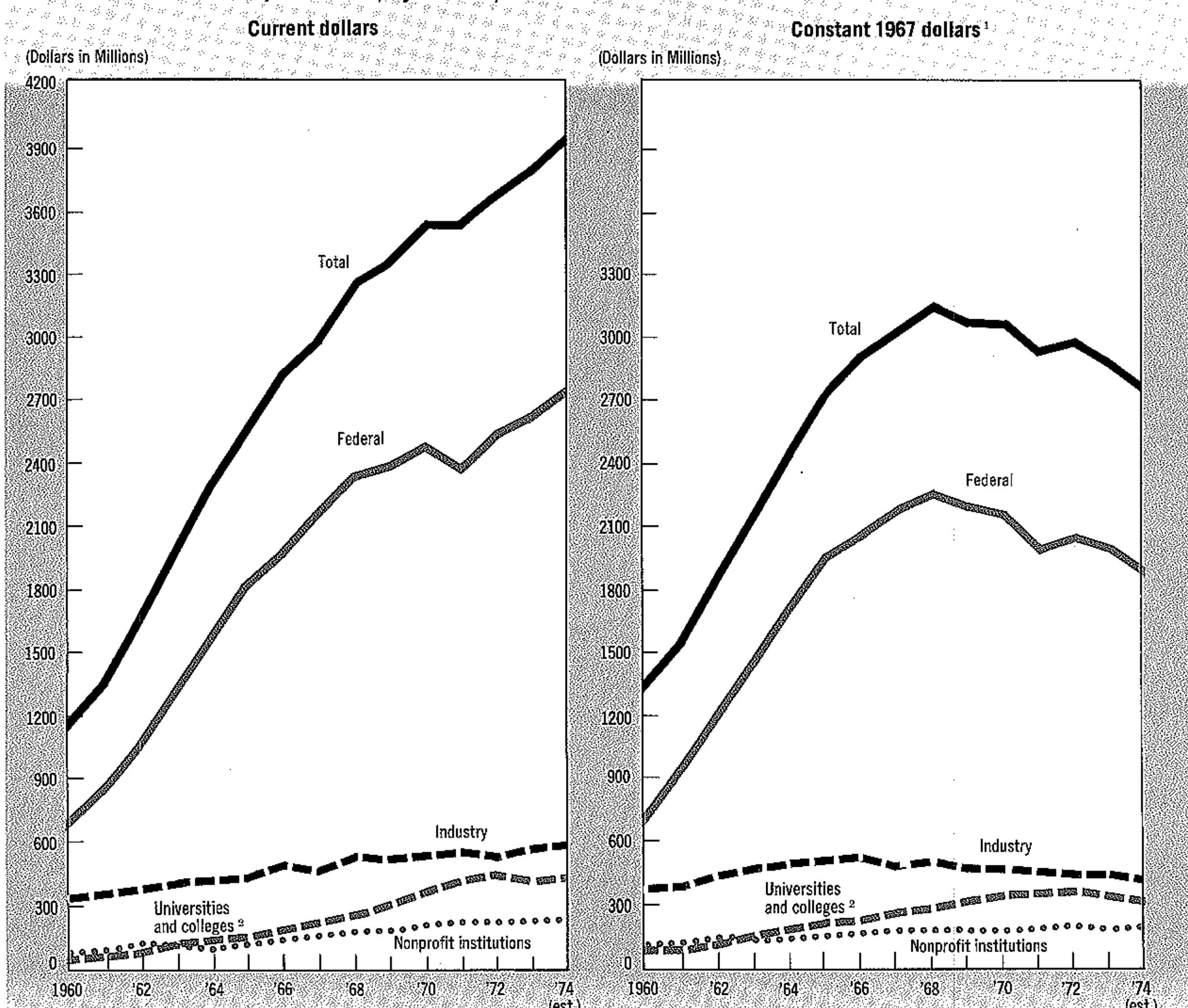
Basic research support by source of funds

The sources of expenditures for basic research are the Federal Government, industry, universities, and nonprofit institutions. Funds supplied for such research by these sources are shown in figure 3-3.

Basic research support from all sources increased in current dollars throughout most of

Figure 3-3

Basic Research Expenditures, by Source, 1960-74



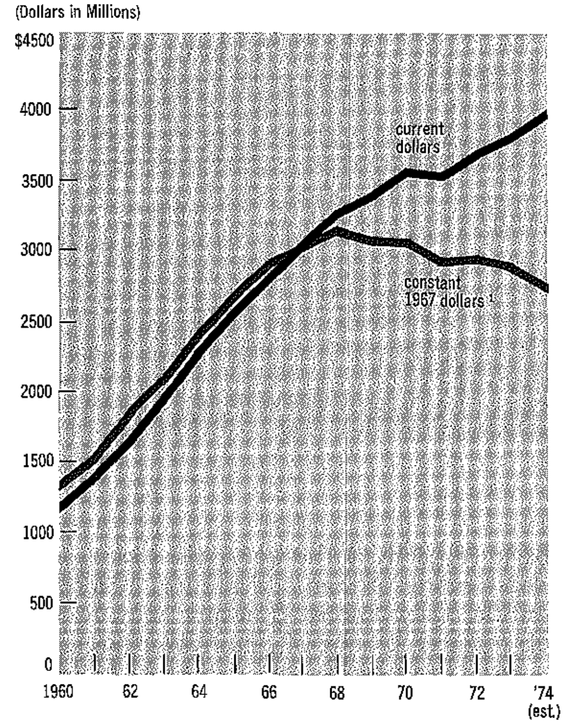
[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
[2] Includes state and local government sources.
SOURCE: National Science Foundation.

more, do not identify the wide applications made of the results of this research. Nor do they represent the economic and social returns from the varied uses made of its cumulative findings. The present indicators, in addition, do not include measures of the effectiveness, or productivity, of the research activity.

Besides these deficiencies, there are other limitations in regard to the data used for the present indicators. There is, for example, uncertainty regarding the precision with which "basic" research can be distinguished from "applied" research. A particular research effort may be identified as basic or applied, depending on whether the classification is made by the sponsor of the research or by the organization performing it. Furthermore, differences among sectors in the assignment of costs to basic research make it difficult to compare expenditures and the magnitude of research efforts among the sectors. Industrial firms, for example, include in their reported expenditures for basic research an annual depreciation cost of the facilities used in the research; universities and Federal laboratories do not. The construction costs of large, Government-financed research facilities such as the National Accelerator Laboratory are not included as basic research expenditures, whereas NASA, in figuring the costs of research using expendable space probes, includes the costs of spacecraft and launch vehicles (in compliance with NSF reporting requirements).

Figure 3-1

Basic Research Expenditures, 1960-74



[1] GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

RESOURCES FOR BASIC RESEARCH

The Nation's total expenditures for basic research increased continuously during the 1960-74 period, rising from $1.2 billion to $4.0 billion in current dollars (figure 3-1). In recent years, however, this growth has not been large enough to offset the eroding effect of inflation. As a result, the actual level of basic research activity—as reflected approximately by expenditures in constant dollars—peaked in 1968 and declined in subsequent years.[2] By 1974, expenditures for basic research were at their 1965 level in constant dollars, and 13 percent less than in 1968.

The proportion of all R&D expenditures reported for basic research has remained essentially constant at some 13 percent since 1965, after rising during the early 1960's.[3]

Expenditures by performer

There are four major sectors of the research community which perform basic research: private industry, Federal laboratories, universities and colleges (and the Federally Funded Research and Development Centers they administer), and other nonprofit institutions which conduct R&D. Because these sectors have differing missions and purposes, two different definitions of basic research are used for data

[2] The use of constant 1967 dollar expenditures to approximate the level of research activity is discussed in the preceding chapter entitled, "Resources for Research and Development."

[3] *National Patterns of R&D Resources, 1953-75*, National Science Foundation (NSF 75-307).

Basic Research

INDICATOR HIGHLIGHTS

- The Nation's total expenditures for basic research rose continually during the 1960-74 period in current dollars; in constant 1967 dollars, funds for basic research in 1974 were equal to the 1965 level, and almost 13 percent lower than the peak year of 1968.

- Universities accounted for approximately 55 percent of the Nation's total expenditures for basic research in 1974 (versus 37 percent in 1960), followed by the Federal Government and private industry at some 15 percent each, and other sectors with the remainder.

- The Federal Government provided the largest share of support for basic research during the 1960-74 period, increasing from nearly 60 percent of all such funds in 1960 to almost 70 percent in 1974; industry's share declined from 28 percent in 1960 to 15 percent in 1974, and the universities' share increased from 6 to 11 percent over this period.

- Funds provided by the Federal Government for basic research increased each year (except for 1971) in current dollars, but declined 13 percent between 1968 and 1974 in constant dollars; the largest reductions in constant dollars were recorded in the physical sciences which declined approximately 25 percent between 1969 and 1974.

- University expenditures for basic research (from all sources of support) rose continuously in current dollars between 1960-74, but declined some 5 percent in constant dollars between 1968 and 1974; this decline is due to reduced growth of Federal support in combination with inflation.

- Basic research expenditures by academic institutions in 1974 were concentrated in the life sciences (51 percent of all expenditures), engineering (12 percent), physical sciences (13 percent), social sciences (8 percent), and the environmental sciences (7 percent).

- Federal support for basic research in universities, which accounted for 70 percent of all such funds in 1974, increased in current dollars between 1964-74 in the broad fields of science and engineering; the level of research effort as reflected by constant dollar expenditures, however, was lower in each field in 1974 than in previous years, with the largest reductions occurring in engineering and the physical sciences.

- Federal support for universities in 1974 was provided primarily through six agencies—NSF, HEW, DOD, USDA, AEC, and NASA—with no more than two agencies supplying at least 70 percent of all Federal basic research support in each major field of science; the NSF provided either the largest or second largest amount of funding among these agencies in each field.

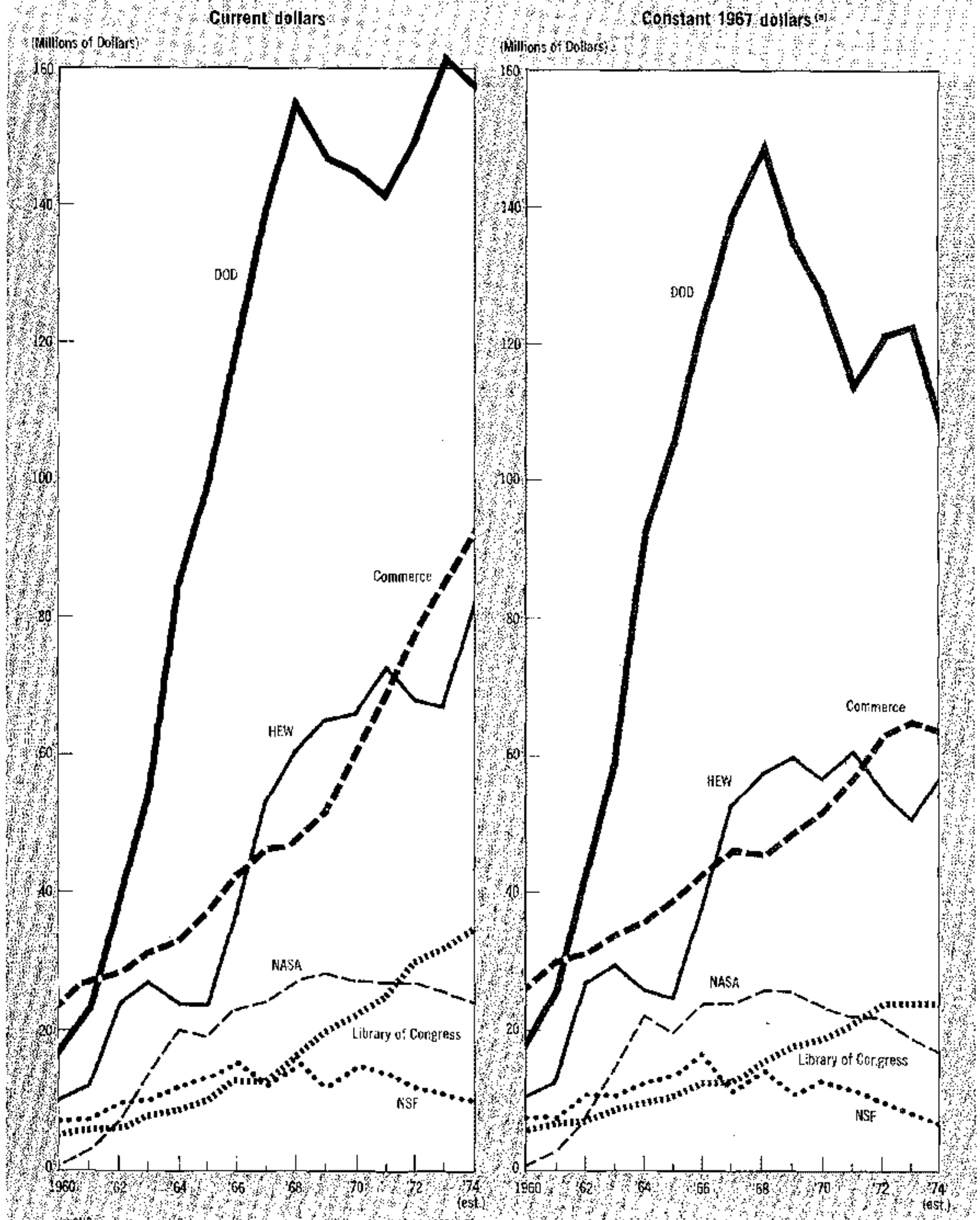
- Expenditures for basic research per scientist and engineer in doctorate-granting institutions were almost 30 percent lower in constant dollars in 1974 than in 1968; the largest decline was in physics, where reductions were nearly 40 percent from 1966 to 1974.

- Federal laboratories accounted for 16 percent of the total national expenditures for basic research in 1974; current dollar expenditures by these laboratories increased throughout most of the 1960-74 period, but the level of research effort in terms of constant dollars was some 20 percent lower in 1974 than in 1970, the year of highest real expenditures.

- Private industry was responsible for 16 percent of the total national expenditures for basic research in 1974; although current dollar expenditures have risen, particularly since 1972, inflation reduced real expen-

Figure 2-18

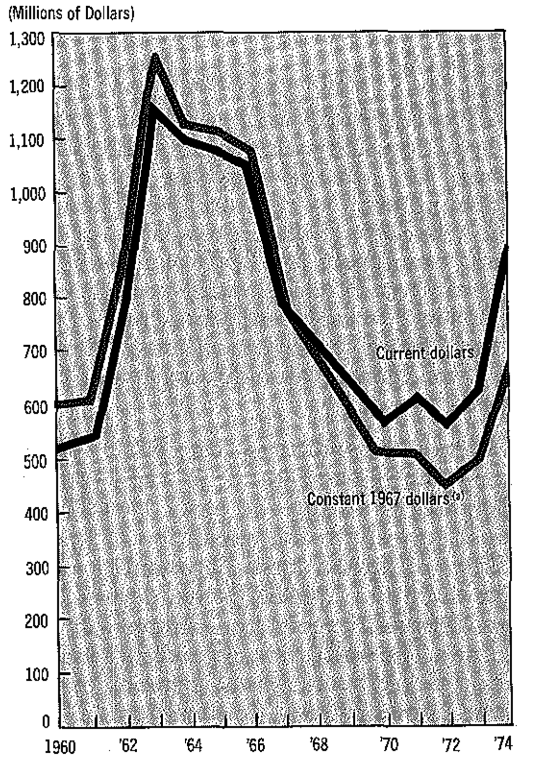
Federal Obligations for Scientific and Technical Information Activities, by Selected Agency, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.

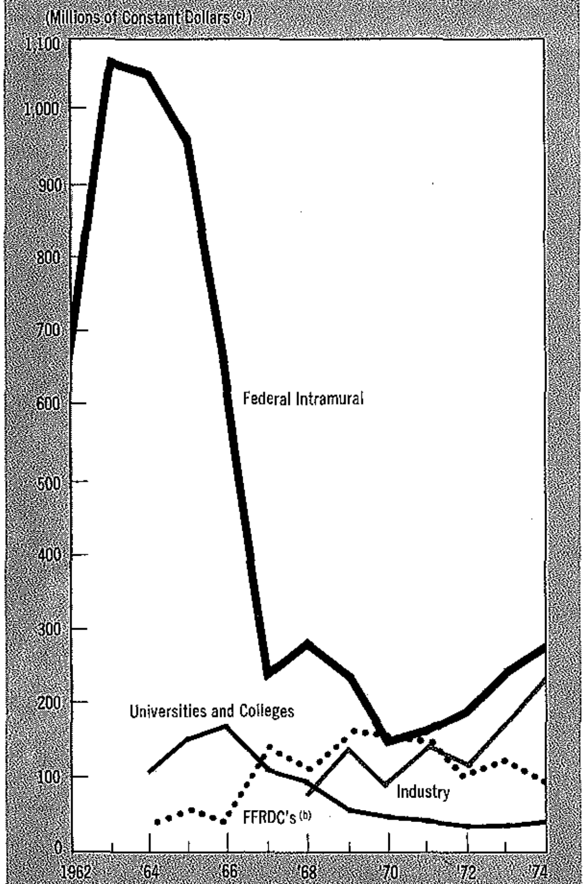
SOURCE: National Science Foundation.

Figure 2-14
Federal Expenditures for R&D Plant, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

Figure 2-15
Federal Obligations for R&D Plant, by Performer, 1962-74(a)



(a) Data for specific performers are not available for earlier years.
(b) Federally Funded Research and Development Centers administered by universities and colleges.
(c) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

the Federal intramural laboratories is due mainly to a like pattern of change in NASA funds for R&D plant. The ratio for university FFRDC's fluctuated from year to year, ending in 1974 at 17 percent. In universities and colleges, on the other hand, the ratio decreased steadily from a peak in 1966 of 9 percent to a low of 2 percent in 1974.

DISSEMINATION OF R&D RESULTS

The publication and dissemination of the scientific knowledge and technical information resulting from R&D are essential steps toward realizing the full benefits from the R&D investment. Such communication may not only prevent duplication of effort, but may also hasten further advances in science and shorten the time between R&D and application.[18]

The total national resources directed to such activities are not known. Some information, however, is available on the funds provided by the Federal Government in this area.

[18] For information on Federal programs aimed at disseminating and transferring scientific and technical knowledge to potential users in the private and public sector, see *Federal Technology Transfer Directory of Programs, Resources, Contact Points*, Federal Council for Science and Technology, Committee on Domestic Technology Transfer, 1975.

sufficiently large to offset the effects of inflation during the period.[14]

R&D in the defense and space sectors, as noted above, differs from the civilian sector in the distribution of funds for basic research, applied research, and development. In these sectors, development accounts for most of the R&D obligations, in contrast to civilian R&D where funds are directed primarily to research—basic and applied. In 1974, 80 percent of the funds for defense R&D were allocated to development activities, 17 percent to applied research, and 3 percent to basic research. And in the space sector, 61 percent of the obligations went for development, 27 percent for basic research, and 12 percent for applied research.

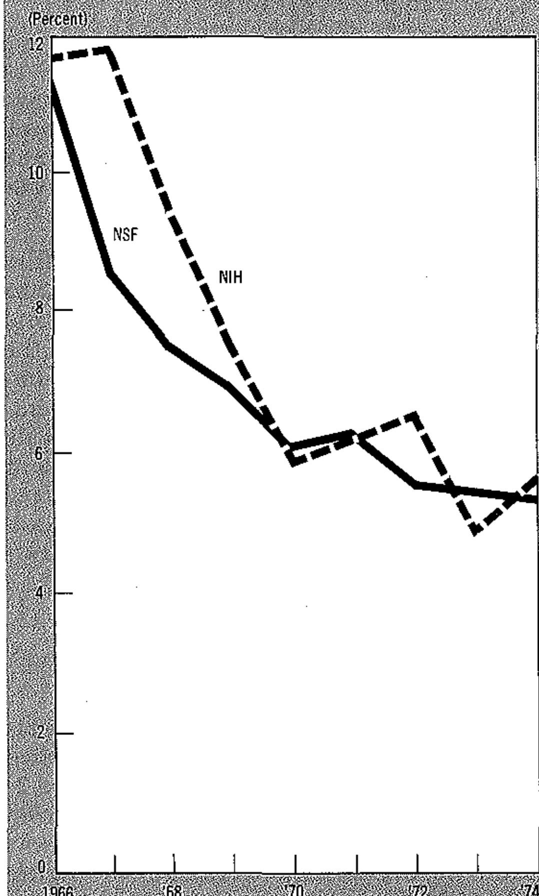
RESEARCH EQUIPMENT AND FACILITIES

Along with human and financial resources, research equipment and facilities constitute the elements essential for performing R&D. Research instrumentation provides the means for accurate measurement and observation, and facilitates data collection and analysis. Progress in science depends increasingly upon such equipment, as the phenomena under study become more fundamental and inaccessible to observation by the unaided human senses. Laboratories and support facilities provide the fixed equipment and physical plant necessary for R&D. Requirements in this area change as science advances, as new areas of research emerge, and as R&D is directed toward new objectives and problems. The excellent equipment and facilities heretofore available to the R&D community in this country are regarded generally as prime elements contributing to the strong international position of U.S. science.

Research equipment

The Federal Government is a major source of funding for the acquisition and maintenance of laboratory equipment, a large portion of which is included in research grants to provide the equipment needed for performing the research. In the two Federal agencies which provide the majority of such support, the National Institutes of Health and the National Science Foundation, the proportion of grant funds allocated for permanent laboratory equipment declined over the entire 1966-74 period. In both agencies, the proportion fell from approximately 11 percent in 1966 to some 5 percent in 1974 (figure 2-12). For the National Science Foundation, this decline represents a 14 percent reduction in current dollar obligations (and 40 percent in constant dollars) for research equipment between 1966 and 1974, despite the 54 percent increase in current dollar obligations (and 22 percent in constant dollars) between 1970 and 1974 (figure 2-13).[15]

Figure 2-12
Proportion of NSF and NIH[a] Research Project Grant Funds Allocated for Permanent Laboratory Equipment, 1966-74



(a) Includes the National Cancer Institute, the National Institute of General Medical Sciences and the National Heart and Lung Institute.

SOURCE: National Science Foundation and National Institutes of Health.

---

[14] Special analysis prepared from *An Analysis of Federal R&D Funding by Function,* National Science Foundation, (NSF 74-313).

[15] Comparable data are not available for the National Institutes of Health.

The R&D programs in the largest of these areas are described below in abbreviated form.

(1) **Health,** which consists of the subfunctions of *biomedical research, mental health, delivery of health care,* and *drug prevention and rehabilitation. Biomedical research,* which accounts for some 90 percent of all Federal obligations for health-related R&D, includes activities of the nine National Institutes of Health which deal with specific chronic and communicable diseases as well as general medical sciences. Among these institutes, the cancer, heart and lung, and child health and development research programs have grown the most rapidly in recent years. The second category, *mental health,* falls entirely within the purview of the National Institute of Mental Health within HEW's Alcohol, Drug Abuse, and Mental Health Administration. This activity received about five percent of the 1974 Federal obligations for health-related R&D. *Delivery of health care* is composed of a number of HEW programs with widely different missions including the health services research and evaluation program, the Center for Disease Control, the maternal and child health services program, and the National Health Statistics program. The last category of health-related activities is *drug prevention and rehabilitation,* which includes the drug abuse and alcoholism research activities of HEW, the drug abuse program of the VA, and the Special Action Office for Drug Abuse and Prevention.

(2) **Environment,** which encompasses three areas: *pollution control and abatement* programs of the Environmental Protection Agency (EPA), the Atomic Energy Commission (AEC), and the Department of Transportation (DOT); research aimed at *understanding, describing, and predicting the environment* supported by the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the National Oceanic and Atmospheric Administration (NOAA); and *environmental health* programs within the AEC, the EPA, the Bureau of Mines of the Department of the Interior, the National Institute of Environmental Health Sciences, the National Institute for Occupational Safety and Health, and the Food and Drug Administration.

(3) **Transportation and Communication,** which consists of R&D in *air, ground, water, and multimodal transportation* along with *communications*-related R&D. *Air transportation* R&D is composed of NASA's aeronautical research and technology program, and R&D supported by the Federal Aviation Administration and the Civil Aeronautics Board. *Ground transportation* R&D includes the R&D efforts of the following DOT programs—the Urban Mass Transportation Administration, the National Highway Safety Administration, and the Federal Railroad Administration. R&D in *water* and *multimodal transportation* includes programs of the Maritime Commission, the U.S. Coast Guard, and the Office of the Secretary of DOT. The *communications* subfunction is composed for the most part of NASA's communications satellite program.

(4) **Science and Technology Base,** which is aimed at expanding and strengthening the Nation's scientific base, is for the most part considered to be untargeted research. Over three-fourths of this function is accounted for by NSF's Scientific Research Project Support Program and AEC's Physical Research Program. Also included in this function are NSF's National Research Centers, the Smithsonians's Basic Research Program, and the National Bureau of Standards (NBS) National Physical Measurement System.

(5) **Natural Resources,** includes R&D activities aimed at improving the utilization of the Nation's *food, mineral, water, land, and recreation resources.* The major programs under *food resources* are the Department of Agriculture's (USDA) research into the production, marketing and use of agricultural products, and NOAA's ocean fisheries and living marine resources program. The *mineral resources* category is composed of four Department of Interior programs including the areas of mining technology, geological and mineral resource surveys, and metallurgy research. R&D in *water resources* is concentrated in the Department of the Interior under the Geological Survey and the Office of Water Resources. The *land resources* category consists of 10 relatively small programs; the largest two are the timber management research and the forest insect and disease research, both of the USDA. The *recreation resources* subfunction is composed of two Department of Interior programs—wildlife resources management

small craft, and military astronautics. The first subfunction, *missiles and related equipment*, includes efforts related to advanced ICBM's, the Trident submarine-based missiles, and the Safeguard antiballistic missile system. *Aircraft and related equipment* represents work related to the B-1 advanced strategic bomber, the EF-111A electronic warfare support aircraft, the CH-53E helicopter, the A-10 close air support aircraft, the V/STOL aircraft, the F-15 air superiority fighter and the F-14 interceptor aircraft. Two Atomic Energy Commission (AEC) programs make up the *atomic energy* subfunction: weapons R&D and testing activities, and naval reactor development. *Ships, small craft, and related equipment* includes work on the amphibious assault landing craft, the Trident submarine, a prototype surface effects ship, and the patrol hydrofoil missile craft. The *military astronautics* subfunction includes such programs as the NAVSTAR global positioning system, the close air support weapon system, the precision location strike system, and the planning efforts related to using the NASA space shuttle for launching military payloads. The remainder of military R&D obligations are spread across the areas of ordnance, combat vehicles, military sciences, other military R&D, other equipment, and program-wide management and support.

Space Exploration. The principal programs, in terms of magnitude of 1974 obligations, were *manned space flight, space sciences, space technology, and supporting space activities.* The main focus of the *manned space program* is the space shuttle, and the Apollo-Soyuz Test Project to rendezvous and dock U.S. and U.S.S.R. spacecraft. Within the *space sciences*, the lunar and planetary program represents the largest activity, followed by the physics and astronomy program, and the launch vehicle support program. *Space technology* consists of materials and structure research, development of guidance control systems, and development of information processing systems. Propulsion systems technology, both chemical and electric, is also part of this subfunction. *Supporting space activities* are related to operations of tracking and data acquisition networks, and improvement of the capabilities of specialized ground equipment.

Civilian R&D. The distribution of Federal R&D obligations among the various civilian areas, as well as funds for defense and space, is shown in figure 2-10 for the years 1969 and 1974. The relatively rapid growth in R&D obligations to the civilian sector—up from $3,556 million in 1969 to $6,055 million in 1974—is due primarily to increased spending in the health and environmental areas, the first area accounting for 39 percent and the latter 17 percent of the total growth in the civilian sector. The several areas comprising this sector are listed in the following table, along with the proportion of funds going to each.

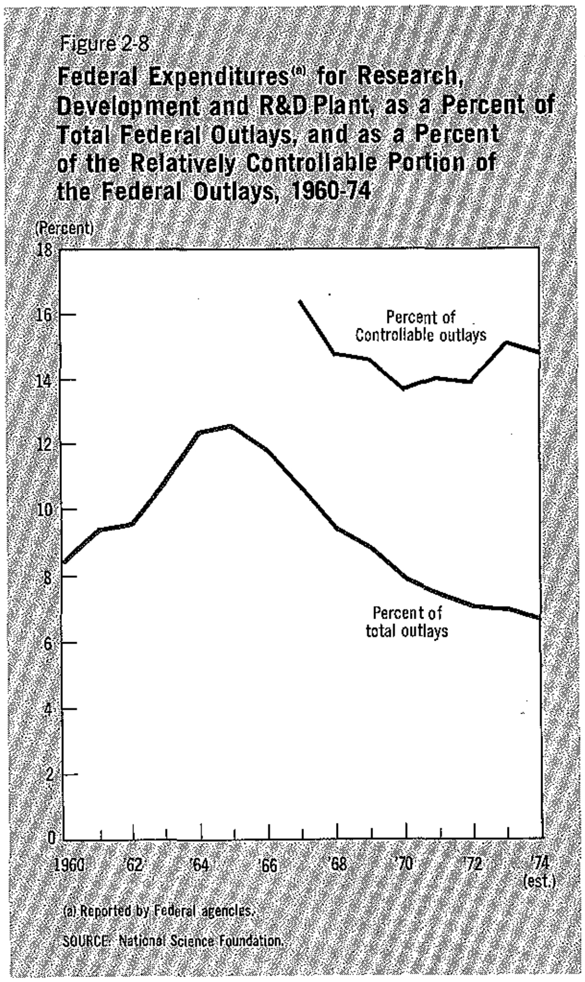
Distribution of Federal R&D obligations among civilian areas, 1974

Areas	Percent of total R&D	Percent of civilian R&D
Health	11.7	34.4
Environment	4.2	12.2
Transportation and communication	3.9	11.4
Science and technology base	3.6	10.7
Natural resources	3.6	10.4
Energy development and conversion	3.2	9.5
Education	1.3	3.8
Income security and social services	.7	2.2
Area and community development & housing	.7	2.1
Economic growth and productivity	.7	1.9
Crime prevention and control	.3	.9
International cooperation and development	.2	.6

budget, and the principal functional areas toward which R&D is directed.[8]

Total Federal outlays and R&D obligations

Federal expenditures for R&D (including R&D plant), as a percentage of total Federal outlays, declined appreciably after 1965, dropping from 13 percent of the total budget to 7 percent in 1974 (figure 2-8). This reduction results from a mixture of rapid growth in Federal outlays in areas which have small R&D expenditures (e.g., income security and social services), and diminished expenditures for space R&D.



Obligations for R&D may be viewed also in relationship to the controllable portion of the Federal budget. To an increasing degree, expansion of the Federal budget is due to "fixed cost and open ended" programs which increase by law, and are not established by the current budgetary action of either the legislative or the executive branches. These include various programs, such as income security, medical benefits, interest on Treasury bonds, and revenue sharing. When these programs are excluded, the remaining portion of the budget—the relatively controllable portion—is estimated to account for 46 percent ($125.4 billion) of the 1974 Federal budget obligations; in 1967 (the earliest year for which such data are available), the controllable fraction is estimated to have amounted to 65 percent of total obligations.[9] Federal funds for R&D represented 15 percent of the relatively controllable portion of the budget in 1974, down from 16 percent in 1967 but greater than the low of 14 percent in 1970 (figure 2-8).

Areas of Federally funded R&D

R&D funded by the Federal Government can be separated into three categories in terms of broad function: national defense, space exploration, and "civilian" areas (such as energy, the environment, and health). This division is shown in figure 2-9 for Federal obligations.[10]

The most salient aspects of the figure are: (a) the large fraction of total Federal R&D obligations for national defense (52 percent in 1974); (b) the rapid growth of R&D expenditures in civilian areas (up from 24 percent of all Federal R&D obligations in 1969[11] to 34 percent in

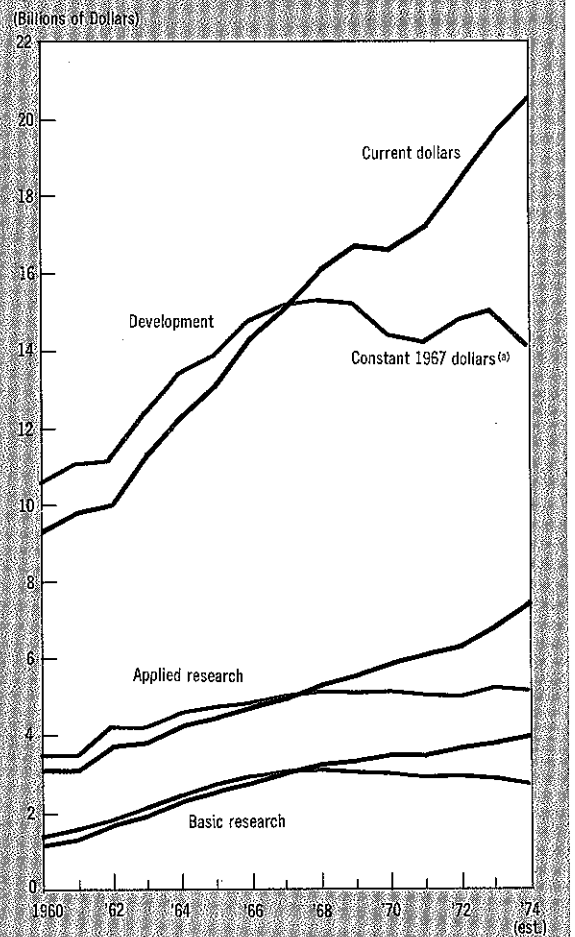
[8] Data are available regarding R&D by functional area only for Federal sources. The chapter titled "Industrial R&D and Innovation" discusses R&D expenditures by industries and by product fields.

[9] These estimates were obtained from *Federal Funds for Research, Development, and other Scientific Activities*, National Science Foundation, (NSF 74-320). The "relatively controllable" and "uncontrollable" components identified in the NSF report are identical, in concept and numerical value, to the "discretionary" and "mandatory" components defined in *Setting National Priorities—The 1975 Budget*, Brookings Institution, 1975.

[10] See the chapter in this report, entitled, "International Position of U.S. Science and Technology" for a comparison of the U.S. with other countries regarding the distribution of government R&D funds among areas of national goals.

[11] Comparable data are not available for years prior to 1969.

Figure 2-6
National R&D Expenditures by Character of Work, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
SOURCE: National Science Foundation.

percent lower in 1974 than in 1968, the year of highest funding. Constant dollar expenditures for applied research, on the other hand, were at their highest level in 1973, whereas spending for basic research in 1974 was 10 percent lower than its peak level of 1968.

Each component of R&D draws its funding from a different combination of sources which may change over time. Such a shift occurred in the funding of basic research during the 1960-74 period, with the industry role becoming smaller while the contributory roles of the Federal Government and universities and colleges increased. In 1974, the Government provided 68 percent of the basic research funds, compared with 59 percent in 1960; universities and colleges furnished 11 percent in 1974 and 6 percent in 1960, while industry supplied only 15 percent of the Nation's basic research expenditures in 1974 compared to 28 percent in 1960 (figure 2-7).

In current dollars, 1974 was the peak year for basic research funding from each source. The magnitude of support, however, was insufficient to maintain the level of effort of earlier years as measured by constant dollars. Federal funding in 1974 was down 13 percent from the 1968 high, industry support was 20 percent below its high of 1966, university expenditures were 10 percent lower than in 1972, and funding by nonprofit institutions was down 4 percent.

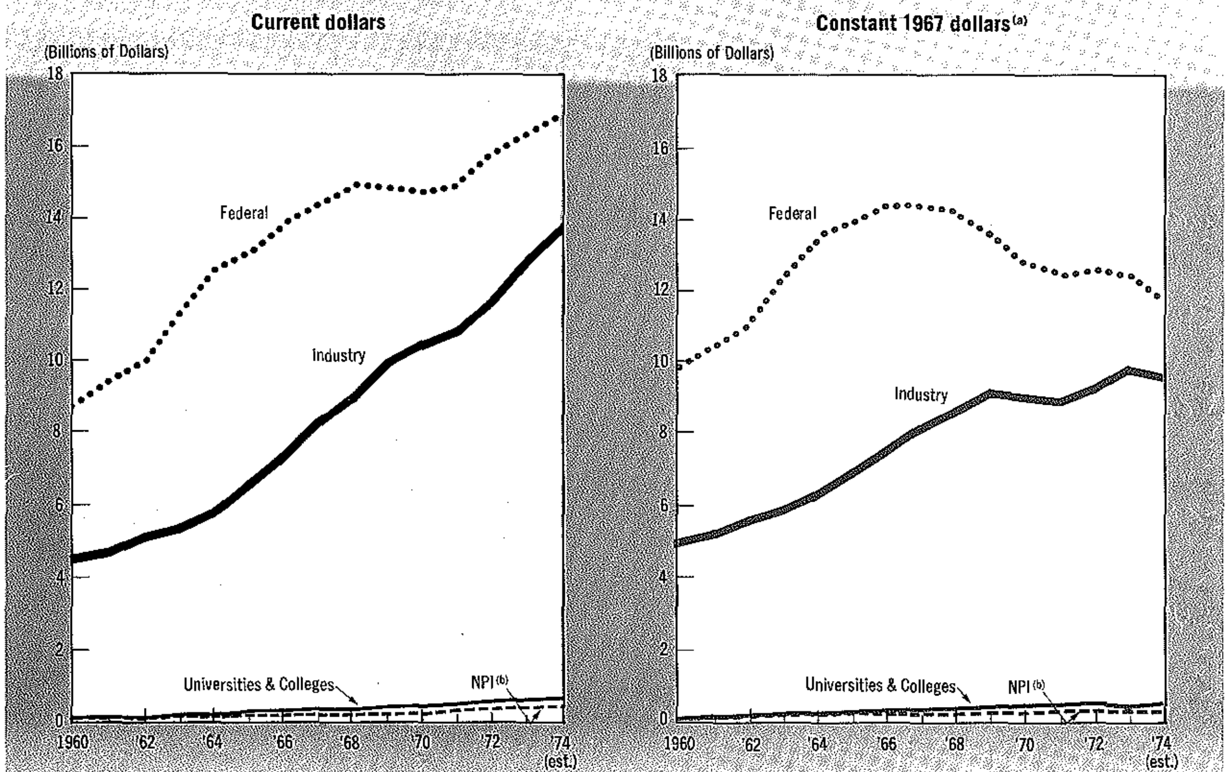
Applied research depends almost entirely on Government and industry support. Federal support in 1974 accounted for 54 percent of all such expenditures and industry for 41 percent. This pattern has been fairly consistent through the years. For each source of funds for applied research, the 1974 constant dollar expenditures were at or near their highest for the 1960-74 period.

Funding for development in 1974 was supplied equally by the Government and by industry, about 50 percent each, in contrast with 1960 when industry's contribution represented only 32 percent. In current dollars, development expenditures from the Federal Government reached a high in 1974, but in constant dollars were 25 percent below the 1966 peak year and approximately the same as in 1961. Industry support for development, on the other hand, has risen to the extent that the constant dollar high occurred in 1973, followed by a small decline in 1974.

FEDERALLY FUNDED R&D IN FUNCTIONAL AREAS

The financial resources provided by the Federal Government for R&D reflect the extent to which the Government depends upon R&D in pursuit of a range of national concerns—from such areas as defense, health, and energy to the expansion of basic scientific knowledge. These resources are described below in relationship to total Federal outlays, the R&D component of the "relatively controllable" portion of the Federal

Figure 2-4
National Expenditures for R&D, by Source, 1960-74



(a) GNP implicit price deflators used to convert current dollars to constant 1967 dollars.
(b) Nonprofit institutions.
SOURCE: National Science Foundation.

Expenditures by R&D-performing sectors

R&D expenditures have increased in all performing sectors without significant interruption from 1960 to 1974 (figure 2-5). However, in all sectors the constant dollar expenditures for 1974 were less than a peak year earlier in the period. The largest decline in constant dollars has been in industry where R&D expenditures in 1974 were 9 percent lower than in 1969, the year of peak spending, and comparable to the 1965-66 level.

Some changes have occurred within the national R&D total in the proportions accounted for by the four sectors. Industry's share, the largest, decreased from 78 percent in 1960 to 69 percent in 1974, even while total R&D spending by industry increased. The Federal intramural laboratories expended 15 percent of the total for 1974 compared to 13 percent in 1960. The university and college portion rose from 5 to 10 percent from 1960 to 1974, while their associated Federally Funded Research and Development Centers remained at about 2 percent.

Scientists and engineers in R&D-performing sectors

The number of scientists and engineers employed in R&D was lower in each sector in 1974 than in some previous year (figure 2-2). In general, the late 1960's were the years of highest R&D employment, corresponding to the years in which R&D funding in constant dollars was at its highest levels. Declines in subsequent years were largest in industry, where the number of scientists and engineers engaged in R&D in 1974

In this and subsequent chapters, data on R&D funding are presented in both current and constant 1967 dollars. The use of constant dollars is an attempt to reflect the reduction in the purchasing power of R&D resources which is caused by inflation, thereby providing a more accurate indication of the "real" level or magnitude of R&D funding and effort. Inflation in the economy at large has reduced the purchase value of the 1967 dollar to 69 cents in 1974, with the largest reductions occurring in the most recent years. In the absence of a price deflator specifically for R&D, the calendar year implicit price deflator for the gross national product (GNP) is used to convert current dollars to constant dollars; 1967 is chosen as the base or reference year, in keeping with Federal statistical standards. The GNP implicit price deflator, which applies to the economy as a whole, is necessarily general in scope and is only approximately appropriate for use in connection with R&D as a whole, or with specific R&D-performing sectors, types of costs, and fields of research. It is believed, however, that a uniform, though approximate, conversion method is preferable to various intuitive estimates of the effects of inflation on R&D.

The present indicators fall short of providing comprehensive and in-depth measures of trends in the allocation and use of resources for R&D. These shortcomings reflect both conceptual problems and data limitations. The indicators presented in this report do not include the full costs of R&D, and thus the magnitude of the R&D activity resulting from the investment of resources cannot be determined. The indicators, in addition, do not provide measures of the extent to which the resources engage the Nation's full R&D capacity. Furthermore, indicators have not been developed for gauging the general effectiveness with which the R&D resources are utilized, nor the efficiency with which these resources are translated into R&D activity. Another deficiency is the lack of indices of the quality of the resources which are directed to R&D, particularly the qualifications of the scientists and engineers involved and the adequacy of their research equipment and facilities. And finally, data and information are incomplete regarding the national purposes to which total R&D resources are directed; only in the case of Federal funding are R&D resources classified according to areas of national concern such as health, energy, and national defense.

NATIONAL RESOURCES FOR RESEARCH AND DEVELOPMENT

Trends in total national expenditures for research and development indicate an increasingly strong commitment from available funding resources; however the impact has been reduced by declining purchasing power due to inflation. Total expenditures in current dollars rose steadily from 1960-74 to $32 billion, almost two and one half times that for 1960 (figure 2-1). R&D funding, however, slowed concurrently with acceleration in inflation. As a result, 1968 was the peak year of total expenditures in constant dollars. Funding since then has been at a lower level; in 1974 the constant dollar total was $22.9 billion, 7 percent below the total for 1968.

The numbers of scientists and engineers employed in R&D rose and fell in close parallel with levels of constant dollar expenditures (figure 2-2), reaching a high of 558,000 in 1969. The subsequent decline occurred largely in the industry sector, as a result of reductions in Federal funding in defense and space programs.

The share of the Gross National Product represented by R&D has dropped continuously over the last 10 years (figure 2-3). From a high of 2.99 percent in 1964, it declined to 2.29 in 1974. R&D funds from the private sector, particularly industry, kept pace with the GNP throughout the 1960-74 period. The growth of Federal R&D funding, however, fell behind, and as a percentage of the GNP declined from 1.99 percent in 1964 to 1.22 percent in 1974.

Sources of support

The Federal Government has been the principal source of R&D funds throughout the 1960-74 period, although the proportion of its support within total R&D funding has declined. Federal support of R&D in 1974 in current dollars was almost double its 1960 support and 18 percent higher in constant dollars (figure 2-4). The peak year for Federal support of R&D in constant dollars was 1966, followed by a 19 percent decline by 1974. Industry-supported R&D expenditures, which together with Federal support accounted for 96 percent of total national R&D expenditures in 1974, were at their highest level in current dollars in 1974, and had diminished only slightly from the 1973 peak year in constant dollars.

Resources for Research and Development

INDICATOR HIGHLIGHTS

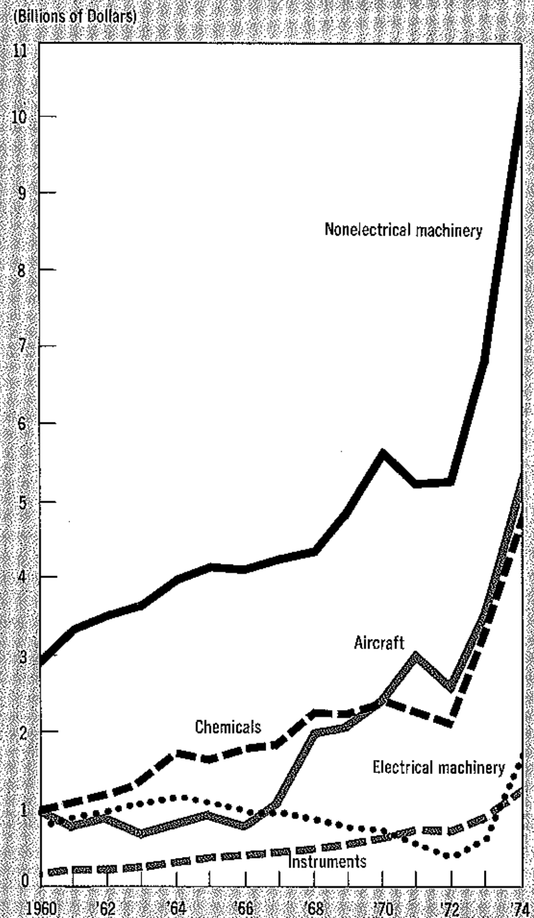
- National expenditures for research and development (R&D) in the United States increased in current dollars each year between 1960-74, reaching $32 billion in 1974; in constant dollars, however, expenditures remained at $22-23 billion between 1968 and 1974.
- The total number of (full-time equivalent) scientists and engineers engaged in R&D reached its highest level in 1969 (at 558,000) and declined to almost 528,000 in 1974; the decline is due largely to reductions of such personnel in industry as a result of cutbacks in Federal funds in the aerospace area.
- The fraction of the gross national product (GNP) going to R&D declined steadily from a high of nearly 3.0 percent in 1964 to a low of 2.3 percent in 1974; Federal funds for R&D, as a fraction of GNP, dropped from 2.0 to 1.2 percent between 1964 and 1974, whereas funds from all other sources combined remained at approximately 1.0 percent of GNP throughout the period.
- Federal funds for R&D increased in current dollars in all but two of the years between 1960-74, reaching their highest level of nearly $17 billion in 1974; funding in constant dollars, however, peaked in 1966 and was down by 19 percent in 1974 to less than $12 billion, which is equivalent to the funding level of 1963.
- R&D funds provided by industry rose more rapidly than those of the Federal Government during the 1960-74 period, reaching nearly $14 billion in current dollars in 1974; funds in constant dollars were at their highest level in 1973, some 2 percent above the level of 1974.
- The Federal Government and industry provided 96 percent of all the funds for R&D in 1974; the Federal share of the total declined from a high of 65 percent in 1965 to a low of 53 percent in 1974, while industry's share grew from 33 to 43 percent of the total.
- R&D expenditures increased in current dollars in all R&D-performing sectors[1] in recent years, whereas funds expended in constant dollars were lower in each sector in 1974 than in previous years; the largest constant dollar decline was in industry where expenditures in 1974 were 9 percent lower than in 1969, due largely to declines in Federal support for industrial R&D.
- The proportion of R&D funds allocated to different types of R&D activities—basic research, applied research, and development—has remained nearly constant since 1965, with development receiving 64 percent, applied research 23 percent, and basic research 13 percent.
- R&D funds provided by the Federal Government are a declining fraction of the total Federal budget, falling from a high of 13 percent in 1965 to 7 percent in 1974; as a fraction of the "relatively controllable" portion of the Federal budget,[2] R&D spending has changed little, at 15 percent in 1974 compared with a high of 16 percent in 1967 and a low of 14 percent in 1970.
- Federal funds for R&D go primarily to national defense, with "civilian"[3] areas and space exploration receiving the remainder; the proportion of total Federal R&D funds

[1] The sectors included are industry, Federal intramural laboratories, universities and colleges with their Federally Funded Research and Development Centers, and other nonprofit institutions.

[2] That part of the budget which is subject to annual appropriations, rather than determined by fixed costs and "open ended" programs whose funds increase by law.

[3] Includes areas such as health, energy, and the environment; see figure 2-10 for a listing of the areas.

Figure 1-20
U.S. Trade Balance in R&D-intensive Manufactured Products, by Product Group, 1960-74



SOURCE: U.S. Department of Commerce.

Professional and scientific instruments maintained a steady but small growth in net exports through 1974.

There have been substantial changes over the last decade in the mix of products underlying the favorable trade balance. Several products have become increasingly important to the maintenance of the positive trade balance in R&D-intensive products (including electronic computers, fertilizers, electronic tubes, transistors and semiconductor devices), while the contribution of other commodities (such as telecommunications apparatus) has led to a negative balance. This mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of the position, however, are partially explained by the "product cycle" concept.[45] Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and then becomes an importer as the production is standardized and moves abroad to minimize costs. This concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.

The favorable position of the United States in R&D-intensive products is based primarily on exports to developing nations, countries of Western Europe, and Canada.[46] The U.S. trade balance in these products is shown in figure 1-21 for selected areas and countries. In 1973, the developing nations accounted for 44 percent of the positive U.S. trade balance; nonelectrical machinery and chemicals were particularly large net export commodities for the United States in trade with these nations. In the case of trade with Western Europe, the United States had its largest net exports in the areas of aircraft and nonelectrical machinery (particularly in computers). U.S. net exports to Canada are concentrated in the areas of nonelectrical and electrical machinery.

A trade deficit in R&D-intensive products developed with Japan in the mid-1960's and persisted through 1974. This deficit occurred primarily in electrical machinery products (particularly consumer electronics) and to a lesser degree in professional and scientific instruments and nonelectrical machinery. Only in the areas of chemicals and aircraft does the

[45] Raymond Vernon, "International Investment and International Trade in the Product Cycle", *Quarterly Journal of Economics*, Vol. 80, May 1966.

[46] For a more complete discussion of these relationships see Keith Pavitt, " 'International' Technology and the U.S. Economy: Is there a Problem?" in *The Effects of International Technology Transfers on U.S. Economy*, National Science Foundation, Papers and Proceedings of a Colloquium (NSF 74-21).

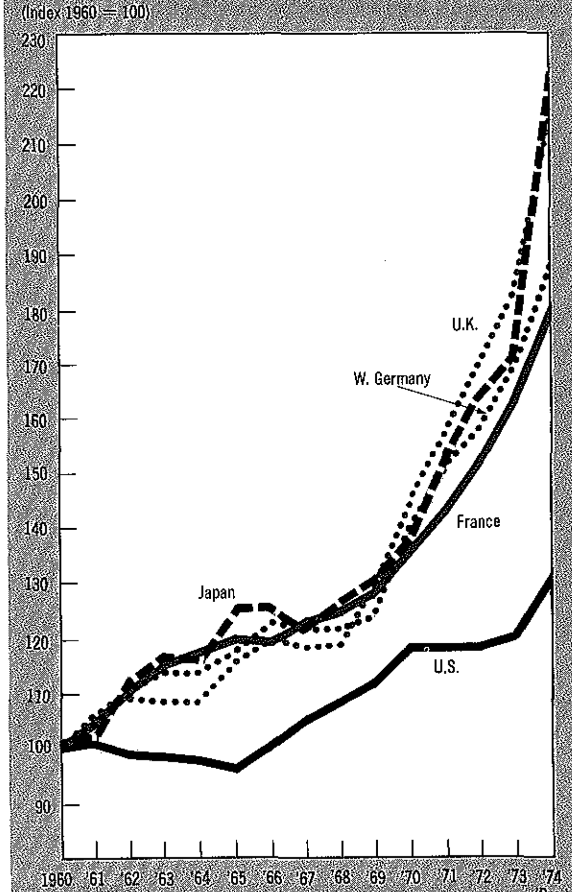
and nearly five times less than increases in Japan, which recorded the largest gains. However, starting from a relatively high level of productivity in 1960, the United States might not be expected to sustain the same high proportional gains as countries starting from a lower productivity base.

The effectiveness of a nation's productivity level is perhaps best indicated by the measure of "unit labor cost" (i.e., hourly labor costs divided by output per man-hour). If gains in productivity exceed increases in the cost of labor, then unit labor costs drop, products can be produced at less cost, and sold at lower prices, placing a nation in a favorable competitive position in the international market.[39]

Trends in this index for manufacturing industries are shown for the five countries in figure 1-18. It can be seen that productivity gains in the U.S. were sufficient to offset increases in labor cost from 1960 through 1965 and again from 1970 through 1973. Productivity rises in 1974 were negligible, however, while hourly labor costs had the largest yearly gain of the entire period. As a result, unit labor costs in manufacturing industries rose more rapidly than in any other year since World War II.

Gains in hourly compensation in 1974 exceeded advances in productivity in other countries also, and by even wider margins than in the United States. Thus, unit labor costs increased to an even greater extent in foreign manufacturing. The 1973-74 increase in Japan was nearly 30 percent and in the United Kingdom nearly 20 percent, both of which were the largest year-to-year gains in unit labor costs experienced by these countries during the 1960-74 period.

Figure 1-18
Unit labor cost[1] in Manufacturing Industries, by Selected Countries, 1960-74



[1] In national currency unadjusted for inflation.
SOURCE: U.S. Department of Labor.

Balance of trade in R&D-intensive products

The U.S. position in world trade depends upon a variety of factors, including the price of its products, the effectiveness of its international marketing, trading arrangements with other countries, and its performance in technological innovation. Such innovation, as discussed elsewhere in this report, depends significantly upon research and development.

The precise role of R&D and technological innovation in U.S. trade have not been determined, although recent studies suggest that it is substantial.[40] Some indication of this is provided by analyzing the U.S. trade balance in terms of the products involved, with the latter classified according to the relative level of R&D investment of the industries which produce the products. For this purpose, products from industries[41] with (a) 25 or more scientists and

[39] For a discussion of recent trends in these factors, see Patricia Capdevielle and Arthur Neef, "Productivity and Unit Labor Costs in the United States and Abroad", *Monthly Labor Review*, July 1975; for a detailed analysis of the role of these factors in international trade, see *Competitiveness of U.S. Industries*, United States Tariff Commission, 1972.

[40] Raymond Vernon (ed.), *The Technology Factor in International Trade*, (New York: Columbia University Press, 1970).

[41] Only manufacturing industries (which account for nearly all industrial expenditures for R&D) are included in the analysis.

Figure 1-15a

U.S. Receipts and Payments for Patents, Manufacturing Rights, Licenses, Etc., 1960-74

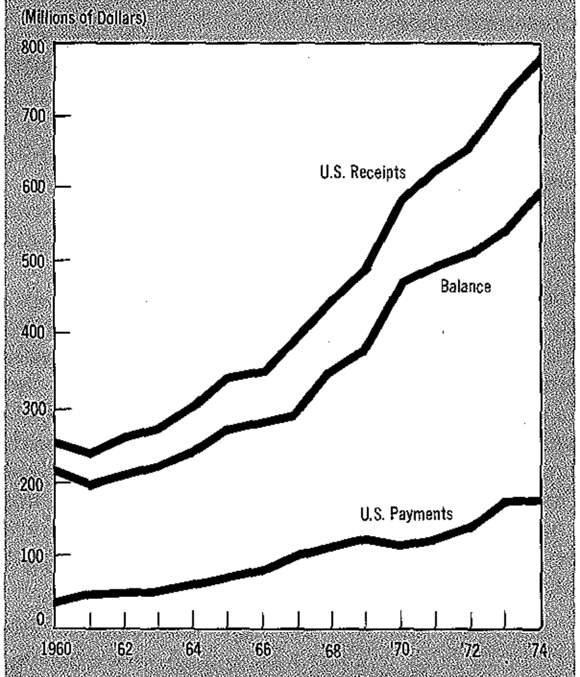
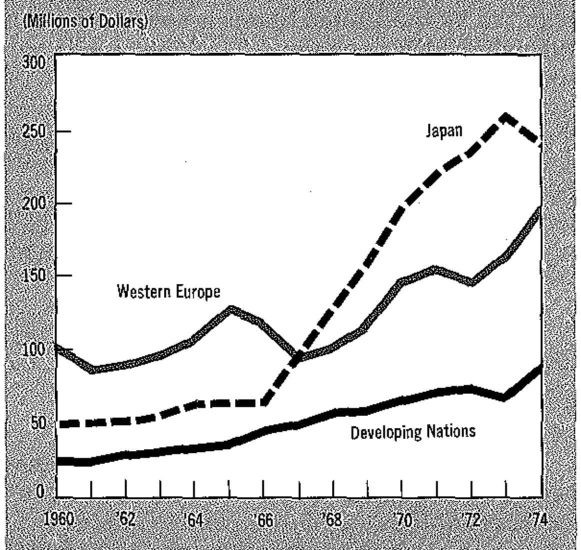


Figure 1-15b

U.S. Net Receipts for Patents, Manufacturing Rights, Licenses, Etc., by Selected Countries, 1960-74



SOURCE: U.S. Department of Commerce

productivity (i.e., Gross Domestic Product per employed civilian) and growth in manufacturing productivity (i.e., output per man-hour) are presented for each major developed country. An approximate indicator of the role of R&D in the U.S. trade balance is developed through an analysis of U.S. exports and imports of manufactured products, in terms of the R&D intensity of the products involved. The indicator is used also to determine the balance of trade in R&D-intensive products between the United States and other specific nations.

Productivity

The level of productivity and its rate of growth can greatly influence the economic strength of nations and affect living standards, costs and prices, and international trading and monetary arrangements—as shown by the experience of many countries in recent years.[37] Productivity expresses the relationship between the quantity of goods and services produced (output) and the quantity of labor, capital, land, energy, and other resources (input) used to produce them. Over time, productivity tends to grow as new knowledge and new technology are embodied in capital investments, as the educational levels of labor forces rise, and as management skills become more effective. While the effect of R&D on productivity growth is not known precisely, the general conclusion based on a large number of studies is that the impact of R&D is "positive, significant, and high".[38]

The measurement of productivity is difficult, particularly when measures are sought for the purpose of international comparisons. Problems arise from a diversity of sources, such as differences in concept and methodology and the availability of data. For these reasons, small reported differences in productivity—between nations and over short periods—may not be significant; interpretation of the indicators, therefore, should be confined to general trends.

A relatively general and approximate measure of productivity is the "real Gross Domestic

[37] Information on the role of productivity in the international area may be found in *Productivity: An International Perspective*, U.S. Department of Labor, Bureau of Labor Statistics, 1974.

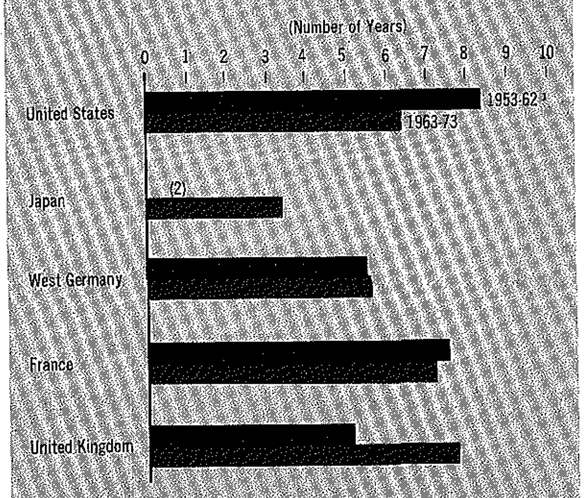
[38] *Research and Development and Economic Growth/Productivity*, Papers and Proceedings of a colloquium, National Science Foundation (NSF 72-303). For a discussion of this relationship, see the chapter entitled, "Industrial R&D and Innovation" in this report.

allied products, machinery, and professional and scientific instruments. In the United Kingdom, aircraft was the principal area in which the innovations were found, whereas those of West Germany were primarily in machinery. Innovations originating in Japan were most often in primary metals or in the broad area of electrical equipment and communication. French innovations were least concentrated, tending to occur in a variety of areas.

Invention and innovation. The inventions (i.e., the first conception of the innovations) originate, for the most part, in the same country as the innovation; 91 percent of all the innovations included in this study were based on domestic inventions. The proportion of each country's innovations which resulted from its own inventions ranged from a high of 100 percent in France to a low of 79 percent for West Germany, with the United States at 93 percent.

The time between invention and innovation ranged from less than one year to 81 years among the present set of major new products and processes. The mean numbers of years in the invention-innovation interval are shown in figure 1-13 for the various countries. (It should be noted that the date of invention is often difficult to determine precisely).

Figure 1-13
Interval Between Invention and Innovation, for Selected Countries, 1953-73



[1] Refers to the date of the innovation.
[2] Sample size does not allow calculation of the time interval.
SOURCE: Gellman Research Associates, Inc.

In the most recent period, 1963-73, Japan had the shortest period between invention and market introduction (3.6 years), followed by West Germany (5.6 years), the United States (6.4 years), France (7.3 years), and the United Kingdom (7.5 years).

"Radicalness" of the innovations. Innovations may embody technologies which range from imitations of existing technologies to radical breakthroughs. To investigate this aspect, each innovation was classified by the innovating company into one of the following five categories: "no new knowledge required", "imitation of existing technology", "improvement of existing technology", "major technological advance", and "radical breakthrough". Only 22 of the 369 innovations for which such data were acquired were assigned to the first two categories; these innovations are excluded from the following analysis. The distribution of the remaining innovations among the other three categories is presented in figure 1-14.

The largest proportion of innovations in the five countries combined were classified as major technological advances (37 percent), followed by improvements in existing technology (35 percent), and radical breakthroughs (29 percent). The innovations originating in the United States were a relatively balanced mix of the three types, whereas innovations of the United Kingdom were most often characterized as radical breakthroughs. France, West Germany, and Japan were similar in that their innovations were most often considered to be major technological advances.

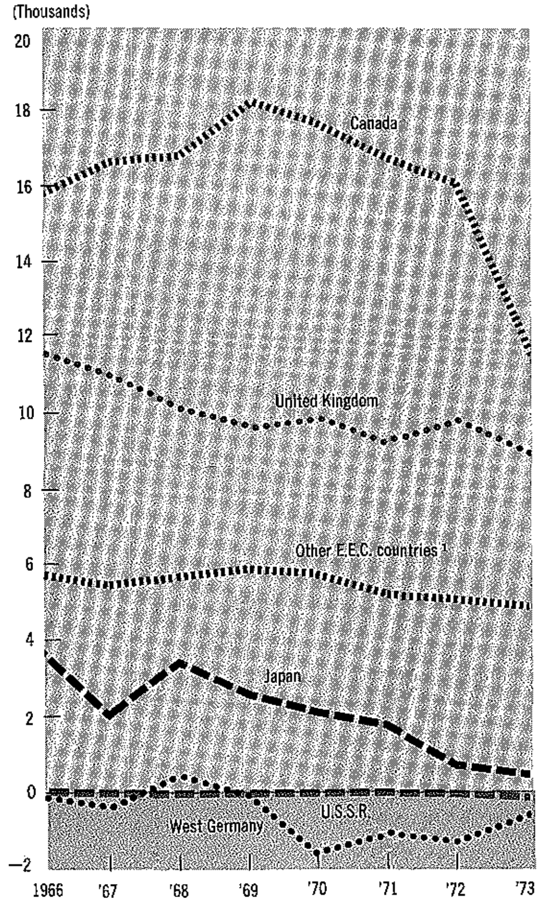
These indicators are particularly inexact for all countries other than the United States because of the small number of innovations involved. Furthermore, only the U.S. innovations were numerous enough to permit the determination of trends, which indicate that the percentage of radical innovations declined nearly 50 percent between the 1953-59 and 1967-73 periods, while those representing major technological advances doubled. The decline in radical innovations was due to a smaller number of such innovations from the electrical equipment and communication, and the machinery industries.

Technical "know-how"

The extent to which nations purchase the technical "know-how" (e.g., patents, licenses,

Figure 1-11

U.S. Patent Balance with Selected Countries, 1966-73



[1] Other European Economic Community (E.E.C.) countries include Belgium, Denmark, Ireland, Luxembourg, and the Netherlands. Data are not available for Italy, and are not reliable for France for use in this study.
SOURCE: World Intellectual Property Organization.

International trends in technological innovation

Technological innovation is a complex process culminating in the introduction of new and improved products and processes. Several steps are involved in bringing a new product into the market, including successful research and development which provide the technical and engineering foundation for innovation. Technological innovation is, in turn, one of the more important factors in determining the productivity, economic growth, and international position of developed nations.[30]

The indicators presented here concerning international trends in technological innovation are based upon a study conducted specifically for this report. The study investigated 500 major technological innovations (i.e., new products or processes embodying a significant technological change) which were introduced into the commercial market[31] between 1953-73. The 500 innovations studied were those receiving the highest ratings among 1,300 major innovations produced by Canada, France, Japan, the United Kingdom, the United States[32] and West Germany. An international panel of experts rated the innovations based on their technological, economic, and social importance.[33]

The present indicators should be interpreted with their several limitations in mind. The number of innovations on which the indicators are based is relatively small, particularly for countries other than the United States, with the result that the national trends presented are somewhat tenuous. Furthermore, only the most important innovations are represented by the indicators, even though the more numerous innovations of a less significant nature may have a greater overall impact. Moreover, the measures do not go beyond the initial introduction of the innovations into the market and, thus, do not include information on factors such as the economic benefits accrued by the innovating nations nor the international diffusion of the innovations. Finally, the indicators do not account for the negative impacts—such as job displacement, environmental pollution, or in-

[30] For further discussion of these relationships see: *The Conditions for Success in Technological Innovation*, Organisation for Economic Co-operation and Development, 1971, and Robert Gilpin, *Technology, Economic Growth, and International Competitiveness*, U.S. Congress, Joint Economic Committee, 94th Congress, 2nd Session, 1975.

[31] Some innovations were brought into the commercial market after having been first introduced in the government market.

[32] The U.S. innovations are more fully analyzed in the "Industrial R&D and Innovation" chapter of this report.

[33] For further information on the methodology and results of the study see *Indicators of International Trends in Technological Innovation*, Gellman Research Associates, Inc., 1975. (A study commissioned specifically for this report). Other topics investigated in the study but not discussed here include: the characteristics of the innovating companies, the role of basic and applied research in the development of each innovation, and the utilization of patents and licensing in acquiring the technology associated with each innovation.

TECHNOLOGICAL INVENTION AND INNOVATION

This section presents indicators of international trends in technological invention and innovation, as well as transactions in technology involving the United States. Indicators of inventions are based upon patent awards in the United States and abroad, and include the identification of areas of technology in which recent patenting activity by foreign countries in the United States was especially high. Innovation indicators are based on major new products of a technological nature, and include trends in the proportion of such innovations produced by each major nation, the time between invention and market introduction, and the "radicalness" of the innovations. Transactions in technology, measured in terms of international sales of technical "know-how", are used as an approximate indicator of the relative state of U.S. technology.

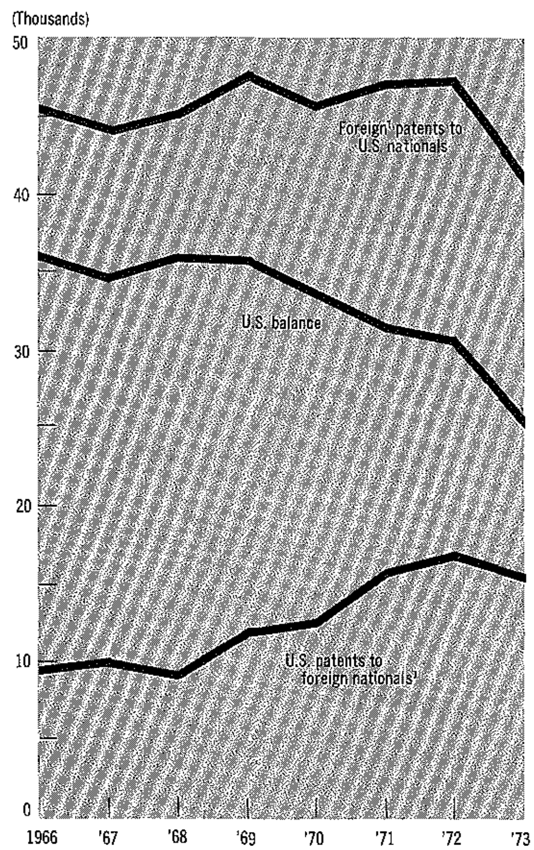
The "patent balance"

Inventions of new and improved products and processes may represent actual or potential advances in technology. Those inventions which are of sufficient originality to be patented provide a basis for indicators of the inventive output of countries. The use of patent statistics for this purpose, however, has several limitations. Some inventions—even major ones—are not patented. And those which are patented vary greatly in their technical and economic significance, with only a small proportion of the total number of inventions ultimately reaching the market. In addition, the criteria for awarding patents differ from country to country; not only does the rigor of tests for originality vary, but so does the extent of protection afforded by patents. The latter factors determine the relative ease and value of obtaining patents in different countries.

The number of patents granted in individual countries is not an adequate measure of inventiveness for purposes of international comparisons. A more meaningful measure relates the number of patents granted to nationals with those granted to foreigners in each country. Such an index[26] reflects the relative success of countries producing inventions of sufficient potential significance to warrant international patent protection. Since it is generally more costly to obtain such protection, the index tends to focus on those inventions which are thought to be most important.

Figure 1-10 presents the total number of patents granted to U.S. nationals by ten countries (Canada, West Germany, Japan, U.S.S.R., United Kingdom, and five other European Economic Community countries, including Belgium, Denmark, Ireland, Luxembourg, and the Netherlands); the number granted to nationals of these countries by the United

Figure 1-10
Patents Granted to U.S. Nationals by Foreign Countries and to Foreign Nationals by the United States, 1966-73



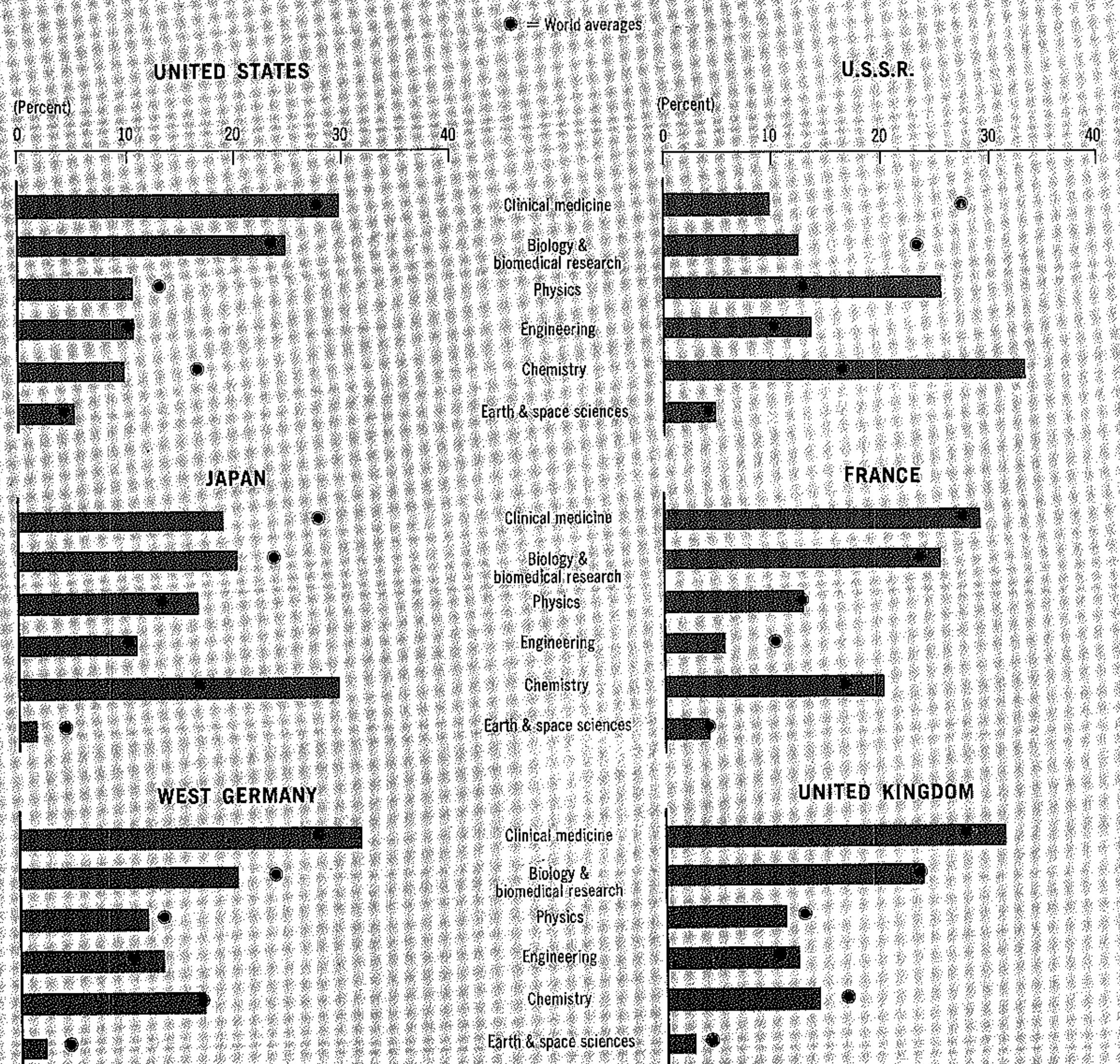
[1] Including Canada, West Germany, Japan, United Kingdom, U.S.S.R., Belgium, Denmark, Ireland, Luxembourg, and the Netherlands.
SOURCE: World Intellectual Property Organization.

[26] When applied to the United States, the index is the number of patents granted to U.S. nationals by foreign countries minus the number of patents granted to foreign nationals by the United States.

The number of awards in individual fields of science are presented in figure 1-9. Over the 1901-74 period as a whole, the United States has the largest total number of awards in physics and in physiology/medicine, and is surpassed only by Germany in the number of prizes received in chemistry. In the most recent period, 1971-74, the United States received 56 percent of the awards in physics, 57 percent of those in chemistry, and 44 percent of those in physiology/medicine. These represent a smaller fraction of the prizes in each category than was received by the United States in the 1951-60 period.

Figure 1-7

Percent Distribution of Scientific Literature[1] by Selected Field,[2] for Each Country, 1973



[1] Includes articles, letters and notes from a sample of 2,121 journals.
[2] The social sciences are excluded because comparable data were not available.
SOURCE: Computer Horizons, Inc.

publications in each field provides an approximate profile of a country's research effort. These 1973 profiles, based on the 278,894 *S.C.I.* publications in seven fields,[19] are shown in figure 1-7.[20] For purposes of comparison, the profile of publications produced by all countries combined is shown also.

The 1973 profile of the United States was most similar to that of West Germany and the United Kingdom in the relative proportion of the total literature in each field, although chemistry was emphasized somewhat more by the latter two countries. The profile of France's scientific research also resembles the United States, except for a smaller proportion of engineering research on the part of France and a larger fraction of literature in chemistry.

The country with the profile which differs most from that of the United States in the literature studied appears to be the U.S.S.R. The life sciences (biology, biomedical research, and clinical medicine) represent nearly 55 percent of the U.S. literature compared with just over 20 percent of the Soviet scientific and technical literature; conversely, engineering and the physical sciences (chemistry and physics) account for some 20 percent of the U.S. literature whereas the U.S.S.R. published almost 60 percent of its literature in these fields.

Literature citations. The significance of a nation's scientific literature is more important than mere counts of publications. One indicator of quality is the recognition that the research reported was dependent on published accounts of earlier investigations. Such a "citation index" is based on the belief that the most significant literature will be more frequently cited. In support of this assumption are a number of studies which demonstrate high correlations between citation counts and other measures of scientific importance, such as judgments of researchers in the field.[21]

The quality of scientific research is far more difficult to measure than its quantity. The use of citation indicators is one such approach, but one which requires considerable caution. Some articles may fail to be noticed because scientists do not have access to them, although this characteristic of the availability of a nation's scientific literature is itself an important aspect of the internationalism of science. Articles may be heavily cited only for the criticisms they provoke, or because they deal with minor improvements in methodology. Authors in some countries may cite only a few outstanding references for reasons such as journal space limitations, while similar scientists in other countries may give more complete citations. The particular choice of a sample of journals to be examined can have an effect on international comparisons if countries do not have appropriate representation in the sample. Because some nations concentrate more on applied research than on basic research, they may be underrepresented in the scientific literature.

The data source for this indicator was the *Science Citation Index*, as augmented for improved coverage of certain fields and countries, comprising 2,121 journals—virtually all of those included in the *S.C.I.* for 1973. The index was created by comparing the actual fraction of the world's total citations in a given field with the expected proportion based on that nation's share of the total publications in that field.

The resulting citation indices are shown in the table below for six fields. An index of 1.0 means that there were as many citations to a country's literature in the field as would be expected from its share of the world's publications; a larger index indicates a proportionally higher level of citation to the literature produced by a country than could be accounted for simply by the volume of its publications.

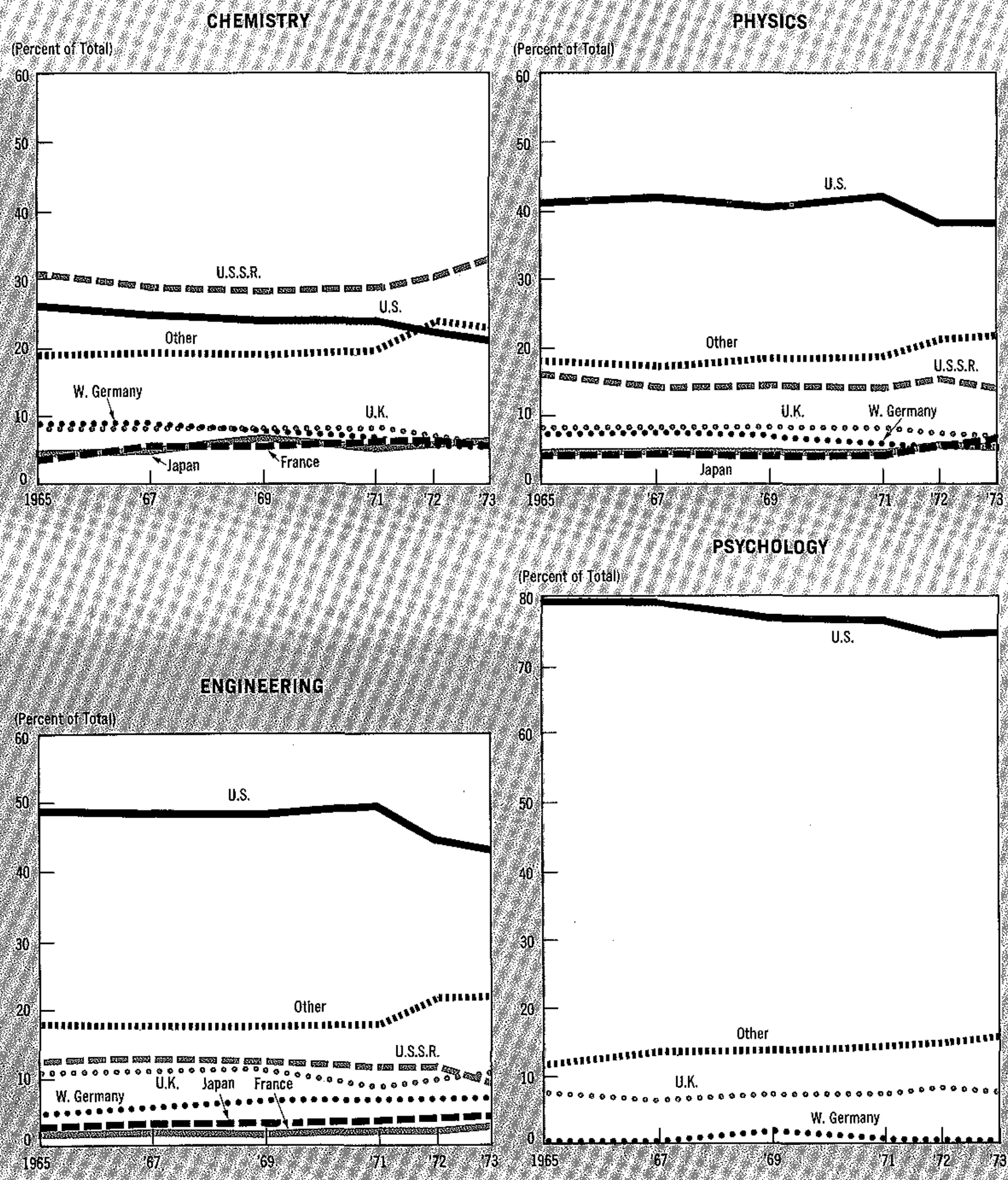
[19] These data employ a somewhat different taxonomy of fields of science than that used for the 492-journal set; see Appendix table 1-7a for the detailed taxonomy of the fields described in *Indicators of the Quantity and Quality of the Scientific Literature*, Computer Horizons, Inc., 1975.

[20] Because of the way this broad sample was selected, some fields may be understated, such as Russian mathematics. However, the scope of the *Science Citation Index* is determined by a 20-member, international editorial board consisting of two Soviet scientists; one is an expert in the information and documentation sciences area, the other is a mathematician. In recent years, the *Science Citation Index* has been expanded to include 90 percent of the 1,000 journals most highly cited by articles in some 2,100 journals and 100 percent of the 575 most highly cited.

[21] See "Citation Analysis: A New Tool for Science Administrators", *Science*, Vol. 188 (1975), pp. 429-432; Jonathan R. Cole and Stephen Cole, *Social Stratification in Science*, (Chicago: University of Chicago Press, 1973); Eugene Garfield, "Citation Analysis as a Tool in Journal Evaluation", *Science*, Vol. 178 (1972), pp. 471-478; J. Margolis, "Citation Indexing and Evaluation of Scientific Papers", *Science*, Vol. 155 (1967), pp. 1213-1219; and C. Roger Myers, "Journal Citations and Scientific Eminence in Contemporary Psychology", *American Psychologist*, Vol. 25 (1970), pp. 1041-1048.

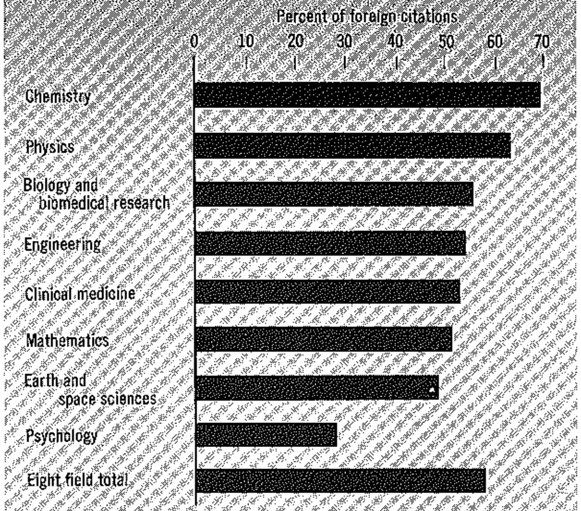
Figure 1-6

Scientific Literature[1] in Selected Fields[2] as a Percent of Total Literature, by Country, 1965-73



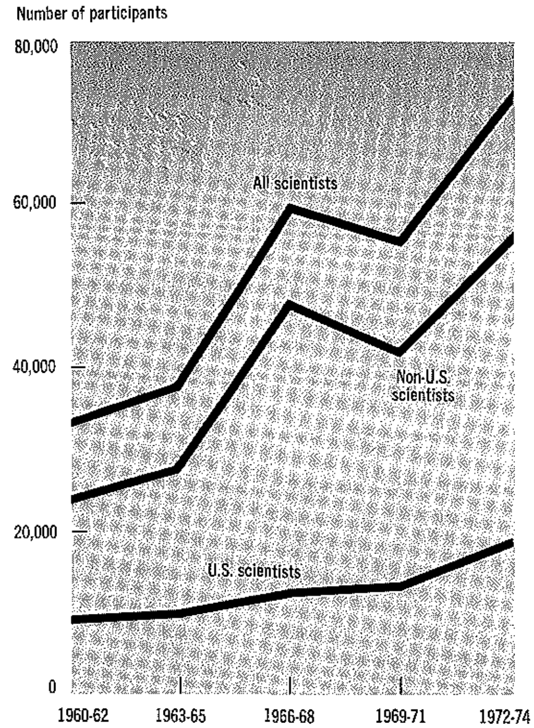
[1] Includes articles, letters and notes from the 492 scientific journals which were most heavily cited in 1965.
[2] The social sciences are excluded because comparable data were not available.
SOURCE: Computer Horizons, Inc.

Figure 1-4
Percent of the Citations in Scientific Literature[1] Citing Countries Other than the Author's Own Country, by Selected Fields,[2] 1973



[1] Based on articles in 2,121 journals in the 1973 Science Citation Index from the U.S., United Kingdom, West Germany, France, U.S.S.R., and Japan.
[2] See Appendix table 7a for the description of fields. The social sciences are excluded because comparable data are not available.
SOURCE: Computer Horizons, Inc.

Figure 1-5
Participation in International Scientific Congresses by the United States and Other Countries, 1960-74



SOURCE: National Academy of Sciences.

tions. The figure shows that almost 60 percent of all citations in the scientific literature of these countries, for the eight fields as a whole, were to research of foreign origin.

Participation in international congresses. International meetings provide opportunities for scientists to exchange information and ideas through personal contact with foreign researchers. Among these are the international scientific congresses of those organizations constituting the International Council of Scientific Unions.

The numbers of scientists from the United States and from other nations who have attended these congresses in recent years are shown in figure 1-5. Although the attendance of U.S. scientists has increased throughout the period, attendance of foreign scientists has grown even more rapidly. In the 1972-74 period, non-U.S. scientists represented 75 percent of all participants. (Peaks in the attendance patterns are due to the larger number of congresses held in certain years).

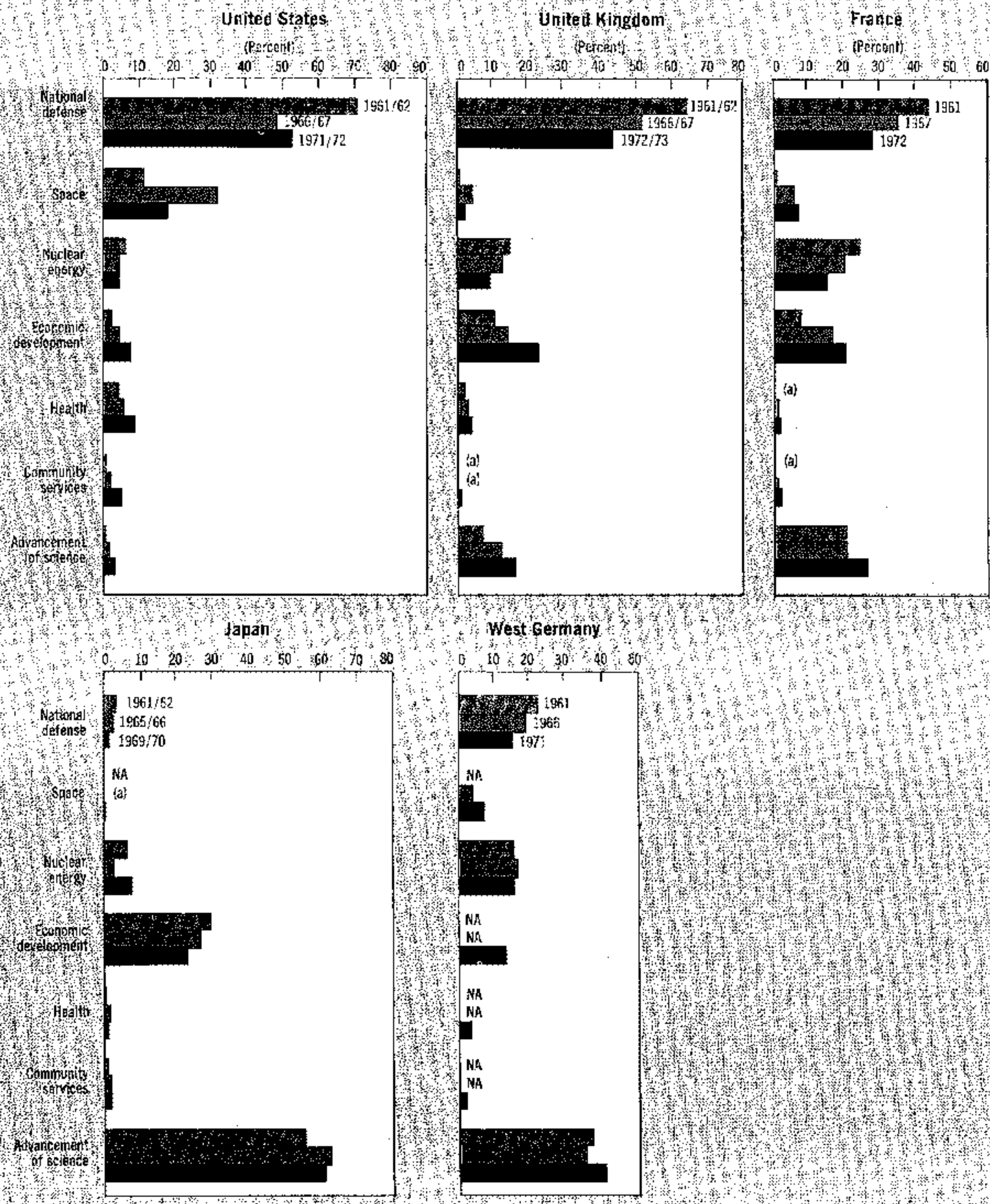
Scientific literature

Research reports published in scientific and technical journals are one of the more direct outputs of scientific effort.[11] Such reports add to the body of scientific knowledge and may stimulate further research. The findings of the research, in addition, may be used in a variety of practical applications, many of which are unanticipated at the time the research is done. Although the reports may vary considerably in their theoretical and practical importance, the critical review which usually precedes publica-

[11] For discussions of publications as measures of the output of science, see: G. Nigel Gilbert and Steve Woolgas, "The Quantitative Study of Science: An Examination of the Literature", *Science Studies* Vol. 4 (1974), pp. 279-294; Henry Menard, *Science: Growth and Change* (Cambridge: Harvard University Press, 1971); and Derek J. deSolla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963).

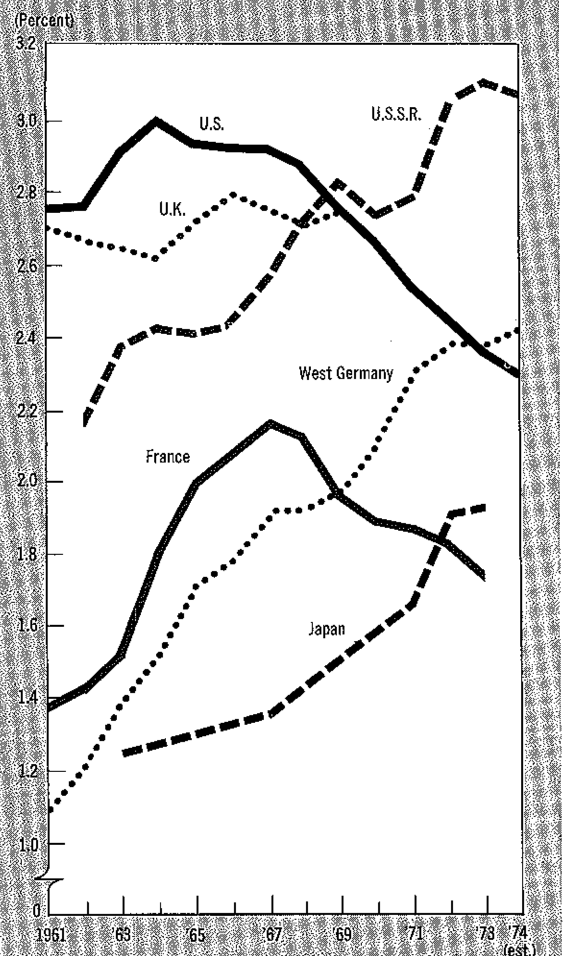
Figure 1-3

Distribution of Government R&D Expenditures among Areas by Country, 1961-73



(a) Less than 0.5 percent.
SOURCE: Organisation for Economic Co-operation and Development.

Figure 1-1
R&D Expenditures as a Percent of Gross National Product (GNP), by Country, 1961-74



SOURCE: Organisation for Economic Co-operation and Development; Individual country sources; U.S.S.R. estimates by Robert W. Campbell, Indiana University.

cost, and effectiveness of R&D—as well as inconsistencies in GNP accounting—the measure is relatively gross. Interpretations of the indicator, therefore, should focus on general trends rather than specific numerical values.

The fraction of the GNP of the United States devoted to R&D has declined steadily over the last 10 years, falling nearly one-fourth from its peak level in 1964. The decline, as discussed elsewhere in this report,[4] is due primarily to reduced growth of expenditures by the Federal Government for R&D in the defense and space areas; increases in R&D funds from all other sources combined kept pace with growth in the GNP. In the case of France, the only other country of those studied which showed a long-term decline in this indicator, the reduction appears to result largely from a slower growth in government R&D expenditures for national defense and nuclear energy.

Both Japan and West Germany recorded substantial growth in the proportion of the GNP directed to R&D. Underlying their growth were continuous large increases in R&D funding from both industry and government. Total R&D expenditures by Japan increased at an average annual rate of 21 percent between 1963 and 1973, and those of West Germany by 15 percent, as compared with 6 percent for the United States. More recently, annual increases between 1969-73 averaged 24 percent for Japan, 16 percent for West Germany, and 4 percent for the United States. While industry is the prime source of R&D funds in Japan and West Germany, funds provided by the government have grown relatively more than those from industry. Government funds for R&D in these two countries are concentrated on advancement of science and, to a lesser extent, on general economic growth and nuclear energy.[5]

For the U.S.S.R. this indicator is based upon limited information and should be regarded only as an estimate. The general upward trend in the proportion of the GNP devoted to R&D is believed to be valid, although the specific numerical values may differ significantly from the true values. Possible differences in the variety of activities regarded as R&D, as well as differences in GNP accounting, make international comparisons involving the U.S.S.R. particularly hazardous.

R&D Personnel

The human resources involved in R&D provide another comparison of the magnitude of national R&D efforts. The number of scientists

[4] See the chapter in this report entitled "Resources for R&D".

[5] Information on the distribution of government R&D expenditures among these and other areas is presented in a later section of this chapter.

International Indicators of Science and Technology

INDICATOR HIGHLIGHTS

- The proportion of the Gross National Product (GNP) spent for R&D has declined steadily over the last decade in the United States, while growing substantially in the U.S.S.R., West Germany, and Japan; in 1973, the fraction of GNP directed to R&D was 2.4 percent in the United States, compared with 3.1 percent for the U.S.S.R., 2.4 percent for West Germany, and 1.9 percent for Japan.[1]
- The number of scientists and engineers engaged in R&D per 10,000 population declined in the United States after 1969 but continued to grow in all other countries studied; by 1973, this number was 25 per 10,000 for the United States, 18 for West Germany, 19 for Japan (1971), and 37 for the U.S.S.R.[1]
- All major R&D-performing countries reduced their proportion of government R&D expenditures for national defense between 1961 and the early 1970's, while either maintaining or expanding expenditures for the advancement of science and economic development; the United States had the largest fraction of expenditures for national defense and the smallest for the latter two areas throughout the period. (Data for the U.S.S.R. are not available).
- The United States was the largest producer of the scientific literature sampled throughout the 1965-73 period in all fields except chemistry and mathematics, where its share was second to that of the U.S.S.R.; in recent years, however, U.S. research publications in the fields of chemistry, engineering, and physics have declined slightly in both absolute and relative terms.
- Citation indices of U.S. scientific research equal or exceed those of other major research-performing countries based on a large sample of the 1973 literature; the United States ranked highest in the fields of chemistry and physics.
- U.S. scientists have received a larger overall number of Nobel Prizes in the sciences (physics, chemistry, and physiology-medicine) than any other country; awards to U.S. scientists, however, declined after the 1951-60 decade, primarily as the result of fewer prizes for research in physics.
- The United States had a favorable but declining "patent balance" between 1966 and 1973; the decline of 30 percent was due primarily to increases in the number of patents awarded by the United States to Japan and West Germany, and to decreases in patents granted to the United States by Canada and the United Kingdom.
- A majority of a sample of major technological innovations of the past twenty years were produced by the United States; the proportion of innovations of U.S. origin, however, declined from a high of 80 percent in the late 1950's to some 55-60 percent since the mid-1960's, while other countries—particularly Japan and West Germany—increased their shares.
- The United States had an increasingly positive balance of payments from the sale of technical "know-how" (patents, licenses and manufacturing rights) over the 1960-73 period, with four to five times more technical "know-how" sold to other nations than purchased from them; the rising net receipts to the United States were due largely to purchases by Japan after the mid-1960's.
- The level of U.S. productivity (Gross Domestic Product per employed civilian)

---

[1] Data regarding the U.S.S.R. should be treated as gross estimates; limited information and differences in basic definitions make international comparisons involving the U.S.S.R. particularly tenuous. (See the following text for discussion of this point).

extending through 1974 where possible. Data which appeared in *Science Indicators—1972* for earlier years are repeated here to encourage longitudinal comparisons and to make it unnecessary to refer to the previous report. Most of the indicators are presented in graphical form and are numbered to correspond with the numerical data tables in the Appendix. Each of the chapters is introduced by an "Indicator Highlights" section which briefly summarizes the major indices of that chapter. It should be noted that these highlights often omit important caveats and discussion contained in the text itself. The original data sources, many of which are publications of the Division of Science Resources Studies, National Science Foundation, are indicated throughout the report. Staff of the Division also took part in the development of charts and text.

The challenge faced in creating and using indicators of complex social systems such as science and technology is substantial, and the present efforts to assess U.S. science are still only in the early stages of maturity. Appreciation is due to the Social Science Research Council which, with NSF support, convened a seminar in 1974 on science indicators and which has recently established a Subcommittee on Science Indicators. The reports to follow in this series will aim to sharpen concepts, refine their treatment, and seek new measures of the state of science. It is hoped that all those interested in science indicators will participate in the search.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $4.60
Stock Number 038-000-00253-8

NATIONAL SCIENCE BOARD
(as of 1975)

Science Indicators Unit