A Satellite Account for Research and Development

BEA has prepared a satellite account that arrays information about research and development (R&D). First, the satellite account provides estimates of expenditures on R&D that are designed to be used in conjunction with the national income and product accounts measures. Second, it treats R&D expenditures as a form of investment, recognizing the role R&D plays in adding to knowledge and in developing new and improved processes and products that lead to increases in productivity and growth. Third, it provides estimates of the stock of knowledge capital. To focus on R&D and facilitate its analysis, the satellite account changes some definitions and classifications used in the national income and product accounts but otherwise is designed to be consistent statistically and conceptually with those accounts. Thus, the satellite account supplements the existing accounts.

BEA's economic accounts have always benefited from discussion and critique of concepts, source data, and estimating methods. The same is to be expected for the R&D satellite account. Comments are welcome.

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IN INDUSTRIAL laboratories, agricultural experiment stations, medical research institutes, and a variety of other settings, the United States undertakes a sizable research and development (R&D) effort. This effort plays a critical role in economic growth and in addressing many specific related concerns. In the words of the National Science Board:

> The absolute magnitude of the [R&D] effort and the manifold tasks to which it is directed are indicative of the critical role that R&D plays in addressing such concerns as national defense, industrial competitiveness, public health, environmental quality, and social well-being. Indeed, the long-term importance of R&D expenditures to technological preeminence, military security, and knowledge growth is axiomatic.[1]

Ideally, to document this role within the economy and thus lay the foundation for policy and other decisions, one would measure the output of R&D—the new understanding, or the knowledge, it creates. However, measures of knowledge created, to the extent that they exist, do not share a common yardstick—such as dollars—with other measures with which they might be used. Almost universally then, analysts turn to expenditures on R&D as a starting point.

Several questions about expenditures on R&D immediately come to mind:

- How much is being spent on R&D today? How much has R&D spending grown in recent decades? How large is R&D compared with GDP in the United States? In other countries?
- Who is performing the R&D? What share is being performed by government, by nonprofit organizations, and by industries? Which industries perform the most R&D?
- Who is funding the R&D?

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1. National Science Board, National Science Foundation [39], page 89.

Expenditures on R&D can be viewed as generating future income and product. With this view, a case is made for treating them as investment, paralleling the treatment of business expenditures on structures and durable equipment, and for recognizing a stock of intangible capital, just as there is a stock of tangible capital. Further questions then arise:

- How large is the stock of R&D capital? How has the stock changed over recent decades?
- How does the stock of R&D capital compare with the stock of buildings, equipment, and other parts of the Nation's wealth?

Answers to these questions have been less than fully satisfactory. On the one hand, the national income and product accounts (NIPA's) might seem the obvious place to look for expenditure estimates: If R&D expenditure estimates were in the accounts, they could readily be compared with GDP or its components, and models could be constructed to relate changes in R&D to other parts of the economy represented in the accounts. However, only a portion of R&D expenditures are identifiable within the NIPA's, and those identified—as well as the unidentified—expenditures on R&D are treated as consumption rather than as investment. Further, because R&D expenditures are not treated as investment, there is no associated stock of capital.[2] On the other hand, R&D data from other sources are not fully consistent with the NIPA's and with the NIPA-based measures of tangible capital, so they cannot readily be used in conjunction with NIPA estimates in analysis.

This article introduces a satellite account that is designed to provide a view of R&D that has ties to the NIPA's, while also using alternative definitions and providing consistent detail that help to focus on the role of R&D in the economy. BEA began work on the satellite account for R&D in 1992, following a preliminary evaluation of the feasibility and usefulness of such an account.[3]

The estimates presented in the satellite account build on data published by the National Science Foundation (NSF), which assembles a wide range of information related to R&D.[4] The estimates extend through 1992, the most recent year for which complete source data are currently available.

The first section of the article defines R&D and describes its role in creating knowledge and then sketches the economic accounting background for the satellite account's investment treatment. The second section provides a methodological overview. The third section presents the estimates of R&D expenditures, investment, capital stocks, and related data. The fourth section discusses future directions that work on the satellite account might follow. A technical note at the end of the article details the construction of the estimates.

Background

R&D and knowledge

R&D is "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." This definition is from a newly revised manual (the *Frascati Manual*) of standard practice for surveys of R&D activity, prepared by the Organisation for Economic Co-operation and Development.[5] It is widely used internationally as the basis for R&D statistics, such as those compiled and analyzed by NSF in the United States.

More commonly, R&D is characterized as the sum of three types of activities—basic research, applied research, and development. These activities also have been defined in the *Frascati Manual*, although in practice it is often difficult—perhaps increasingly so—to establish the boundaries between them:

- Basic research is "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view."
- Applied research is "original investigation undertaken in order to acquire new knowledge . . . directed primarily towards a specific practical aim or objective."
- Development is "systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, to installing new processes, systems

2. In an integrated set of economic accounts, flows of fixed investment are viewed as forming stocks of reproducible capital. BEA however, estimates the stocks of consumer durables and of government equipment and structures *as if* personal consumption expenditures on durable goods and government purchases of durable goods and structures had been treated as fixed investment flows. Flows derived from the NIPA series are used to estimate the stocks, which are, therefore, consistent with the NIPA's.

3. For an early presentation about the preliminary work, see Carol Carson and Bruce Grimm [13].

4. See, for example, National Science Board, National Science Foundation [39].

5. See Organisation for Economic Co-operation and Development [43], page 29. This is the fifth edition of the Frascati Manual. The manual was first prepared in 1961.

and services, or to improving substantially those already produced or installed."[6]

R&D is to be distinguished from a wide range of related activities that are linked to R&D both through flows of information and in terms of operations, institutions, and personnel. The basic criterion, according to the *Frascati Manual*, to be used to distinguish R&D from related activities "is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty." R&D does not include, for example, the following: Routine activities (such as product testing, quality control, experimental production, routine software development, and monitoring and evaluation of operational programs), patent and license work, final product or design engineering and manufacturing start-up, and training of scientific and technical personnel.

R&D may be viewed as increasing the stock of knowledge that leads to improved understanding or to improved processes or products. Basic research creates a pool of knowledge that can be drawn upon for further basic research or for performing applied research.[7] Applied research draws upon both basic research and earlier applied research to create knowledge that can be used to develop new or improved processes and products. Development draws upon both applied research and earlier development. New or improved processes or products come into being only at the end of the development process. There are lags between the creation of knowledge, particularly that produced by basic research, and its effects on output. The lags reflect both the time needed for R&D to lead to improved processes and products and the time needed for the improved processes and products to be fully adopted throughout the economy.

Neither the creation of knowledge nor the resulting stock of knowledge are measurable directly. Measures of output, such as the number of scientific and technical journal articles published and the number of patents awarded, only roughly approximate the creation of knowledge because they only cover a portion of R&D and because many innovations are not patented. A frequently used method for measuring the output of knowledge is to equate that output with the expenditures required to produce it. Those expenditures can be cumulated over time—with or without depreciation—to measure the stock of knowledge.

R&D in economic accounting

R&D in standard economic accounts.—In accounting for a nation's production by adding up expenditures to derive gross domestic product (GDP), two main issues about the treatment of R&D arise:

- Are expenditures on R&D considered expenditures on final goods and services—that is, one of the products whose value is added up in deriving an unduplicated production total such as GDP?
- Even when the expenditures on R&D are considered expenditures on final goods and services, are they considered investment?

In the NIPA's, expenditures on R&D by business—whether actually purchased from others or carried out inhouse—are treated as intermediate rather than final; they are considered as a current expense of production and are not among the expenditures added up in deriving GDP. Treating them as a current expense follows general business accounting practice; the uncertainty about the future benefits of individual projects is a key argument for expensing R&D. Expenditures on R&D by government and by nonprofit institutions are treated as expenditures on final goods and services. All expenditures on R&D by government and nonprofit institutions are treated as part of consumption in the current period, the former as part of government purchases and the latter as part of personal consumption expenditures; none are treated as investment. In the NIPA's, investment—specifically gross private domestic investment—consists solely of purchases of structures, durable equipment, and change in inventories by the business sector. Expenditures by a U.S. resident for R&D performed abroad are treated as imports, and expenditures by a foreign resident for R&D performed in the United States are treated as exports. These points are summarized in table A, which also indicates that, with the exception of contractual R&D in Federal national defense purchases, R&D expenditures are not identified in GDP.

The issue of the scope of investment in the economic accounts, and in particular the issue of including R&D in investment, is a longstanding one. John Kendrick, in 1951, identified activities related to improvements in technology and technical innovations as leading to improved productivity;

6. The definitions of R&D and the three types of activities that are found elsewhere—for example, in financial accounting standards and in NSF's specific surveys—are similar to these definitions but place emphasis on elements of the definitions that are relevant to the context.

7. See James Adams [1] and [2].

he noted that technological innovations depend on advances in knowledge, and he focused on research as a source of these advances.[8] He viewed research expenditures—whether directed toward improving structures and equipment, raising the level of health, or dealing with problems of land and natural resource use—as expenditures devoted to increasing productivity. Accordingly, he proposed that they be treated as investment in the economic accounts. He noted that gross product would be higher by the amount of expenditure by business on R&D, which would be counted as final product rather than expensed; because expenditures by nonprofit institutions and government are already counted as final product, a change to treat them as investment would not change gross product.

The issue was raised again a few years later at a conference that led to the volume *A Critique of the United States Income and Product Accounts*.[9] The case was made that these expenditures "pay" in terms of yielding future returns and thus fit the general characterization of investment. Although various conceptual and statistical difficulties were identified as obstacles, there were some prospects for better statistics.

The 1968 revision of the System of National Accounts, published by the United Nations as international guidelines for economic accounting, referred to the urgent need to clarify the question of R&D expenditures in dealing with the boundary between current and capital expenditures. It was noted that the clarification could come only on the basis of experience.

R&D in extended economic accounts.—A number of analysts, working with the U.S. economic accounts, have proposed systems that expand the boundaries of investment by including R&D and several other categories of expenditures.

Nancy Ruggles and Richard Ruggles, in 1970, proposed a category of "development" outlays defined as those that meet the criterion that the value of the services provided by the outlay must accrue in future periods rather than entirely in the present period.[10] Outlays on education and training and some outlays on health, as well as outlays on R&D, were viewed as meeting the criterion. Their proposed system included stocks of "development" capital. They valued the services of the R&D portion of the capital stock as the amortization adjusted to market prices plus an imputed interest charge on the capital stock.

John Kendrick implemented his view that expenditures on certain intangibles are "made primarily to improve the quality or productivity of the tangible... factors in which they are embodied" and should be treated as investment that creates intangible capital.[11] The intangible investment and capital included R&D, education and

8. John Kendrick [33], pp. 79–81.

9. See Eric Schiff [51], pp. 434–435 and George Jaszi [31], pp. 454–455.

10. See Nancy Ruggles and Richard Ruggles [50], especially page 99.

11. See John Kendrick [32], especially pp. 1–21.

Table A.—Research and Development in the NIPA's

Published NIPA components containing R&D [1]	R&D identified in NIPA component	R&D included in NIPA component
Gross national product (1.1, 1)		
Personal consumption expenditures (1.1, 2) [2]		
Nonprofit hospitals (2.4, 52)	No	R&D funding from nonprofit hospitals
Education and research (2.4, 102)		
Higher education (2.4, 103)	No	R&D funding from private universities and colleges
Other (2.4, 105)	No	R&D funding from other nonprofit institutions serving individuals
Religious and welfare activities (2.4, 106)	No	Operating expenses for R&D grants
Gross private domestic investment (1.1, 6)	No [3]	
Net exports of goods and services (1.1, 15)		
Exports of services (4.1, 6)	No	R&D funding from foreign sources to U.S. performers
Imports of services (4.1, 14)	No	R&D funding from U.S. sources to foreign performers
Government purchases (1.1, 18)		
Federal (1.1, 19)		
National defense (1.1, 20)		
Contractual research and development (3.10, 20)	Yes	R&D contracted for by the Departments of Defense and Energy [4]
Other	No	Defense R&D performed in-house
Nondefense (1.1, 21)	No	Nondefense R&D funding by the Federal Government
State and local (1.1, 22)	No	R&D funding by State and local governments
Addendum: Business current expenses of production	No	R&D funding by business

1. Numbers in parentheses indicate the NIPA table number and the line number of published series.
2. Personal consumption expenditures are likely to contain some expenditures for R&D funded by the business and government sectors but performed by universities and colleges, nonprofit hospitals, and other nonprofit institutions serving individuals.
3. Not applicable, business spending on R&D is considered to be an intermediate expenditure.
4. Includes only the atomic energy research among that contracted for by the Department of Energy.
NIPA's National income and product accounts
R&D Research and development

training, health and safety, and labor mobility. He created gross stock by cumulating investments over their lifetimes and net stocks by cumulating depreciation on each vintage of investment and subtracting it from the gross stock. He estimated rental values of the capital stocks (referred to by other authors as service values or returns) for the nonbusiness sectors and added them to income and product. His effort, published in 1976, was viewed as a pilot study for determining the feasibility and usefulness of developing estimates of total investment and capital stocks.

Robert Eisner used "include investment in intangible and human capital" as one of the guiding principles for his total incomes system of accounts, published in 1989.[12] His interest in investment stemmed in major part from its relation to productivity and growth. His intangible capital comprised R&D, education and training, and health. His methodology for measuring R&D investment and capitalizing it was essentially the same as Kendrick's.

Satellite accounts.—Meanwhile, the possibility of treating R&D and several other activities as investment was discussed at length in preparing for the *System of National Accounts 1993*.[13] At the outset of the discussion, there was strong support for treating at least some portion of R&D expenditures as investment. Several proposals were made to identify a portion that was most clearly linked to a future return—for example, the portion of development expenditures in which the expenditures are identifiable and the outcome reasonably certain enough to assure that the costs of the project would be exceeded by the revenue.

In the end, however, no change was made in the treatment of R&D. The explanation of the treatment of business expenditures on R&D noted that they are undertaken to improve efficiency or to derive other future benefits and so are inherently investment-type activities. However, practical difficulties in meeting the accounting requirements for treating R&D and similar activities as investment suggested that they be treated as intermediate:

> In order to classify such activities as investment type it would be necessary to have clear criteria for delineating them from other activities, to be able to identify and classify the assets produced, to be able to value such assets in an economically meaningful way and to know the rate at which they depreciate over time. In practice it is difficult to meet all these requirements. By convention, therefore, all the outputs produced by research and development, staff training, market research and similar activities are treated as being consumed as intermediate inputs even though some of them may bring future benefits.[14]

Nevertheless, there was strong interest in being able to identify R&D within the economic accounts, and work toward classification systems that would help do so was encouraged. In addition, R&D was recognized as a prime candidate for presentation in a satellite account, an economic accounting tool that achieved international recognition when it was incorporated in the *System of National Accounts 1993*.

In brief, satellite accounts are frameworks designed to expand the analytical capacity of the economic accounts without overburdening them with detail or interfering with their general-purpose orientation. Satellite accounts, which are meant to supplement, rather than replace, the existing accounts, organize information in an internally consistent way that suits the particular analytical focus at hand, while maintaining links to the existing accounts. In their most flexible application, they may use definitions and classifications that differ from those in the existing accounts; for example, the R&D satellite account uses a different definition of investment, and it classifies transactors into different groupings. In addition, satellite accounts typically add detail or other information, including nonmonetary information, about a particular aspect of the economy to that in the existing accounts; for example, the R&D satellite account includes information about R&D employment.

The advantages of using R&D information assembled along the lines of the *Frascati Manual* to prepare a satellite account have become increasingly clear. One of the first satellite accounts, prepared in France in the 1970's, built on such R&D information.[15] More recently, a framework for an R&D satellite account for the Netherlands was constructed to use such information.[16] The new *Frascati Manual* specifically recognizes the connection between the data it describes and economic accounting, and it includes an annex that explains satellite accounts to experts on science and technology who are not familiar with economic accounting.

12. See Robert Eisner [24], especially pp. 8–20.
13. See [52].
14. See System of National Accounts [52], paragraph 6.163.
15. See Michael Braibant [5].
16. See Fritz Bos, et al. [4].

Methodological Overview

The R&D satellite account focuses on the value of R&D produced in the United States and the use of that output as investment. Because no direct measure of output is available, R&D produced is measured by summing the costs of its production, a technique of measurement used in economic accounting for most nonmarket production. The resulting total is referred to as R&D expenditures. The expenditure estimates were prepared by starting with the information available from surveys conducted for NSF and adjusting it to statistical and conceptual consistency with the NIPA's. The decision to work with information that is not extensively used to prepare the NIPA estimates was made because the regular source data and estimating methods do not permit the required level of resolution needed to focus on R&D.[17]

The satellite account groups organizations in a way that reflects the features of their institutional structures and purposes that are relevant to R&D. In light of the interest in academic R&D, universities and colleges (along with their affiliated institutions, agricultural experiment stations, and associated schools of agriculture) need to be shown separately. Federally funded research and development centers (FFRDC's), which are R&D organizations financed almost entirely by the Federal Government, are shown separately and grouped with the several kinds of entities that administer them. (At present, there are 39 FFRDC's, including the RAND Corporation, Argonne National Laboratory, E.O. Lawrence Livermore Laboratory, and Brookhaven National Laboratory.) The satellite account shows two major groups: "Private" organizations and "government." "Private" organizations consist of business (labeled "industry"); private universities and colleges, private hospitals, charitable foundations, and other nonprofit institutions serving households; and most FFRDC's. "Government" consists of the Federal Government, State and local governments (excluding universities and colleges), public universities and colleges, and FFRDC's administered by State and local government organizations, primarily public universities and colleges.

Constant-dollar R&D expenditures are derived by deflation, the method most often used in the NIPA's. In deflation, constant-dollar estimates are obtained by dividing the most detailed current-dollar components by appropriate price indexes. In the case of R&D, the current-dollar components are its costs of production. The expenditure estimates are treated as investment and cumulated to yield R&D capital stocks using methodologies developed by BEA to estimate fixed reproducible tangible capital stocks.

The most important of the methodological issues encountered in preparing the satellite account are described in this section.

Current-dollar expenditures

The measure of expenditures—reflecting labor costs, the costs of materials and supplies, and overhead costs (including a charge for the capital used in producing R&D)—is based on data by performer, when available, from NSF surveys. Only the data by performer provide the cost components needed to construct constant dollars.

BEA supplements the coverage of the survey-based data and extends it back in time. Missing data, primarily for State and local government R&D and the R&D of some types of nonprofit institutions, are interpolated and extrapolated from years for which data are available. Estimates for years prior to the first NSF survey in 1953 (which are needed to estimate stocks and related measures but are not presented in this article) are primarily based on outside studies that estimated R&D for selected years.[18] Some supporting data—in particular, for pre-1953 FFRDC's—are estimated by BEA using various sources.

A number of adjustments are made to the NSF survey-based spending data to make them statistically and conceptually consistent with the NIPA's. The statistical adjustments are for timing and geographic coverage and to fill gaps with estimates for some industries in some years. A conceptual adjustment is made to put depreciation of structures and equipment used in producing R&D on a basis that reflects the valuation and consistency appropriate for economic accounts.

BEA has implemented three disaggregations of R&D expenditures for analytical use in the satellite account: By performer, with industry detail; by source of funding; and by type. R&D by performer serves the same purposes for R&D as breakdowns by sector or industry of origin in analyses of production, which are often a first step in studies of structural change. R&D by funder is useful because a substantial portion of R&D is not financed by the performer. R&D by type

17. In BEA's input-output accounts, neither current expenses nor receipts for R&D are identified at the published level of detail. A portion of R&D is identified at the level of detail at which the estimates are prepared.

18. See Nestor Terleckyj [54] and Vannevar Bush [12].

is useful because the different types interact with the economy in different ways and with different lags. Other disaggregations would also be useful, but are not practical given current resources. For example, R&D disaggregated by purpose, such as defense or health, would help relate R&D expenditures to other issues. Geographic breakdowns would also be of interest—for example, in location decisions, for which proximity to research resources may be a factor.

Constant-dollar expenditures

The R&D satellite account provides estimates of constant-dollar expenditures by performer. In the absence of outputs and output price measures, costs of inputs are deflated by weighted indexes of input prices. The costs of inputs are derived, at the finest level of detail possible, from the limited cost information available from NSF surveys. The cost components are matched as closely as possible with "proxy" prices. The individual constant-dollar cost components are summed to derive constant-dollar expenditures by performer. (Implicit price deflators for R&D by performer are a byproduct of the procedure.)

Constant-dollar estimates derived in this way take into account the changing mix of R&D performers over time. The estimates of constant-dollar compensation of employees, which overall is about 45 percent of inputs, reflect changes in labor productivity only to the extent that the price indexes used reflect a procedure that picks up changes in the mix of employee skills. For example, the indexes that include Federal employee compensation reflect changes in the skill mix estimated by taking into account changes over time in the level of experience and education. Consistent with NIPA practice, the estimates do not include any additional, specific adjustment, such as an assumed rate of increase in labor productivity based on observations in related fields.

Ideally, the same breakdowns available for current-dollar expenditures would be prepared in constant dollars—that is, by funder and by type as well as by performer. However, because most performers have multiple sources of funding and because all groups of performers do at least some of each type of R&D, more detail on cost components is necessary to deflate R&D by funder or type. It is possible that constant-dollar estimates by funder could be derived by allocating cost components in the cases for which performer and funder do not coincide. Deriving constant-dollar estimates by type of R&D will be more problematic.

Stocks of R&D capital

It is generally agreed that stocks of intangible capital, such as R&D, are best obtained by cumulating investment flows rather than surveying stocks directly. BEA's review of the methods available led to reliance on the following three elements: (1) The performer breakdown currently available for constant-dollar R&D investment; (2) BEA's current methodology for fixed reproducible tangible capital stocks; and (3) uniform service lives for all R&D capital. The resulting R&D capital stock estimates are the first ones that are fully consistent with BEA's estimates of tangible capital.

Scope of R&D capital.—Some researchers have questioned whether expenditures on all types of R&D and in all fields should be treated as capital formation. Some have excluded basic research because they view it as being undertaken for the purpose of improving understanding of the world and not for the purpose of increasing productivity or adding to production.[19] Other researchers have excluded specific fields of research—for example, defense or space R&D—because they view those fields as having little applicability to commercial production.[20] Alternatively, if R&D is regarded solely as an input to the production process, comparable to the blueprints for a new building, only businesses' development expenditures for commercial applications might be included. Some researchers, particularly those who have constructed a broadened view of investment and wealth, have included all R&D.[21] Including all types of R&D in all fields, as the satellite account does, is consistent with a view of R&D as a new kind of wealth. Ideally, an R&D satellite account would publish R&D capital stocks showing detailed information that would allow users of the account to decide which categories of R&D to include or exclude, depending on their use of the estimates, but the satellite account does not yet do so.

Others have questioned whether all R&D, both successful and unsuccessful, should be treated as capital formation.[22] The R&D satellite account is consistent in this respect with the existing NIPA treatment of mineral exploration expenditures, which are all treated as investment in line

19. See, for example, Federal Republic of Germany, Federal Statistical Office [26].

20. See, for example, Zvi Griliches [28].

21. See, for example, John Kendrick [32].

22. Eric Schiff [51] and Fritz Bos, et al. [4].

with the view that returns from the successes are sufficient overall to pay for the failures.

Allocation of R&D capital and consumption of fixed capital.—In doing analytical work on R&D, some researchers have allocated most R&D capital financed by government and by nonprofit institutions to the business sector.[23] The Congressional Budget Office allocated all R&D to the economy at large.[24] In a more general setting, most presentations of capital stocks, including BEA's fixed reproducible tangible wealth, are on an ownership basis, allocating stocks to the sectors that own them.

For R&D capital in the satellite account, an allocation by funder would be closer to an ownership basis than an allocation by performer. However, the constant-dollar estimates of R&D expenditures by funder needed to prepare the capital stocks by funder will require additional work (see the section "Future Directions"). The R&D satellite account thus allocates the total R&D capital stock on the basis of performer to private and government components. Similarly, the consumption of fixed capital is allocated on the basis of performer.

Timing.—R&D projects typically take more than a year from the time they are started until their results are embedded in new knowledge or in new processes or products. Researchers have identified two types of lags: Gestation lags and applications lags. Gestation lags refer to the time needed to complete an R&D project. Applications lags refer to the time between completion of the R&D and its initial commercial use. The sum of the two lags yields the time needed for R&D investments to increase the stocks of knowledge that are actually being used. Survey-based research has found that gestation lags range from 1 to 2 years and that applications lags range from somewhat less than 1 year to somewhat more than 2 years.[25] Researchers have also studied the total lag between R&D and its peak effects on productivity or profits.[26] They have generally found long lags, particularly for basic research, because most new products and processes that result from R&D are adopted only gradually.

The R&D satellite account only needs to take into account the gestation lag, which is assumed to be 1 year. However, because the U.S. economic accounts measure production at the time that capital and labor are used in the production process, the gestation lag means that another category of output—R&D inventories—must be introduced. These inventories are the equivalent of work-in-progress for some tangible fixed capital goods whose production requires more than one time period. R&D inventories are converted to stocks of R&D intangible fixed capital at the end of the gestation lag.

Depreciation patterns and rates.—Some researchers have treated some, or all, capital created by R&D as immortal—that is, as a permanent part of the capital stock once it is added.[27] Other researchers have assumed that once R&D capital has entered the capital stock, it is gradually removed by depreciation—or, more formally, in economic accounting terms, by consumption of fixed capital. They used a variety of patterns and rates of depreciation.[28] In the satellite account, R&D is assumed to depreciate over a finite lifespan. The depreciation is due to obsolescence as knowledge from newer R&D supplants the knowledge from older R&D, or as applied R&D produces newer processes and products that supplant older ones. (For those who wish to treat R&D capital as immortal, the satellite account includes supplemental series that show cumulative R&D expenditures since 1929.)

The choice of a depreciation pattern for R&D stocks is of necessity somewhat arbitrary. There are no R&D capital markets to provide information on the value of "used" R&D. A study of patent renewal rates in several European countries was inconclusive; its findings could support assumptions about the pattern of depreciation ranging from geometric to slower-then-faster-than-straight-line.[29]

In the R&D satellite account, the stock of R&D capital is constructed using the same methodology that is currently used to construct BEA's estimates of fixed reproducible tangible capital: The perpetual inventory method is used with uniform average service lives, straight-line depreciation, and a bell-shaped distribution within each vintage of capital to determine discards. The current-dollar stock of R&D is measured at replacement cost rather than at historical cost.[30]

23. See, for example, Robert Eisner [24] and John Kendrick [32].

24. See Congressional Budget Office [14].

25. See John Kendrick [32], John Rapoport [46], and Lenore Wagner [57].

26. See, for example, James Adams [1], James Adams and Leo Sveikauskas [3], Gellman Associates [27], Edwin Mansfield [37], Ariel Pakes [44], David Ravenscraft and F.M. Scherer [47], and Nestor Terleckyj [53] and [55].

27. See, for example, Zvi Griliches [28], John Kendrick [32], David Levy and Nestor Terleckyj [34], Frank Lichtenberg and Donald Siegel [35], and Nestor Terleckyj [53] and [55].

28. See, for example, Bureau of Labor Statistics [11], Congressional Budget Office [14], Robert Eisner [24], and M. Ishaq Nadiri and Ingmar Prucha [38].

29. See Ariel Pakes and Mark Schankerman [45].

30. A full description of BEA's estimates of tangible capital stock may be found in Bureau of Economic Analysis [7]. BEA is now reviewing the

Empirical estimates have been made using geometric depreciation patterns. Among more recent studies, Ariel Pakes and Mark Schankerman found rates of 0.11 to 0.12 per year in some countries, but they reported estimates of 0.17 to 0.26 in the United Kingdom.[31] James Adams estimated depreciation rates of 0.09 to 0.13 for basic research.[32] M. Ishaq Nadiri and Ingmar Prucha estimated a rate of 0.12 for industrial R&D.[33]

The R&D satellite account uses the straight-line lifespan that corresponds most closely to a geometric depreciation of 0.11 per year, a rate chosen because it is near the center of a plausible range of rates. This straight-line average service life is 18 years. A study that compared R&D net capital stocks estimated using an 18-year average service life with alternative estimates made using geometric depreciation and a rate of depreciation of 0.11 per year revealed only modest differences that exhibited no particular time trends.

appropriateness of the concepts and measurement methods underlying these estimates. Future BEA capital stock estimates may be based on somewhat different concepts and measurement methods.

31. See Ariel Pakes and Mark Schankerman [45].

32. See James Adams [1].

33. M. Ishaq Nadiri and Ingmar Prucha [38].

Estimates of R&D Flows and Stocks

Table B summarizes some results from the R&D satellite account. It shows the following:

- Industry has performed two-thirds or more of R&D for the last 40 years.
- The Federal Government has funded a large, but declining, share of R&D. The decline was steep after 1987.
- By 1992, basic research was 17 percent of all R&D, almost double its 1960 share. The offsetting decline was in development, which was 59 percent of all R&D in 1992. The share of applied research has changed little.
- R&D funded by government and nonprofit institutions was equal to 1.2 percent of GDP in 1992, and R&D funded by industry was equal to 1.7 percent. Since 1960, the sum of the two has ranged from 2.2 percent in 1978 to 2.9 percent in the mid-1960's, in 1985, and in 1992.
- Constant-dollar expenditures increased at an average annual rate of over 7 percent from 1953 to 1968. Constant-dollar expenditures

Table B.—Selected Summary Measures

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
	Current-dollar measures											
R&D performed (percent of expenditures):												
Industry	77.2	68.2	66.7	65.6	68.3	72.5	71.4	70.9	70.4	70.5	70.8	70.6
Federal Government	12.7	15.4	15.6	15.3	12.4	10.8	10.5	10.4	10.4	10.1	9.7	9.7
Universities and colleges	4.9	7.4	9.0	9.8	9.8	8.5	9.6	10.1	10.5	10.7	10.8	11.2
Other	5.2	9.0	8.7	9.3	9.5	8.2	8.5	8.6	8.7	8.7	8.7	8.5
R&D funded (percent of expenditures):												
Industry	33.1	32.3	39.5	44.1	48.7	50.9	49.7	51.0	53.1	54.9	57.3	58.7
Federal Government	64.6	65.0	57.3	51.7	47.3	45.2	45.9	44.4	42.0	40.1	37.6	36.1
Universities and colleges	.5	.6	.9	1.2	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.1
Other	1.8	2.1	2.3	3.0	2.6	2.4	2.7	2.8	3.0	3.0	3.0	3.1
R&D by type (percent of expenditures):												
Basic	8.9	12.5	13.2	13.3	13.3	12.4	14.2	14.0	15.2	16.1	17.4	17.3
Applied	21.6	21.3	22.0	22.7	21.9	22.4	22.3	22.3	23.0	23.5	24.5	23.8
Development	69.5	66.2	64.8	63.9	64.7	65.2	63.5	63.6	61.8	60.4	58.1	58.9
R&D funding as a percent of GDP:												
Government and nonprofit institutions	1.8	2.0	1.6	1.3	1.2	1.4	1.4	1.3	1.3	1.2	1.2	1.2
Industry	.9	.9	1.0	1.0	1.2	1.5	1.4	1.4	1.4	1.5	1.6	1.7
	Constant-cost measures											
R&D net fixed intangible capital as a percent of government and business net fixed reproducible tangible capital [1]	5.8	7.5	8.4	8.0	7.4	7.7	8.0	8.1	8.2	8.4	8.5	8.7
Average age, in years, of R&D gross fixed intangible capital	6.5	6.6	7.2	8.3	8.9	8.8	8.5	8.4	8.4	8.3	8.2	8.2
Private	5.9	6.3	7.1	8.3	9.0	8.7	8.4	8.3	8.2	8.1	8.1	8.1
Government	7.9	7.7	7.4	8.1	8.8	9.1	9.1	9.0	9.0	8.9	8.8	8.8
	Indexes, 1960=100											
R&D expenditures (constant dollars)	100	132	136	131	161	219	229	234	237	245	252	254
R&D net fixed intangible capital (constant cost)	100	155	209	233	247	287	313	327	340	352	365	378

1. Business fixed reproducible tangible capital includes capital owned by nonprofit institutions.
R&D Research and development

then leveled off for nearly a decade before resuming an uptrend, but at a more moderate rate.

- With lags and moving more smoothly, the constant-cost R&D net fixed capital stock mirrored the pattern of constant-dollar expenditures. In 1992, R&D capital would have added almost 9 percent to the net wealth of government and business.
- The average age of the constant-cost R&D gross fixed stock, a rough indicator of the age of the knowledge in the stock, increased from about 6.5 years in 1960 to a high of 8.9 years in 1980. It then decreased to 8.2 years in 1992.

The tables that make up the R&D satellite account are in five groups. The tables numbered 1 are summary tables that present expenditures and investment for 1953–92, and stocks for 1959–92, in current dollars (or at current cost) and in constant dollars (or at constant cost)—tables 1.1 and 1.2, respectively. The tables numbered 2 present expenditures in current dollars by performer, by funder, and by type. The tables numbered 3 present estimates by industry in current dollars. The tables numbered 4 present constant-dollar expenditures, including expenditures by performing industry along with the number of scientists and engineers by industry. The tables numbered 5 present implicit price deflators.

Current-dollar R&D expenditures

Table 2.1 shows R&D expenditures by performer, and within each performer, by source of funds. Chart 1, which is based on this table, shows shares of R&D expenditures by performer for 1992. Industry, with expenditures of $119.5 billion, was the largest performer of R&D, accounting for 71 percent of total R&D expenditures. It has maintained at least a two-thirds share for most of the last 40 years. Public and private universities and colleges combined, with $18.9 billion, were the second largest performers of R&D. The Federal Government followed with $16.3 billion. Expenditures on R&D activities performed within the Federal Government, which had a share of 23 percent in 1953, had a 10-percent share in 1992. The combined expenditures for R&D performed by State and local governments, nonprofit institutions, and FFRDC's—at $14.6 billion—accounted for the remaining share of 9 percent.

For 1992, the Federal Government, in addition to funding all the R&D it performs, funded a majority of the R&D performed by universities and colleges (59 percent), FFRDC's (99 percent), and other nonprofit institutions (57 percent). However, the share of R&D funded by the Federal Government has declined steadily over time. Industry and State and local governments fund most of their own R&D work, 81 percent and 71 percent, respectively.

Table 2.2 shows R&D expenditures by source of funds, and within each source, by performer. Five sources of funds are shown in the R&D satellite account: Industry, the Federal Government, State and local governments, private universities and colleges, and "other." Because of data limitations, some small flows are combined with the major sources of funding; for example, industry's funding of R&D performed by industry includes funds from the rest of the world, because this funding source cannot be separately identified.

Chart 1 also shows shares of R&D expenditures by source of funds for 1992. Industry, providing $99.4 billion, is the largest source of R&D funds, with a 59-percent share. The Federal Government, providing $61.2 billion, is the second largest source. Together, these two sources provided 95 percent, or $160.8 billion, of the total spent on R&D in 1992. Over the 40-year period covered by the satellite account, these two sources of funds have always accounted for most R&D expenditures, but the shares of the two have changed over time. The Federal Government's share reached a high of 67 percent in 1964 and fell to 36 percent in 1992. By contrast, the industry share of R&D funding has steadily increased over time.

Tables 2.3 and 2.4 show R&D expenditures as the sum of expenditures on the three types of R&D—basic research, applied research, and development. Chart 1 also shows shares of R&D expenditures by type for 1992. Development, at $99.8 billion, is over half the total (59 percent). Applied research, with $40.2 billion, or a 24-percent share, is less than half as large. Basic research, at $29.3 billion, is 17 percent of the total. The share of basic research has increased steadily: By 1992, it had almost doubled its 1960 share. The increases in the share of basic research were offset by declines in development. The share of applied research has remained steady.

Basic research is increasingly being performed at universities and colleges: In 1953, universities and colleges performed less than 30 percent of basic research; by 1992, they performed over 40 percent of it. Most applied R&D is performed by industry. Industry currently performs over two-thirds of applied research and well over 80 percent of development. The Federal Gov-

ernment performs about 10 percent of applied R&D.

Table 3.1 shows expenditures by major R&D performing industries.[34] Manufacturing industries are shown at the two-digit standard industrial classification, except that transportation equipment is split into "aircraft and missiles" and "other transportation equipment" because the share of federally funded R&D in the former is so large. All nonmanufacturing R&D expenditures are combined.

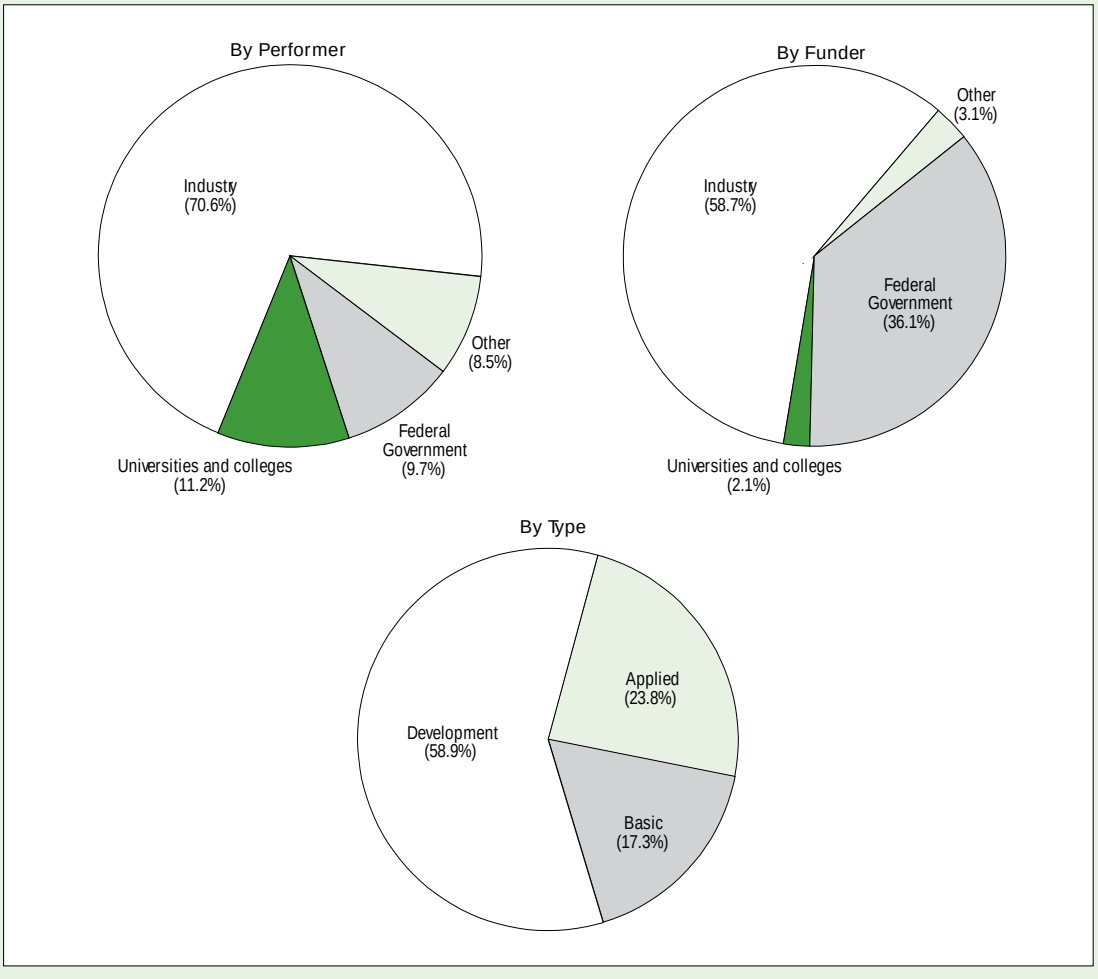
Expenditures on R&D performed by industry were $122.3 billion in 1992. Until 1992, the aircraft and missile industry consistently had the largest R&D expenditures, with a peak of $24.6 billion in 1987. In 1992, chemicals and allied products took top ranking, with expenditures of $16.8 billion. These two industries were followed by industrial machinery, electronic and other electrical equipment, and other transportation equipment. The nonmanufacturing industries, continuing a sharp uptrend, had R&D expenditures of $30.4 billion. (Nonmanufacturing industries include communication services; computer programming, data processing, other computer-related engineering, architectural, and surveying services; and research, development, and testing laboratories.)

The federally funded share of industry R&D has been steadily declining over the last 30 years, from a high of 59 percent in 1959 to a low of 20 percent in 1992. The Federal share has shrunk

34. In the tables showing industry detail, FFRDC's administered by industry are combined with the remainder of industry because source data do not provide FFRDC's administered by industry separately by industry classifications.

CHART 1

R&D Expenditures, 1992



Source: Tables 2.1., 2.2., and 2.3.

U.S. Department of Commerce, Bureau of Economic Analysis

rapidly since the mid-1980's, particularly in the aircraft and missiles industry. Federal funding accounted for 61 percent of funding in this industry in 1992, down from 76 percent in 1987. When Federal funding is removed, the aircraft and missile industry drops from second place to sixth place ($6.3 billion). Chemicals and allied products led non-federally funded manufacturing R&D performance with expenditures of $16.5 billion. Nonmanufacturing industries, continuing a sharp uptrend, reached $24.4 billion in non-federally funded R&D.

Table 3.2 shows company-funded R&D expenditures performed outside the United States by U.S. companies and their foreign subsidiaries. The chemicals and allied products industry is the leader, with expenditures of $2.7 billion, in 1992. This industry accounted for 28 percent of the 1992 industry-funded expenditures of foreign subsidiaries.

Comparison of R&D Capital Stock Estimates

The accompanying table shows BEA's estimates of the total R&D capital stock, and of selected components, together with estimates that others have published. In addition, it shows an alternative set of BEA estimates that is based on 11-percent per year geometric depreciation (rather than straight-line depreciation). The upper panel of the table contains estimates of R&D stocks for selected years. The lower panel shows BEA's estimates less the estimates by others. The comparison should be viewed as rough, because it was necessary to convert most of the other estimates to 1987 dollars from other base periods by using the ratios of BEA's R&D deflator in various base years to its 1987 value of 100. Because of weight shifts over time, the conversion factors yield only approximations of what would be the actual values of rebased deflators.

The alternative BEA stock estimates are not very different from the BEA estimates in the satellite account, and the two series show no tendency to diverge over time. Estimates made by John Kendrick [32] are increasingly higher than the BEA estimates over time. Estimates made by Robert Eisner [24] begin slightly higher than the BEA estimates and become increasingly higher over time. Estimates made by the Office of Management and Budget (OMB)—which appeared in the *Analytical Perspectives* volume of the fiscal year 1995 *Budget of the United States Government* [40]—begin at about the same level and become increasingly higher.

A major reason for these divergences is that BEA's methodology depreciates basic research capital, while the others' methodologies treat it as immortal and do not depreciate it. The rebasing of prices may also explain some of the differences between the Kendrick and Eisner estimates and the BEA estimates. Other differences result from different methodologies for calculating depreciation and from the others' use of NSF estimates of R&D expenditures rather than BEA's estimates; Eisner's use of a 20-year life for other R&D capital also contributed to the differences.

Estimates of the federally financed R&D capital stock made by OMB are increasingly larger than those produced using a rough BEA approximation of BEA's constant-dollar expenditures with geometric depreciation. This divergence reflects OMB's assumption that basic research capital is immortal. In addition, OMB's estimates assume a 10-percent rate of depreciation for other research, somewhat lower than the 11-percent depreciation rate underlying BEA's alternative estimates. Other differences arise because OMB used Federal outlays on a fiscal year basis, whereas BEA's estimates are primarily based on performers' reports of expenditures on a calendar year basis.

Estimates of industry R&D capital stock from a study by the Bureau of Labor Statistics (BLS) [11] are increasingly lower than the corresponding BEA estimates from 1960 to 1965 and are roughly the same amount lower thereafter. The principal reason for the lower values is that the BLS study did not include development expenditures in their capital formation estimates. Other differences arise from the BLS study's assumption that basic research capital is immortal, its lower—10 percent per year—rate of depreciation for applied research, its longer gestation lags, and its different method of deflation.

Estimates of industry R&D capital stock made by Nadiri and Prucha [38] are somewhat higher than BEA's corresponding estimates for 1965. Thereafter, their estimated capital stocks grow a little more slowly, on average, and are modestly lower in 1985. The initial difference may be due to the assumed seed value that begins their capital stock estimates. Thereafter, the slower growth reflects a 12-percent per year estimate for the rate of depreciation, somewhat higher than BEA's effective rates of depreciation.

Comparison of BEA and Others' R&D Capital Stock Estimates

[Billions of 1987 dollars]

	1960	1965	1970	1975	1980	1985	1990
	Levels						
R&D net total capital stock:							
BEA	278	429	581	646	686	797	978
BEA alternative with 11-percent depreciation rate	280	423	551	604	670	810	978
Kendrick	441	661	.....	.....	.....	.....	.....
Eisner	298	476	664	835	1,096	.....	.....
OMB [1]	200	400	600	700	800	1,000	1,200
R&D net federally-funded capital stock:							
BEA alternative with 11-percent depreciation rate	.....	.....	312	321	338	381	442
OMB	.....	.....	384	427	460	509	593
R&D net industry capital stock:							
BEA	189	297	391	425	451	547	698
BLS	98	143	202	262	314	392	.....
Nadiri and Prucha	295	352	401	410	433	521	.....
	BEA less other estimates						
R&D net total capital stock:							
BEA alternative with 11-percent depreciation rate	–2	6	30	42	16	–13	0
Kendrick [2]	–163	–232	–298	.....	.....	.....	.....
Eisner	–20	–47	–83	–189	–410	.....	.....
OMB [1]	0	0	0	–100	–100	–200	–200
R&D net federally funded capital stock:							
OMB	.....	.....	–72	–106	–122	–128	–151
R&D net industry capital stock:							
BLS	91	154	189	163	137	155	.....
Nadiri and Prucha	–106	–55	–10	15	18	26	.....

1. Published estimates are rounded to the nearest $100 billion.
2. The difference shown for 1970 is actually for 1969, the latest year available.
BLS Bureau of Labor Statistics
OMB Office of Management and Budget
R&D Research and development

Constant-dollar R&D expenditures

Table 4.1 shows R&D expenditures by performer in constant dollars. Total R&D expenditures grew at an average annual rate of 7.3 percent in 1953–68. (Over much of the period, Federal spending on defense-related and space R&D increased sharply.) Expenditures then leveled off for nearly a decade, with an average decline of 1.3 percent in 1968–75. An uptrend then resumed, but at a more moderate rate; the average annual rate of increase in 1975–92 was 4.0 percent. (During this period, R&D spent on energy, following the 1973 oil embargo, and on health stepped up.) Chart 2 presents expenditures by performer group. Expenditure patterns have been similar for each of the groups performing R&D. Expenditures increased steadily until the late 1960's, leveled off or declined somewhat for a decade, and, except for Federal performance, then increased through 1992. Federal performance has been flat since the late 1980's.

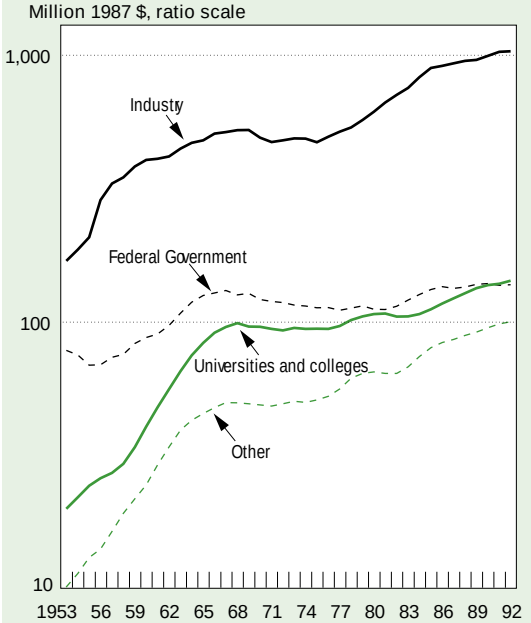
Table 4.2 shows constant-dollar expenditures by industry (including FFRDC's administered by industry). The recent growth in R&D expenditures for industry has been uneven. From 1987 to 1992, real R&D performed by industry increased at an average annual rate of 2.1 percent; however, 7 of the 14 industry groups had declining R&D expenditures during this period. The fastest rates of decline were in stone, clay, and glass products and in aircraft and missiles. The fastest growth has been in nonmanufacturing, which tripled its R&D expenditures between 1987 and 1992.

Table 4.3 shows the number of R&D scientists and engineers by industry, an additional input series. Like the constant-dollar expenditure series, it abstracts from price change over time, but it is narrower in coverage than expenditures. From 1987 to 1992, the picture of uneven growth across industry groups seen in the constant-dollar estimates is also seen in the number of scientists and engineers. Again, the fastest growth is in nonmanufacturing, but the number of scientists and engineers doubled rather than tripling as the constant-dollar expenditures did.

Tables 5.1 and 5.2 show implicit price deflators (IPD's) for each of the performers. IPD's are constructed to derive constant-dollar estimates; the overall IPD for R&D is a byproduct of the constant-dollar estimates.[35] The IPD's of most performers do not greatly differ from the IPD for total R&D, which grew at an average annual rate of 3.7 percent during 1987–92. Notable exceptions are universities and colleges and FFRDC's. During 1987–92, the IPD's for private and public universities and colleges grew at average annual rates of 5.9 percent and 5.8 percent, respectively. On the other end of the scale, the IPD's for FFRDC's administered by nonprofit institutions and by governments grew at average annual rates of 2.5 percent and 2.6 percent, respectively.

CHART 2

Constant-Dollar R&D Expenditures by Performer



Source: Table 1.2.

U.S. Department of Commerce, Bureau of Economic Analysis

Stock of R&D capital

Investment, consumption of R&D capital, and gross and net stocks are shown in tables 1.1 and 1.2 in current dollars and in constant dollars, respectively. Stocks and consumption of R&D capital are not shown prior to 1959, because the perpetual inventory method for deriving R&D net fixed intangible capital stock would require additional years of constant-dollar investment data, which are not available.

35. BEA constructed the R&D IPD at the finest level of detail possible. In contrast, NSF and others have used the GDP implicit price deflator or other summary price measures to produce estimates of constant-dollar R&D expenditures. A comparison of the total R&D IPD and the GDP IPD shows that the latter provides a reasonable approximation to the former for deflating total R&D expenditures. Use of the GDP IPD overstates the historical growth in R&D performed in public and private universities and colleges and understates the historical growth in R&D performed in many FFRDC's. NSF views the GDP deflator as an "opportunity cost" of the real resources forgone in engaging in R&D rather than as measuring the costs of doing R&D, and recognizes that the deflator is less useful for calculating finer-level components of R&D. See National Science Board, National Science Foundation [39].

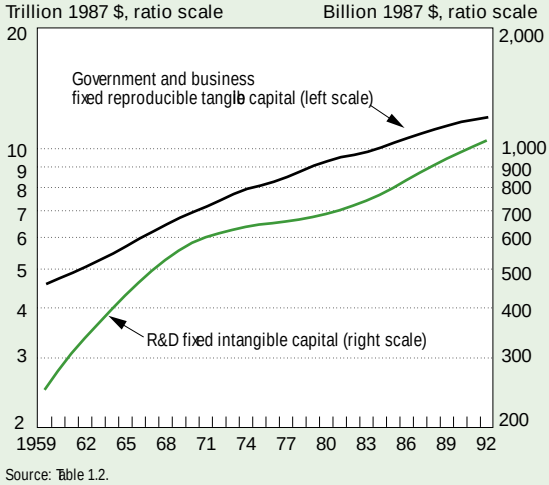
In 1992, constant-dollar fixed tangible investment was $723 billion; the constant-cost net stock of fixed reproducible tangible capital of government and business (including nonprofit institutions) was $12,020 billion. Adding constant-dollar R&D fixed intangible investment would increase fixed investment by 19 percent, or $140 billion; adding the resulting R&D stock would increase the constant-cost net stock of fixed reproducible capital by almost 9 percent, or $1,049 billion.

Chart 3 compares the constant-cost net stock of R&D fixed capital with the constant-cost net stock of fixed reproducible tangible capital of government and business. The chart shows that while the constant-cost fixed reproducible tangible capital stock grew rather steadily from 1959 to 1992 (left scale), the stock of R&D capital grew rapidly until 1970, slowed sharply from 1970 to 1981, and then grew somewhat more rapidly thereafter (right scale). The ratio of the R&D stock to the fixed reproducible tangible stock increased sharply until 1970, fell until 1981, and has increased thereafter.

The average age of the R&D gross fixed intangible capital stock, a rough indicator of the age of the knowledge in the stock, is a byproduct of the perpetual inventory method. As shown in the addenda to table 1.2, the average age of the total constant-cost gross R&D stock increased from about 6.5 years in 1960 to a high of 8.9 years in 1980, then deceased to 8.2 years in 1992. The age of private stock, which makes up about three-quarters of the total stock, showed a very similar pattern. The age of the government stock started higher, at almost 8 years, decreased about half a year over the decade to 1970, and then increased to 9 years at the end of the 1980's; it stood at 8.8 years in 1992.

CHART 3

Constant-Cost Net Stocks of Capital



Source: Table 1.2.

U.S. Department of Commerce, Bureau of Economic Analysis

Future Directions

The R&D satellite account now presents basic information about R&D—the value of its production by performer, by funder, and by type in current dollars and by performer in constant dollars—and treats the expenditures that measure that production as investment to obtain a stock of R&D fixed intangible capital. Future work could proceed in several directions: Rounding out the view of R&D within an economic accounting framework, refining the existing estimates and providing additional information, and enhancing the international comparability of the satellite account presentation of R&D.

Rounding out the economic accounting view of R&D.—The satellite account presents the total value of R&D produced in the United States by adjusting the best available source of information about R&D to prepare estimates consistent with the NIPA's. The restructured GDP that is implied is shown as follows:

Personal consumption expenditures
  Less: Expenditures on R&D
  Plus: Consumption of fixed R&D capital
Gross domestic investment
  Gross fixed investment
    Tangible fixed investment
    R&D fixed investment
  Change in inventories
    Business tangible inventories
    R&D inventories
Net exports of goods and services
Government purchases
  Less: Expenditures on R&D
  Plus: Consumption of fixed R&D capital

Nonprofit institution and government expenditures on R&D are subtracted from personal consumption expenditures and government purchases, respectively. Those expenditures are added to business expenditures on R&D to obtain total R&D investment, split as described earlier between fixed investment and change in inventories. (The term "tangible" is introduced to distinguish the investment in the existing accounts from R&D.) Consumption of fixed R&D capital is allocated to nonprofit institutions and to government; the consumption of fixed R&D capital

allocated to business does not appear because it is intermediate consumption. GDP is increased by the addition of business expenditure on R&D (which had been intermediate consumption) and the addition of the difference between expenditures on R&D and the consumption of fixed R&D capital that is included in personal consumption expenditures and in government purchases.

This view of the production of R&D is useful, but could be more fully rounded out within an economic accounting framework. To do so within the national income and product (NIP) account—the first of the five accounts in the NIPA summary set of accounts—would call for identifying components on the product and income sides of the NIP account that include subcomponents that relate to R&D. For example, tangible investment includes investment that provides the capital used to produce R&D, and identifying that investment within the total may be useful.

Rounding out the treatment in the NIP account would lead to changes in the other four accounts of the NIPA summary set. In particular, the gross saving and investment account would reflect changes in the coverage of investment, consumption of fixed capital, and sector saving.

Further, the investment allocated to government and nonprofit institutions might be expected to have a net return (over and above costs, such as consumption of fixed capital) that would appear both on the product (or expenditure) side of the account and on the income side. At present, the NIPA's do not include such a return for nonprofit institutions' investment, and they do not treat any government expenditure as investment (so that there is no return to be considered). However, BEA, as part of an ongoing modernization of the accounts, is considering treating government expenditures on structures and durable equipment as investment, and a major issue is whether a net return on the capital created should be estimated. Especially if a net return is calculated for government fixed reproducible tangible capital, the R&D satellite account should be brought into line to have a consistent treatment for all government capital.

These points are raised within the context of the existing NIPA's and the associated capital stock estimates. However, BEA is reviewing the appropriateness of the concepts and methods underlying its capital stock estimates, and future estimates may be based on somewhat different concepts and measurement methods.[36] In keeping with the approach of constructing the R&D satellite account measures to be consistent with the more general measures with which they might be used and compared, the satellite account measures could change also. Further, as the U.S. accounts are modernized along the lines of the international guidelines in the *System of National Accounts 1993*, further modifications might be made.

Refining the estimates.—Refining the estimates and providing additional breakdowns would strengthen the satellite account. R&D expenditures funded by the Federal Government by agency would provide a proxy for a partial breakdown of R&D by purpose. This breakdown also could lead to a defense-nondefense split; the defense portion would include both purchases of contractual R&D and R&D performed inhouse. Such additional detail could be expected to be of wide interest and also improve the NIPA estimates.

Sources of data on R&D other than NSF have the potential of improving the accuracy of the estimates and of facilitating the provision of additional information. One possibility is that other sources of R&D data could be used to supplement the information from NSF's surveys. These sources could be useful, for example, in developing the analytically interesting but difficult breakdowns by purpose or region. For example, health-related R&D, by all performers, might be separately identified. Another possibility is that BEA's survey data on direct investment—foreign direct investment in the United States and U.S. direct investment abroad—and on international trade in services could be further mined for information about international R&D expenditure flows. Because the knowledge gained from R&D is highly mobile internationally, and because there is some evidence that the internationalization of R&D is intensifying, there is substantial interest in tracing the flows.

Further work to refine the deflation of R&D could yield constant-dollar estimates by source of funding and by type of R&D. These constant-dollar estimates would yield, in turn, R&D capital stocks that would allow users to examine whether R&D capital from different sources of funding have different effects. For example, this refinement would allow further examination of the finding by some analysts that government-funded R&D has different effects on productivity than other R&D. Similarly, stocks of R&D capital by type would allow the examination of whether the different types have effects on productivity with different time patterns.

36. See Jack E. Triplett [56].

International comparability.—Because of the substantial interest in comparing R&D across countries, several strands of work in the international area could contribute to, and benefit from, the U.S. R&D satellite account. First, further work on R&D and other forms of intangible capital formation and capital stock is on the research agenda that emerged from the preparation of the *System of National Accounts 1993.* This work might lead to some useful standardization on aspects for which empirical work is not likely to lead to firm answers—for example, on the issue of longevity of basic research capital. Second, several international classifications that identify purpose, or function, are to be completed or updated in the future. One of the specific goals of the work is to include R&D—for example, in the classification of functions for government and for nonprofit institutions. The classification work is likely to draw upon the *Frascati Manual.* Third, as noted earlier, several countries prepare or are exploring the preparation of R&D satellite accounts.

In looking to the future of BEA's R&D satellite account, it is especially fitting to note that satellite accounts are sometimes called economic accountants' laboratories. The work in these laboratories—both in the United States, reflecting comments from users and BEA's experience, and abroad—can be expected to add to knowledge. This knowledge, combined with resources, would help set a course for future improvements.

Data Availability

A complete set of data in the R&D satellite account is available on a microcomputer diskette. The data set includes the tables published in the article, but for all years rather than just the selected years shown in the article. The first year of data shown in most tables is either 1953 or 1959, depending on the availability of source data. The disk also includes supplemental tables.

The BEA accession number for the diskette, which is a 3½-inch HD diskette, is 53–94–40–001. Its price is $20.

For more information about the contents of the diskette, call Carol Moylan at 202–606–9711 or Bruce Grimm at 202–606–9623. To order the diskette using MasterCard or Visa, call BEA's public information office at 202–606–9900. To order by mail, write to the Public Information Office, Order Desk, BE-53, Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC 20230. Specify the R&D Satellite Account diskette, accession number, and its price. For foreign shipment, add 25 percent to the total amount of the order. A check or money order payable to "Bureau of Economic Analysis" must accompany all written orders. Be sure to include a return address.

Technical Note

This note provides additional information about the construction of the R&D satellite account. It covers the sources of data, estimating methods, and assumptions used to construct the three major segments of the account: Current-dollar expenditures, constant-dollar expenditures, and current-cost and constant-cost gross and net capital stocks. Because the R&D satellite account is designed to supplement the U.S. economic accounts, the methods used to estimate R&D flows and stocks are consistent with those used to construct the U.S. national income and product accounts (NIPA's) and the associated estimates of capital stocks. As it does with other estimates, BEA has modified available source data to tailor them to the statistical and conceptual requirements of the account.

Current-dollar expenditures

The estimates of R&D expenditures are largely based on, or are extensions of, data that began in 1953 from four annual surveys published by the National Science Foundation (NSF): *Federal Funds for Research and Development*, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions*, *Academic Science and Engineering: R&D Expenditures*, and *Research and Development in Industry*.[37] The two Federal surveys are universe surveys, the academic survey is close to a universe survey, and the industry survey uses a sample that is redrawn every 5 years.[38] The surveys are intended to cover all formal R&D activities, not just the activities assigned to separate R&D units.

The first survey measures obligations and outlays by Federal agency, and the second survey measures obligations by Federal agency. The last two surveys measure expenditures. These survey measures differ with respect to the kind of information they collect about the tangible capital used in performing R&D. For example, the two Federal surveys include a separate measure of tangible capital spending, but exclude its depreciation. The academic and industry surveys do not include a separate measure of capital spending, but include its depreciation as an unidentifiable part of overhead costs. All of these measures are

37. See Division of Science Resource Studies, National Science Foundation [15], [16], [17], [18], [20], and [22] for more information.

38. Beginning in 1992, the industry samples will be redrawn annually.

broken down by type of R&D, and each survey includes at least some geographic detail. In addition, the industry survey provides tabulations of the net sales of R&D performing companies and the full-time-equivalent number of industry R&D scientists and engineers.

Data from surveys of State and local R&D expenditures and of nonprofit institution R&D expenditures, published occasionally by NSF, were also used.[39] These data were interpolated and extrapolated to obtain estimates for missing years.

Performer-based estimates.—The R&D satellite account features estimates of R&D expenditures that are largely based on data reported by performers of the R&D rather than by funders of the R&D. This approach attempts to avoid at least two problems. First, the data reported by funders would have to be adjusted to convert them from a time-of-payment-to-the-performer basis to a time-of-expenditure-by-the-performer basis in order to be consistent with the timing with which purchases of goods and services are generally recorded in the NIPA's. Second, the data reported by funders would have to be adjusted to avoid double-counting. Otherwise, R&D that is subcontracted would be counted twice—once by the primary source of funding and once by the secondary source of funding that subcontracted the R&D.

Expenditures for R&D performed by industry, by public and private universities and colleges, and by academically administered, federally funded research and development centers (FFRDC's) are prepared from data reported by R&D performers. In recent years, these performers have accounted for roughly 85 percent of all R&D expenditures. For the remaining 15 percent, performer reports are not available, and expenditures are based on data reported by funders.

Adjustments to the survey data.—BEA adjusts the survey-based data to make them conceptually and statistically consistent with the NIPA's. The adjustments raised the level of current-dollar expenditures, on average, 2.5 percent in 1953–92; in 1987–92, the adjustments raised the level somewhat less, an average of 1.5 percent. The four major types of adjustments to the NSF survey data are summarized in table C.

First, BEA adjusts the R&D expenditures from NSF surveys to obtain consumption of fixed tangi-

39. See Division of Science Resources Studies, National Science Foundation [20] and [22] for more information.

Table C.—Major Adjustments to National Science Foundation Survey Data to Derive R&D Satellite Account Expenditures

Type of adjustment	Method used	R&D performers affected
Adjustments to obtain consumption of fixed tangible capital used in performing R&D.	Expenditures for R&D structures and equipment are removed from R&D expenditures. Consumption of this capital is estimated using perpetual inventory methodology and added to R&D expenditures.	Federal Government State and local governments
	Implied depreciation of fixed tangible capital used in performing R&D is put on an economic accounting basis.	Private universities and colleges Public universities and colleges FFRDC's administered by universities and colleges Industry
Timing adjustments	Fiscal years are converted to calendar years, using weighted averages.	Federal Government State and local governments FFRDC's administered by NPI's Other NPI's (Federal funds)
	Academic years are converted to calendar years, using weighted averages.	Private universities and colleges Public universities and colleges FFRDC's administered by NPI's
	Federal R&D obligations are converted to expenditures, using statistically estimated phase-out patterns.	Federal Government FFRDC's administered by NPI's Other NPI's (Federal funds)
Geographic coverage adjustments	R&D expenditures primarily in U.S. territories and possessions are removed from R&D expenditures.	Private universities and colleges Public universities and colleges FFRDC's administered by universities and colleges
Adding estimates of suppressed industry detail	Judgmental estimates are used where R&D data have been suppressed by NSF to avoid disclosures of confidential survey data.	Industry

FFRDC's Federally funded research and development centers
NPI's Nonprofit institutions
NSF National Science Foundation

ble capital used in performing R&D. Two methods are used, depending on the handling of this capital in the surveys. For the Federal Government and for State and local governments, BEA removes expenditures on fixed reproducible tangible capital—structures and equipment—and adds an estimate of the consumption of that capital based on BEA's perpetual inventory methodology. For other performers, BEA converts the depreciation implied in the R&D survey (part of overhead) to a basis that reflects the valuation and consistency (for example, of service lives) appropriate for economic accounts.

To make the conversion for private and public universities and colleges and for FFRDC's administered by universities and colleges, an estimate of expenditures on R&D structures and equipment is made as a first step. Equipment is then split between capital equipment and expensed "research" equipment. (Research equipment is purchased by the academic institution from current fund accounts.) Next, the implied depreciation of structures and capital equipment is calculated using the depreciation patterns and the service lives prescribed for NSF reporting purposes. This implied depreciation and the expenditures on research equipment are then subtracted from reported R&D expenditures. Finally, BEA's estimate of consumption of structures and equipment, which is estimated using BEA's perpetual inventory methodology and the same service lives used in preparing fixed tangible capital stocks, is added back in; it is valued at current cost.

To make the conversion for industry performers, the information on capital expenditures needed to develop an estimate of implied depreciation is not available. BEA developed estimates based on the 1958 survey-based depreciation reported by NSF and the 1982 depreciation charges of R&D auxiliaries from the Bureau of the Census *1982 Enterprise Statistics* [6]. For each industry, the depreciation is converted to an economic basis using the ratios of historical-cost to current-cost valuation from the estimates of academic expenditures described above.

Second, two timing adjustments are made. Data from the Federal Government are on a fiscal year basis, and data from universities and colleges are on an academic year basis. These data are converted to a calendar year basis by using weighted averages of adjacent years. Federal obligations by performer—for example, contracts awarded or other binding commitments made that will require outlays—are converted to expenditures using statistically estimated phasing patterns prepared by BEA.

Third, data from the academic surveys are adjusted to exclude R&D performed in geographic areas—primarily U.S. territories and possessions—that are not included in the NIPA's. Because these academic surveys tabulate expenditures by individual school or FFRDC, these expenditures could be removed.

In the fourth adjustment, BEA developed R&D expenditure estimates for industries and years that had been suppressed by NSF in order to avoid disclosure of confidential information from the industry survey. The BEA estimates are based on statistical techniques (primarily interpolations), on fragmentary data from other sources, and on judgment; they do not disclose confidential company data.

Backward extensions of the survey data.—In order to develop the necessary statistical foundation to construct capital stock estimates using the perpetual inventory method, BEA prepared estimates of R&D expenditures for years prior to 1953, when the NSF surveys began. Using various data sources, BEA extended the R&D expenditure estimates back to 1920. Estimates of R&D expenditures are not made for years before 1920, because little information is available; it is assumed that R&D expenditures before 1920 were quite small.

The BEA estimates of expenditures by R&D performers for 1920–52 are made using a methodology generally similar to that described by John Kendrick.[40] First, expenditures are established for benchmark years. Benchmark years are 1921, 1930, 1940, and 1951 for total R&D expenditures and 1921, 1927, 1931, 1933, 1938, 1940, 1946, and 1951 for industry R&D, and the expenditures are from Nestor Terleckyj.[41] Expenditures in the non-benchmark years in 1920–41 are estimated by interpolation or extrapolation, using estimates of R&D reported by Vannevar Bush as indicators when available.[42] Expenditures for nonbenchmark years in 1942–52 are estimated using data published by the Research and Development Board.[43]

The BEA estimates for 1920–52 are supplemented in two ways. Expenditures for FFRDC's, from their inception in 1942, are based on data published in a study by the Denver Research Institute.[44] Expenditures on the Manhattan project

40. See John Kendrick [32].
41. See Nestor Terleckyj [54].
42. See Vanevar Bush [12].
43. See Research and Development Board, Department of Defense [54].
44. See Denver Research Institute [15].

(which developed the first atomic bomb) for 1942–46 are based on data reported by Richard Hewlett and Oscar Anderson, Jr.[45] At its peak in 1944, the Manhattan project accounted for nearly one-tenth of all R&D performed in the United States.

Issues with R&D by funder and by type.—As discussed above, the basic framework for the R&D satellite account is R&D arrayed by performer. In addition, R&D is shown broken down by source of funding and by type.

In the R&D satellite account, a maximum of five sources of funding are distinguished: Federal Government, State and local governments, industry, universities and colleges, and other (which includes nonprofit institutions and foreign sources). The satellite account shows less source-of-funding detail for some performers because of varying source data. For example, three sources of funding are distinguished for R&D performed by industry (see table 2.1), although industry source data divide R&D performed into only two funding categories—Federal funds and all other funds. Within the other funds category, BEA estimated State and local government funding using data from surveys of State and local R&D. BEA assumed that the funding of industry R&D from universities and colleges and from other nonprofit institutions is negligible and that foreign funding is small enough so that the remainder of industry R&D funding could be labeled "from industry."

The breakdowns by type embody substantial uncertainty. Because there are no clear-cut distinctions between the types, uncertainties must be resolved by the judgment of the survey respondents. It is unlikely that these resolutions will be the same among reporting groups. For example, academic respondents may be less likely to report research as applied or development. In addition, the breakdowns by type are voluntary on industry and academic surveys, and not all surveys ask for the full three-way breakdown.

Constant-dollar expenditures

Table D provides an overview of the source data and methods used in deriving constant-dollar R&D expenditures. For each group of performers, constant-dollar expenditures are calculated by dividing current-dollar expenditures by price deflators at the most detailed cost level available. Constant-dollar estimates begin in 1929, the year NIPA price indexes become available. The methodology of using cost components that are matched with existing indexes builds on both existing BEA work and work done by others—most notably John Jankowski of NSF and Edwin Mansfield of the University of Pennsylvania for industry R&D expenditures and D. Kent Halstead of Research Associates of Washington for academic R&D expenditures.[46]

Typically, the cost components are compensation of employees, materials and supplies, and overhead. Data used for deflation include information on prices paid by the Federal Government, the NIPA price index for noncommercial research organizations, the producer price index for industrial commodities published by the Bureau of Labor Statistics (BLS), average hourly earnings and median weekly salaries of managers and administrators from BLS, annual mean salaries of engineers from the Engineering Manpower Commission, component price indexes from the National Institute of Health's biomedical R&D price index, and higher education price indexes published by Research Associates of Washington.[47] The base year is 1987, for which each price index is set equal to 100.

Capital stocks

R&D investment is broken into two components—fixed investment and change in R&D inventories. In the R&D satellite account, it is assumed that expenditures on R&D are inventoried for 1 year before they are included in R&D fixed capital in order to allow for the time needed to complete R&D projects. When measured in constant dollars, R&D fixed investment is equal to the R&D expenditures for the preceding year, and for each year, the change in R&D inventories is equal to the change in R&D expenditures. Because the beginning and ending inventory levels reflect different price levels, current-dollar R&D inventories from the end of the preceding year are revalued to correspond to the prices for the current year by using an inventory valuation adjustment.[48]

R&D fixed capital stocks are constructed using the methods BEA uses to construct capital stocks associated with the NIPA's, including the same perpetual inventory method that is used for

45. See Richard Hewlett and Oscar Anderson, Jr. [29]

46. See John Jankowski [30], Edwin Mansfield [36], and Research Associates of Washington [48].

47. Additional information on BEA's deflators for Federal purchases of R&D may be obtained from the Bureau of Economic Analysis [8]. Additional information on BEA's deflators for higher education and research may be obtained from the Bureau of Economic Analysis [10]. Additional information on the biomedical R&D price index may be obtained from Office of Science Policy and Technology Transfer, National Institutes of Health [42].

48. See Bureau of Economic Analysis [9] for more information about the NIPA inventory valuation adjustment.

Table D.—Research and Development Expenditures by Performer: Sources and Methods for Constant-Dollar Estimates

Cost component	Source data for cost component	1987 (billions of dollars)	Method and source data
R&D expenditures		127.39	Sum of detail
Industry		93.25	Sum of detail
Compensation of employees	NSF reported distribution of wages of R&D personnel by industry.	38.32	Sum of detail
Scientists and engineers	Based on a 1975 split	24.43	Deflation: Proxy prices by industry—annual professional income of engineers from the Engineering Manpower Commission.
Support staff	Based on a 1975 split	13.89	Deflation: Proxy prices by industry—indexes of average hourly earnings of production workers.
Materials and supplies	NSF reported distribution of costs of materials and supplies by industry.	16.73	Deflation: Proxy prices—PPI for industrial commodities less fuel.
Overhead less CFC	NSF reported distribution of other costs by industry less BEA estimate of depreciation.	33.25	Deflation: Proxy prices—median weekly salaries of managers and administrators.
CFC for structures and equipment	Based on 1958 NSF reported distribution of depreciation and on 1982 depreciation charges of R&D auxiliaries from the Bureau of the Census *1982 Enterprise Statistics*.	4.94	Deflation: Proxy prices—a composite of IPD's for private purchases of new industrial nonresidential structures and producers' durable equipment.
Private universities and colleges		4.21	Sum of detail
Compensation of employees	Derived from sample of individual schools: Based on direct costs less materials and supplies.	1.86	Deflation: Proxy prices by school (from a sample of private universities and medical schools representing 90 percent of R&D expenditures)—fixed weighted price indexes for academic personnel costs (salaries and fringe benefits) from the NIH BRDPI.
Materials and supplies	Weight from NIH BRDPI	.73	Deflation: Proxy prices—fixed weighted price index from academic nonpersonnel costs from the NIH BRDPI.
Overhead less CFC	R&D expenditures less direct costs	1.28	Deflation: Proxy prices by school (from a sample of private universities and medical schools representing 90 percent of R&D expenditures)—product of the price index of direct costs and an index of the indirect cost rate.
CFC for structures	Expenditures for R&D structures	.17	Deflation: Proxy prices—NIPA IPD for educational services structures.
CFC for equipment	Expenditures for R&D capital equipment and reclassification of research equipment from current expense to investment.	.17	Deflation: Proxy prices—NIPA IPD for educational services equipment.
FFRDC's administered by private universities and colleges.	Weight of expenditures based on R&D obligations to individual FFRDC's from four agency categories.	2.38	Sum of detail
DOD funded		.44	Deflation: Proxy prices—NIPA IPD for DOD purchases of R&D.
DOE funded		.75	Deflation: Proxy prices—NIPA IPD for DOE purchases of R&D.
NASA funded		.82	Deflation: Proxy prices—NIPA IPD for NASA purchases of R&D.
All other funded		.13	Deflation: Proxy prices—NIPA IPD for Federal other nondefense purchases of R&D.
CFC for structures	Expenditures for R&D structures	.15	Deflation: Proxy prices—NIPA IPD for educational services structures.
CFC for equipment	Expenditures for R&D capital equipment and the reclassification of research equipment from current expense to investment.	.09	Deflation: Proxy prices—NIPA IPD for educational services equipment.
FFRDC's administered by other nonprofit institutions	Weight of expenditures based on R&D obligations to FFRDC's administered by nonprofit institutions divided into four agency categories.	.59	Sum of detail
DOD funded		.47	Deflation: Proxy prices—NIPA IPD for DOD purchases of R&D price.
DOE funded		.11	Deflation: Proxy prices—NIPA IPD for DOE purchases of R&D.
NASA funded		<.01	Deflation: Proxy prices—NIPA IPD for NASA purchases of R&D.
All other funded		.02	Deflation: Proxy prices—NIPA IPD for Federal other purchases of R&D.
Other nonprofit institutions	R&D expenditures	2.90	Deflation: Proxy prices—NIPA index for noncommercial R&D.
Federal		13.33	Sum of detail
Compensation of employees	Federal obligations for intramural R&D personnel costs divided into four agency categories.	4.94	Sum of detail
DOD		2.38	Deflation: Proxy prices—NIPA IPD for Federal defense compensation of civilian employees.
All other agencies		2.55	Deflation: Proxy prices—NIPA IPD for Federal nondefense compensation of employees.
Materials and supplies and overhead excluding CFC.	Expenditures excluding compensation of employees and OMB budget based estimates of equipment.	6.06	Sum of detail
DOD		4.11	Deflation: Proxy prices—NIPA IPD for Federal installation support services.
DOE		.07	Deflation: Proxy prices—NIPA IPD for Federal weapons support services.

gross and net stocks of fixed reproducible tangible capital. Thus, the estimates of fixed intangible R&D capital are comparable with those of fixed reproducible tangible capital.

With the perpetual inventory method, the gross capital stock for a given period is obtained by cumulating past investment and deducting the cumulated value of investment that has been discarded, using estimated average service lives and retirement patterns.[49] The gross stock of fixed capital is a measure of the cumulative value of past investment still in existence. The net capital stock is equal to the gross stock less the accumulated depreciation on the assets in the gross stock.

49. For a more complete description of the NIPA perpetual inventory method, see Bureau of Economic Analysis [9], page M-3.

Table D.—Research and Development Expenditures by Performer: Sources and Methods for Constant-Dollar Estimates—Continued

Cost component	Source data for cost component	1987 (billions of dollars)	Method and source data
All other agencies		1.88	Deflation: Proxy prices—NIPA IPD for Federal nondefense services excluding compensation of employees.
CFC for structures	Federal obligations for intramural R&D plant and judgment split between structures and large equipment.	.67	Deflation: Proxy prices—NIPA IPD for Federal nondefense industrial building, less force account construction.
CFC for equipment	OMB budget detail on equipment, Federal obligations for intramural R&D plant, and judgment.	1.68	Deflation: Proxy prices—NIPA IPD for Federal nondefense durable goods.
State and local		.71	Sum of detail
Compensation of employees, materials and supplies, and overhead excluding CFC.	R&D expenditures excluding expenditures on plant	.61	Deflation: Proxy prices—NIPA price index for noncommercial R&D.
CFC for structures	State and local expenditures on R&D plant and judgmental split between structures and large equipment.	.03	Deflation: Proxy prices—NIPA IPD for State and local structures new construction put-in-place, other buildings.
CFC for equipment	State and local expenditures on R&D plant and judgmental split between structures and large equipment.	.07	Deflation: Proxy prices—NIPA IPD for State and local new equipment.
Public universities and colleges		8.02	Sum of detail
Compensation of employees	Derived from sample of individual schools: Based on direct costs less materials and supplies.	4.18	Deflation: Proxy prices by school (from a sample of public universities and medical schools representing 80 percent of R&D expenditures)—Fixed weighted price indexes for academic personnel costs (salaries and fringe benefits) from the NIH BRDPI.
Materials and supplies	Weight from NIH BRDPI	1.40	Deflation: Proxy prices—Fixed weighted price index for academic nonpersonnel costs from the NIH BRDPI.
Overhead excluding CFC	R&D expenditures less compensation of employees, materials and supplies, and research equipment.	1.84	Deflation: Proxy prices by school (from a sample of public universities and medical schools representing 80 percent of R&D expenditures)—Product of the price index of direct costs and an index of the indirect cost rate.
CFC for structures	Expenditures for R&D structures	.30	Deflation: Proxy prices—NIPA IPD for educational services structures.
CFC for equipment	Expenditures for R&D capital equipment and the reclassification of research equipment from current expense to investment.	.30	Deflation: Proxy prices—NIPA educational services equipment IPD.
FFRDC's administered by public universities and colleges.	Weight of expenditures excluding CFC based on R&D obligations to individual FFRDC's from four agency categories.	1.99	Sum of detail
DOD funded		.46	Deflation: Proxy prices—NIPA IPD for DOD purchases of R&D.
DOE funded		1.32	Deflation: Proxy prices—NIPA IPD for DOE purchases of R&D.
NASA funded		<.01	Deflation: Proxy prices—NIPA IPD for NASA purchases of R&D.
All other funded		.03	Deflation: Proxy prices—NIPA IPD for Federal other nondefense purchases of R&D.
CFC for structures	Expenditures for R&D structures	.09	Deflation: Proxy prices—NIPA IPD for educational services structures.
CFC for equipment	Expenditures for R&D capital equipment and reclassification of research equipment from current expense to investment.	.09	Deflation: Proxy prices—NIPA IPD for educational services equipment.

BEA Bureau of Economic Analysis
BRDPI Biomedical research and development price index
CFC Consumption of fixed capital
DOD U.S. Department of Defense
DOE U.S. Department of Energy
FFRDC Federally funded research and development center
IPD Implicit price deflator
NASA National Aeronautics and Space Administration
NIH National Institutes of Health
NIPA National income and products accounts
NSF National Science Foundation
OMB U.S. Office of Management and Budget
PPI Producer price index
R&D Research and development

The perpetual inventory method used by BEA is based on uniform service lives, straight-line depreciation, and replacement cost. To adjust for varying retirement patterns, discards (retirement years) are based on a Winfrey S-3 distribution, which is a bell-shaped distribution around the expected service life of the R&D capital. Discards of capital begin as early as 45 percent of, and end as late as 155 percent of, the average lifespan.

In deciding how to apply its methodology to R&D, BEA examined several alternative depreciation patterns and performed sensitivity studies. Geometric depreciation is the pattern typically used in R&D studies, and a rate of 11 percent per year for R&D fixed capital is a plausible midpoint of a range published by academic researchers. (Some recent studies had estimates that ranged from 9 to 13 percent per year and tended to concentrate near 11 percent.) BEA's studies showed that using a depreciation rate for R&D fixed capital of 12 percent yielded a real stock of R&D capital for 1991 that was $65 billion lower (1987 dollars) than a stock constructed using a rate of 11 percent. Using a rate of 10 percent yielded a real stock of R&D capital that was $74 billion higher. Regardless of which rates are used, the general patterns of R&D stock are similar over time.

Because BEA currently uses the straight-line perpetual inventory method for fixed tangible capital, an average service life for R&D capital was chosen that yields a net stock comparable to a net stock from a geometric depreciation rate of 11 percent; an 18-year service life for straight-line depreciation yields the closest match. The gross and net stocks constructed in the account for 1959–92 are based on current- and constant-dollar R&D investment for 1930–91.

As with the constant-dollar expenditure estimates, constant-cost net and gross stocks are expressed in 1987 prices. Net and gross stocks valued at replacement cost are constructed by multiplying the constant-cost stocks by the corresponding R&D implicit price deflator.

References

1. Adams, James. "Fundamental Stocks of Knowledge and Productivity Growth." *Journal of Political Economy* 98 (August 1990): 673–702.
2. Adams, James. "Science, R&D and Invention Potential Recharge: U.S. Evidence." Center for Economic Studies Discussion Paper CES 93–2. Washington, DC: Census Bureau, 1993.
3. Adams, James, and Leo Sveikauskas. "Academic Science, Industrial R&D, and the Growth of Inputs." Center for Economic Studies Discussion Paper CES 93–1. Washington, DC: Census Bureau, 1993.
4. Bos, Fritz, Hugo Hollanders, and Steven Keuning. "A Research and Development Module Supplementing the National Accounts." *Review of Income and Wealth* 40 (September 1994): 273–286.
5. Braibant, Michel. *Satellite Accounts*. Paris: Institut National de la Statistique et des Etudes Economiques, 1994.
6. Bureau of the Census. *1982 Enterprise Statistics: Auxiliary Establishment Report*. Washington, DC: U.S. Government Printing Office, 1986.
7. Bureau of Economic Analysis. U.S. Department of Commerce. *Fixed Reproducible Tangible Wealth in the United States, 1925–89*. Washington, DC: U.S. Government Printing Office, 1993.
8. Bureau of Economic Analysis. U.S. Department of Commerce. *Government Transactions*. Methodology Paper Series MP-5. Washington, DC: U.S. Government Printing Office, 1988.
9. Bureau of Economic Analysis. U.S. Department of Commerce. *National Income and Product Accounts of the United States: Volume 2, 1959–88*. Washington, DC: U.S. Government Printing Office, 1992.
10. Bureau of Economic Analysis. U.S. Department of Commerce. *Personal Consumption Expenditures*. Methodology Paper Series MP-6. Washington, DC: U.S. Government Printing Office, 1990.
11. Bureau of Labor Statistics (BLS). U.S. Department of Labor. *The Impact of Research and Development on Productivity Growth*. BLS Bulletin 2331. Washington, DC: U.S. Government Printing Office, 1989.
12. Bush, Vannevar. *Science, The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research*. Washington, DC: U.S. Government Printing Office, 1945.
13. Carson, Carol, and Bruce Grimm. "Satellite Accounts in a Modernized and Extended System of Economic Accounts." *Business Economics* 26 (January 1991): 58–63.
14. Congressional Budget Office. *Trends in Public Investment*. Washington, DC: U.S. Government Printing Office, 1987.

15. Denver Research Institute. *Contract Research and Development Adjuncts of Federal Agencies*. Denver, CO: University of Denver, 1969.
16. Division of Science Resources Studies. National Science Foundation (NSF). *Academic Science and Engineering: R&D Expenditures*. Washington, DC: NSF, annually.
17. Division of Science Resources Studies. National Science Foundation. *Federal Funds for Research and Development*. Washington, DC: NSF, annually.
18. Division of Science Resources Studies. National Science Foundation. *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions*. Washington, DC: NSF, annually.
19. Division of Science Resources Studies. National Science Foundation. *National Patterns of R&D Resources, 1992*. NSF 92–330. Washington, DC: NSF, 1992.
20. Division of Science Resources Studies. National Science Foundation. *Research and Development Expenditures of State Government Agencies*. Washington, DC: NSF, 1970, 1979, 1990.
21. Division of Science Resources Studies. National Science Foundation. *Research and Development by Industry*. Washington, DC: NSF, annually.
22. Division of Science Resources Studies. National Science Foundation. *Scientific Activities of Nonprofit Institutions*. Washington, DC: NSF, 1960, 1964, 1970, 1973.
23. Division of Science Resources Studies. National Science Foundation. *Scientific and Engineering Research Facilities at Universities and Colleges*. Washington, DC: NSF, 1986, 1988, 1990, 1992.
24. Eisner, Robert. *The Total Income System of Accounts*. Chicago, IL: University of Chicago Press, 1989.
25. Engineering Manpower Commission. *Engineers' Salaries: Special Industry Report*. Washington, DC: American Association of Engineering Societies, Inc., annually.
26. Federal Republic of Germany. Federal Statistical Office. "Capital Consumption on Expenditures for Research and Development." Wiesbaden, Germany: Federal Republic of Germany, 1988.
27. Gellman Associates. "Indicators of International Trends in Technological Innovation." Unpublished report to the National Science Foundation. Washington, DC, 1976.
28. Griliches, Zvi. "Returns to Research and Development Expenditures in the Private Sector." In *New Developments in Productivity Measurement and Analysis*. Studies in Income and Wealth, vol. 44, edited by John Kendrick and Beatrice Vaccara, 419–454. Chicago, IL: University of Chicago Press, for the National Bureau of Economic Research, 1980.
29. Hewlett, Richard, and Oscar Anderson, Jr. *The New World, 1939/1946: A History of the United States Atomic Energy Commission*, vol. I. University Park, PA: Pennsylvania State University Press, 1962.
30. Jankowski, John E. Jr. "Do We Need a Price Index for Industrial R&D?" *Research Policy* 22 (June 1993): 195–205.
31. Jaszi, George. "Comment on the Schiff Paper." In *A Critique of the United States Income and Product Accounts*. Studies in Income and Wealth, vol. 22, 454–455. Princeton, NJ: Princeton University Press, for the National Bureau of Economic Research, 1958.
32. Kendrick, John. *The Formation and Stocks of Total Capital*. New York: Columbia University Press, for the National Bureau of Economic Research, 1976.
33. Kendrick, John. "National Productivity and Its Longer Term Projection." In *Long-Range Economic Projections*. Studies in Income and Wealth, vol. 16, 67–104. Princeton, NJ: Princeton University Press, for the National Bureau of Economic Research, 1954.
34. Levy, David, and Nestor Terleckyj. "Government R&D, Private Investment and Productivity Growth." NPA Working Paper 1–7–82. Washington, DC: National Planning Association, 1982.
35. Lichtenberg, Frank, and Donald Siegel. "The Impact of R&D Investment on Productivity—New Evidence Using Linked R&D-LRD Data." *Economic Inquiry* 29 (April 1991): 203–229.
36. Mansfield, Edwin. "Price Indexes for R and D and Inputs, 1969–1983." *Management Science* 33 (January 1987): 124–129.
37. Mansfield, Edwin. "R&D and Innovation: Some Empirical Findings." In *R&D, Patents, and Productivity*, edited by Zvi Griliches, 127–148. Chicago, IL: University of Chicago Press, 1984.
38. Nadiri, M. Ishaq and Ingmar Prucha. "Estimation of the Depreciation Rate of Physical

and R&D Capital in the U.S. Total Manufacturing Sector." Working Paper 4591. Cambridge, MA: National Bureau of Economic Research, 1993.

39. National Science Board. National Science Foundation. *Science & Engineering Indicators, 1993.* Washington, DC: U.S. Government Printing Office, 1993.
40. Office of Management and Budget. *Budget of the United States Government, Fiscal Year 1995: Analytical Perspectives.* Washington, DC: U.S. Government Printing Office, 1994.
41. Office of Management and Budget. *Budget of the United States Government: Appendix.* Washington, DC: U.S. Government Printing Office, annually.
42. Office of Science Policy and Technology Transfer, National Institutes of Health (NIH). *Biomedical Research and Development Price Index.* Bethesda, MD: NIH, 1993.
43. Organisation for Economic Co-operation and Development (OECD). *Frascati Manual 1993: The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys of Research and Experimental Development.* Paris: OECD, 1994.
44. Pakes, Ariel. "Patents, R&D, and the Stock Market Rate of Return." Working Paper 786. Cambridge, MA: National Bureau of Economic Research, 1981.
45. Pakes, Ariel, and Mark Schankerman. "The Rate Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources." In *R&D, Patents, and Productivity,* edited by Zvi Griliches, 73–88. Chicago, IL: University of Chicago Press, for the National Bureau of Economic Research, 1984.
46. Rapoport, John. "The Anatomy of the Product-Innovation Process: Cost and Time." In *Research and Innovation in the Modern Corporation,* edited by Edwin Mansfield, 110–135. New York: W.W. Norton, 1971.
47. Ravenscraft, David, and F.M. Scherer. "The Lag Structure of Returns to R&D." *Applied Economics* 14 (1982): 603–620.
48. Research Associates of Washington. *Inflation Measures for Schools and Colleges.* Washington, DC: annually.
49. Research and Development Board. Department of Defense. *The Growth of Scientific Research and Development.* Washington, DC: Department of Defense, 1953.
50. Ruggles, Nancy, and Richard Ruggles. *The Design of Economic Accounts.* New York: Columbia University Press, for the National Bureau of Economic Research, 1970.
51. Schiff, Eric. "Business Plant and Equipment." In *A Critique of the United States Income and Product Accounts.* Studies in Income and Wealth, vol. 16, 431–435. Princeton, NJ: Princeton University Press, for the National Bureau of Economic Research, 1958.
52. *System of National Accounts 1993.* Brussels: Commission of the European Communities, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank, 1993.
53. Terleckyj, Nestor. "The Economic Effects of Government R&D Spending in the United States." NPA Discussion Paper 8–31–84. Washington, DC: National Planning Association, 1984.
54. Terleckyj, Nestor. *Research and Development: Its Growth and Composition.* Studies in Business Economics No. 82. New York: National Industrial Conference Board, 1963.
55. Terleckyj, Nestor. "R&D as a Source of Growth of Productivity and of Income." NPA Working Paper 5–18–82. Washington, DC: National Planning Association, 1982.
56. Triplett, Jack E. "Measuring the Capital Stock: A Review of Concepts and Data Needs." Paper given at the Conference on Research in Income and Wealth, Workshop on the Measurement of Depreciation and Capital Stock. Washington, DC: Bureau of Economic Analysis, (June 5, 1992).
57. Wagner, Lenore. "Problems in Estimating Research and Development Investment and Stock." *Proceedings of the Business and Economic Statistics Section,* American Statistical Association (ASA). Washington, DC: ASA, 1968.

Tables 1.1 through 5.2 follow.

Table 1.1.—Research and Development Expenditures, Investment, and Stock by Performer

[Millions of dollars]

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Research and development expenditures, total	**5,288**	**5,777**	**6,397**	**8,528**	**10,022**	**10,955**	**12,517**	**13,735**	**14,526**	**15,588**
Basic research	451	500	561	680	783	899	1,037	1,221	1,400	1,695
Applied research	1,260	1,364	1,486	1,866	2,360	2,682	2,848	2,966	3,009	3,611
Development	3,577	3,913	4,350	5,982	6,879	7,374	8,632	9,548	10,117	10,282
Cumulative research and development expenditures [1]	35,802	41,579	47,976	56,504	66,526	77,481	89,998	103,733	118,259	133,847
Change in research and development inventories	1,501	392	432	1,871	1,203	576	1,179	859	413	669
Research and development fixed investment	3,787	5,385	5,965	6,657	8,819	10,379	11,338	12,876	14,113	14,919
Consumption of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5,030	5,742	6,551	7,410
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	92,983	106,334	120,864	136,026
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	59,799	68,799	78,366	87,997
Private research and development expenditures	**3,897**	**4,374**	**4,988**	**7,004**	**8,314**	**9,064**	**10,425**	**11,440**	**11,988**	**12,724**
Basic research	253	287	334	425	485	557	648	768	870	1,056
Applied research	829	927	1,050	1,402	1,846	2,112	2,219	2,282	2,260	2,773
Development	2,815	3,160	3,604	5,177	5,983	6,395	7,558	8,390	8,858	8,895
Cumulative research and development expenditures [1]	25,216	29,590	34,578	41,582	49,896	58,960	69,385	80,825	92,813	105,537
Change in research and development inventories	1,082	416	506	1,846	1,095	517	1,004	699	268	406
Research and development fixed investment	2,815	3,958	4,482	5,158	7,219	8,547	9,421	10,741	11,720	12,318
Consumption of research and development fixed intangibleq capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,699	4,317	4,992	5,722
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	68,865	80,158	92,324	105,119
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	46,028	53,892	62,109	70,359
Government research and development expenditures	**1,391**	**1,403**	**1,409**	**1,524**	**1,708**	**1,891**	**2,092**	**2,295**	**2,538**	**2,864**
Basic research	198	213	227	255	298	342	389	453	530	639
Applied research	431	437	436	464	514	570	629	684	749	838
Development	762	753	746	805	896	979	1,074	1,158	1,259	1,387
Cumulative research and development expenditures [1]	10,586	11,989	13,398	14,922	16,630	18,521	20,613	22,908	25,446	28,310
Change in research and development inventories	419	–24	–74	25	108	59	175	160	145	263
Research and development fixed investment	972	1,427	1,483	1,499	1,600	1,832	1,917	2,135	2,393	2,601
Consumption of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,331	1,425	1,559	1,688
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24,118	26,176	28,540	30,907
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13,771	14,907	16,257	17,638

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Research and development expenditures, total	**17,449**	**19,078**	**20,343**	**22,299**	**23,653**	**25,133**	**26,490**	**26,765**	**27,476**	**29,305**
Basic research	1,982	2,268	2,540	2,828	3,063	3,278	3,410	3,532	3,656	3,801
Applied research	3,783	4,105	4,333	4,710	4,925	5,236	5,555	5,882	6,027	6,326
Development	11,684	12,705	13,470	14,761	15,665	16,619	17,525	17,351	17,793	19,178
Cumulative research and development expenditures [1]	151,296	170,374	190,717	213,016	236,669	261,802	288,292	315,057	342,533	371,838
Change in research and development inventories	1,415	1,202	735	1,193	476	259	–31	–1,478	–887	268
Research and development fixed investment	16,034	17,876	19,608	21,106	23,177	24,874	26,521	28,243	28,363	29,037
Consumption of research and development fixed intangible capital	8,342	9,350	10,464	11,820	13,274	15,022	16,942	19,196	21,453	23,675
Gross stock of research and development fixed intangible capital	152,580	171,095	192,332	216,550	244,542	276,646	312,883	353,303	392,592	435,533
Net stock of research and development fixed intangible capital	98,174	109,494	122,331	136,626	153,037	171,278	191,218	212,795	232,218	252,541
Private research and development expenditures	**14,110**	**15,185**	**16,026**	**17,637**	**18,651**	**19,846**	**20,843**	**20,715**	**21,027**	**22,403**
Basic research	1,192	1,318	1,458	1,605	1,716	1,802	1,808	1,810	1,827	1,883
Applied research	2,824	3,003	3,105	3,348	3,450	3,677	3,850	4,045	4,093	4,226
Development	10,094	10,864	11,463	12,684	13,485	14,367	15,185	14,860	15,107	16,294
Cumulative research and development expenditures [1]	119,647	134,832	150,858	168,495	187,146	206,992	227,835	248,550	269,577	291,980
Change in research and development inventories	1,026	800	447	998	302	320	–57	–1,309	–841	280
Research and development fixed investment	13,084	14,385	15,579	16,639	18,349	19,526	20,900	22,024	21,868	22,123
Consumption of research and development fixed intangible capital	6,512	7,321	8,224	9,333	10,522	11,884	13,402	15,068	16,787	18,443
Gross stock of research and development fixed intangible capital	118,723	133,669	150,817	170,581	193,118	218,231	246,000	276,530	306,080	338,917
Net stock of research and development fixed intangible capital	78,749	87,815	98,003	109,388	122,262	136,155	151,083	166,986	181,103	196,145
Government research and development expenditures	**3,339**	**3,893**	**4,317**	**4,662**	**5,002**	**5,287**	**5,647**	**6,050**	**6,449**	**6,902**
Basic research	790	950	1,082	1,223	1,347	1,476	1,602	1,722	1,829	1,918
Applied research	959	1,102	1,228	1,362	1,475	1,559	1,705	1,837	1,934	2,100
Development	1,590	1,841	2,007	2,077	2,180	2,252	2,340	2,491	2,686	2,884
Cumulative research and development expenditures [1]	31,649	35,542	39,859	44,521	49,523	54,810	60,457	66,507	72,956	79,858
Change in research and development inventories	389	402	288	195	174	–61	26	–169	–46	–12
Research and development fixed investment	2,950	3,491	4,029	4,467	4,828	5,348	5,621	6,219	6,495	6,914
Consumption of research and development fixed intangible capital	1,830	2,029	2,240	2,487	2,752	3,138	3,540	4,128	4,666	5,232
Gross stock of research and development fixed intangible capital	33,857	37,426	41,515	45,969	51,424	58,415	66,883	76,773	86,512	96,616
Net stock of research and development fixed intangible capital	19,425	21,679	24,328	27,238	30,775	35,123	40,135	45,809	51,115	56,396

See footnotes at end of table.

Table 1.1.—Research and Development Expenditures, Investment, and Stock by Performer—Continued

[Millions of dollars]

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Research and development expenditures, total	**31,731**	**34,268**	**36,794**	**40,617**	**44,512**	**49,882**	**57,211**	**65,185**	**74,486**	**82,854**
Basic research	4,038	4,477	4,908	5,324	5,976	6,927	7,786	8,685	9,773	10,667
Applied research	6,920	7,611	8,368	9,327	10,034	11,026	12,595	14,305	17,057	19,009
Development	20,773	22,180	23,518	25,966	28,502	31,929	36,830	42,195	47,656	53,178
Cumulative research and development expenditures [1]	403,569	437,837	474,631	515,248	559,760	609,642	666,853	732,038	806,524	889,378
Change in research and development inventories	353	–103	–845	1,420	1,429	1,913	3,008	3,104	4,081	3,864
Research and development fixed investment	31,378	34,371	37,639	39,197	43,083	47,969	54,203	62,081	70,405	78,990
Consumption of research and development fixed intangible capital	26,283	29,479	33,337	36,422	39,458	43,398	48,084	53,182	58,630	63,516
Gross stock of research and development fixed intangible capital	486,919	550,106	613,511	668,449	731,197	809,843	897,483	992,890	1,085,968	1,171,988
Net stock of research and development fixed intangible capital	277,052	307,491	337,107	361,133	389,629	426,904	469,670	517,922	566,454	613,375
Private research and development expenditures	**24,343**	**26,390**	**28,160**	**31,298**	**34,528**	**38,766**	**44,654**	**51,587**	**59,539**	**66,592**
Basic research	2,014	2,237	2,442	2,658	2,998	3,483	3,865	4,333	4,941	5,415
Applied research	4,581	5,117	5,515	6,148	6,738	7,547	8,697	10,052	12,437	14,152
Development	17,748	19,036	20,203	22,492	24,792	27,736	32,092	37,202	42,161	47,025
Cumulative research and development expenditures [1]	316,323	342,713	370,873	402,171	436,699	475,465	520,119	571,706	631,245	697,837
Change in research and development inventories	356	–75	–826	1,333	1,429	1,552	2,630	3,157	3,991	3,636
Research and development fixed investment	23,987	26,465	28,986	29,965	33,099	37,214	42,024	48,430	55,548	62,956
Consumption of research and development fixed intangible capital	20,452	23,003	25,982	28,316	30,559	33,582	37,111	41,004	45,105	48,784
Gross stock of research and development fixed intangible capital	379,342	429,064	477,799	518,972	566,486	626,426	692,905	764,977	834,898	901,216
Net stock of research and development fixed intangible capital	215,097	238,786	261,229	278,780	300,130	328,562	361,158	398,034	435,388	472,918
Government research and development expenditures	**7,388**	**7,878**	**8,634**	**9,319**	**9,984**	**11,116**	**12,557**	**13,598**	**14,947**	**16,262**
Basic research	2,024	2,240	2,466	2,666	2,978	3,444	3,921	4,352	4,832	5,252
Applied research	2,339	2,494	2,853	3,179	3,296	3,479	3,898	4,253	4,620	4,857
Development	3,025	3,144	3,315	3,474	3,710	4,193	4,738	4,993	5,495	6,153
Cumulative research and development expenditures [1]	87,246	95,124	103,758	113,077	123,061	134,177	146,734	160,332	175,279	191,541
Change in research and development inventories	–3	–28	–19	87	0	361	378	–53	90	228
Research and development fixed investment	7,391	7,906	8,653	9,232	9,984	10,755	12,179	13,651	14,857	16,034
Consumption of research and development fixed intangible capital	5,831	6,476	7,355	8,106	8,899	9,816	10,973	12,178	13,525	14,732
Gross stock of research and development fixed intangible capital	107,577	121,042	135,712	149,477	164,711	183,417	204,578	227,913	251,070	70,772
Net stock of research and development fixed intangible capital	61,955	68,705	75,878	82,353	89,499	98,342	108,512	119,888	131,066	140,457

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**91,578**	**103,597**	**115,435**	**121,224**	**127,390**	**134,880**	**142,918**	**153,448**	**162,818**	**169,308**
Basic research	11,789	13,059	14,309	16,695	18,064	18,914	21,673	24,671	28,346	29,308
Applied research	20,964	23,135	25,892	27,806	28,467	30,139	32,930	36,054	39,896	40,205
Development	58,825	67,403	75,234	76,723	80,859	85,827	88,315	92,723	94,576	99,795
Cumulative research and development expenditures [1]	980,956	1,084,553	1,199,988	1,321,212	1,448,602	1,583,482	1,726,400	1,879,848	2,042,666	2,211,974
Change in research and development inventories	4,738	8,003	8,012	2,807	2,621	3,144	1,982	4,758	4,531	1,188
Research and development fixed investment	86,840	95,594	107,423	118,417	124,769	131,736	140,936	148,690	158,287	168,120
Consumption of research and development fixed intangible capital	68,121	72,905	77,769	82,459	87,923	94,144	101,838	109,645	117,121	125,169
Gross stock of research and development fixed intangible capital	1,255,274	1,340,428	1,425,140	1,514,514	1,616,123	1,737,364	1,871,842	2,004,242	2,134,514	2,246,959
Net stock of research and development fixed intangible capital	660,640	710,695	763,511	821,287	885,298	959,412	1,039,932	1,117,323	1,192,648	1,256,565
Private research and development expenditures	**73,751**	**84,103**	**94,146**	**98,373**	**103,336**	**109,042**	**115,098**	**123,782**	**131,774**	**136,922**
Basic research	5,989	6,736	7,414	9,123	9,843	10,061	12,042	14,254	17,104	17,287
Applied research	15,846	17,827	20,394	22,011	22,266	23,437	25,612	28,248	31,406	31,210
Development	51,916	59,540	66,338	67,239	71,227	75,544	77,444	81,280	83,264	88,425
Cumulative research and development expenditures [1]	771,588	855,691	949,837	1,048,210	1,151,546	1,260,588	1,375,686	1,499,468	1,631,242	1,768,164
Change in research and development inventories	3,991	7,129	7,085	1,998	2,401	2,441	1,116	4,270	4,556	821
Research and development fixed investment	69,760	76,974	87,061	96,375	100,935	106,601	113,982	119,512	127,218	136,101
Consumption of research and development fixed intangible capital	52,434	56,299	60,183	63,956	68,295	73,270	79,674	85,954	91,807	98,526
Gross stock of research and development fixed intangible capital	967,669	1,035,392	1,102,947	1,174,007	1,254,372	1,353,273	1,462,947	1,567,734	1,671,934	1,768,322
Net stock of research and development fixed intangible capital	512,151	553,474	597,223	644,858	696,825	758,293	824,677	886,238	946,631	1,001,329
Government research and development expenditures	**17,827**	**19,494**	**21,289**	**22,851**	**24,054**	**25,838**	**27,820**	**29,666**	**31,044**	**32,386**
Basic research	5,800	6,323	6,895	7,572	8,221	8,853	9,631	10,417	11,242	12,021
Applied research	5,118	5,308	5,498	5,795	6,201	6,702	7,318	7,806	8,490	8,995
Development	6,909	7,863	8,896	9,484	9,632	10,283	10,871	11,443	11,312	11,370
Cumulative research and development expenditures [1]	209,368	228,862	250,151	273,002	297,056	322,894	350,714	380,380	411,424	443,810
Change in research and development inventories	747	874	927	809	220	703	866	488	–25	367
Research and development fixed investment	17,080	18,620	20,362	22,042	23,834	25,135	26,954	29,178	31,069	32,019
Consumption of research and development fixed intangible capital	15,687	16,606	17,586	18,503	19,628	20,874	22,164	23,691	25,314	26,643
Gross stock of research and development fixed intangible capital	287,605	305,036	322,193	340,507	361,751	384,091	408,895	436,508	462,580	478,637
Net stock of research and development fixed intangible capital	148,489	157,221	166,288	176,429	188,473	201,119	215,255	231,085	246,017	255,236

n.a. Not available.
1. Cumulative since 1929.

Table 1.2.—Research and Development Expenditures, Investment, and Stock by Performer in Constant Dollars

[Millions of 1987 dollars]

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Research and development expenditures, total	**27,688**	**29,475**	**31,330**	**39,496**	**44,736**	**47,208**	**52,134**	**55,697**	**57,529**	**60,365**
Cumulative research and development expenditures [1]	79,521	109,151	140,936	180,290	224,436	271,343	322,596	377,505	434,346	493,498
Change in research and development inventories	27,688	29,475	31,330	39,494	33,781	47,208	4,926	55,697	47,150	15,629
Research and development fixed investment	19,815	27,688	29,475	31,330	39,496	44,736	47,208	52,134	55,697	57,529
Consumption of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	21,448	23,744	26,250	28,858
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	390,712	432,582	477,102	522,415
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	249,314	277,674	307,086	335,754
Private research and development expenditures	**18,456**	**20,398**	**22,708**	**30,732**	**35,382**	**37,553**	**41,598**	**44,373**	**45,517**	**47,140**
Cumulative research and development expenditures [1]	48,970	69,368	92,076	122,808	158,190	195,743	237,341	281,714	327,231	374,371
Change in research and development inventories	63,192	20,041	33,663	31,306	26,318	37,553	4,045	44,373	36,970	11,758
Research and development fixed investment	13,361	18,456	20,398	22,708	30,732	35,382	37,553	41,598	44,373	45,517
Consumption of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	14,760	16,725	18,862	21,079
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	270,720	306,128	343,739	381,931
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	180,799	205,661	231,119	255,580
Government research and development expenditures	**9,232**	**9,077**	**8,622**	**8,764**	**9,354**	**9,655**	**10,536**	**11,324**	**12,012**	**13,225**
Cumulative research and development expenditures [1]	30,551	39,783	48,860	57,482	66,246	75,600	85,255	95,791	107,115	119,127
Change in research and development inventories	–35,504	9,434	–2,333	8,188	7,463	9,655	881	11,324	10,180	3,871
Research and development fixed investment	6,454	9,232	9,077	8,622	8,764	9,354	9,655	10,536	11,324	12,012
Consumption of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6,688	7,019	7,388	7,779
Gross stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	119,992	126,454	133,363	140,484
Net stock of research and development fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	68,515	72,013	75,967	80,174
Addenda:										
Average age, in years, of R&D gross fixed intangible capital	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.6	6.5	6.5	6.5
Private	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.0	5.9	5.9	6.0
Government	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.9	7.9	8.0	8.0
Government and business net fixed reproducible tangible capital [2]	3,702,100	3,845,700	4,007,200	4,155,900	4,299,300	4,430,200	4,593,500	4,749,000	4,905,900	5,079,800

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Research and development expenditures	**65,886**	**70,504**	**73,327**	**77,442**	**79,113**	**79,854**	**79,733**	**75,668**	**73,344**	**73,970**
Cumulative research and development expenditures [1]	559,384	629,888	703,215	780,657	859,770	939,624	1,019,357	1,095,025	1,168,369	1,242,339
Change in research and development inventories	66,243	59,549	72,751	75,551	79,113	70,199	79,733	73,836	63,990	74,094
Research and development fixed investment	60,365	65,886	70,504	73,327	77,442	79,113	79,854	79,733	75,668	73,344
Consumption of research and development fixed intangible capital	31,547	34,423	37,527	40,765	44,085	47,461	50,800	54,020	56,941	59,493
Gross stock of research and development fixed intangible capital	569,675	621,255	676,436	732,803	791,295	850,214	908,392	964,142	1,013,144	1,057,120
Net stock of research and development fixed intangible capital	364,615	396,042	429,103	461,585	494,897	526,509	555,591	581,351	600,037	613,820
Private research and development expenditures	**50,916**	**53,811**	**55,441**	**58,774**	**59,774**	**60,737**	**60,529**	**56,987**	**54,794**	**55,451**
Cumulative research and development expenditures [1]	425,287	479,098	534,539	593,313	653,087	713,824	774,353	831,340	886,134	941,585
Change in research and development inventories	51,149	44,747	54,924	65,371	59,774	85,909	60,529	63,205	78,471	55,365
Research and development fixed investment	47,140	50,916	53,811	55,441	58,774	59,774	60,737	60,529	56,987	54,794
Consumption of research and development fixed intangible capital	23,341	25,717	28,233	30,817	33,459	36,132	38,758	41,278	43,534	45,465
Gross stock of research and development fixed intangible capital	421,181	463,341	507,677	552,534	599,413	645,964	691,943	735,650	773,498	806,818
Net stock of research and development fixed intangible capital	279,419	304,570	330,207	354,769	380,066	403,700	425,706	445,013	458,443	467,717
Government research and development expenditures	**14,970**	**16,693**	**17,886**	**18,668**	**19,339**	**19,117**	**19,204**	**18,681**	**18,550**	**18,519**
Cumulative research and development expenditures [1]	134,097	150,790	168,676	187,344	206,683	225,800	245,004	263,685	282,235	300,754
Change in research and development inventories	15,094	14,802	17,827	10,180	19,339	–15,710	19,204	10,631	–14,481	18,729
Research and development fixed investment	13,225	14,970	16,693	17,886	18,668	19,339	19,117	19,204	18,681	18,550
Consumption of research and development fixed intangible capital	8,206	8,706	9,294	9,948	10,626	11,329	12,042	12,742	13,407	14,028
Gross stock of research and development fixed intangible capital	148,494	157,914	168,759	180,269	191,882	204,250	216,449	228,492	239,646	250,302
Net stock of research and development fixed intangible capital	85,196	91,472	98,896	106,816	114,831	122,809	129,885	136,338	141,594	146,103
Addenda:										
Average age, in years, of R&D gross fixed intangible capital	6.5	6.6	6.6	6.7	6.8	6.9	7.0	7.2	7.4	7.6
Private	6.0	6.1	6.3	6.4	6.5	6.7	6.9	7.1	7.3	7.6
Government	7.9	7.8	7.7	7.6	7.4	7.4	7.4	7.4	7.5	7.6
Government and business net fixed reproducible tangible capital [2]	5,271,700	5,478,000	5,720,200	5,978,100	6,217,200	6,478,400	6,736,100	6,957,700	7,187,800	7,434,400

See footnotes at end of table.

Table 1.2.—Research and Development Expenditures, Investment, and Stock by Performer in Constant Dollars—Continued

[Millions of 1987 dollars]

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Research and development expenditures	**74,773**	**74,530**	**72,922**	**75,476**	**77,932**	**81,067**	**85,503**	**89,660**	**94,747**	**99,312**
Cumulative research and development expenditures [1]	1,317,112	1,391,642	1,464,564	1,540,040	1,617,972	1,699,039	1,784,542	1,874,202	1,968,949	2,068,261
Change in research and development inventories	72,882	74,471	64,434	75,476	43,105	81,067	77,453	56,629	94,957	90,824
Research and development fixed investment	73,970	74,773	74,530	72,922	75,476	77,932	81,067	85,503	89,660	94,747
Consumption of research and development fixed intangible capital	61,804	63,954	65,915	67,602	69,092	70,514	71,888	73,286	74,758	76,345
Gross stock of research and development fixed intangible capital	1,098,707	1,137,821	1,173,343	1,203,353	1,232,252	1,259,927	1,286,892	1,314,738	1,343,574	1,374,495
Net stock of research and development fixed intangible capital	626,039	636,843	645,486	650,799	657,202	664,625	673,792	686,000	700,876	719,288
Private research and development expenditures	**56,262**	**56,084**	**54,516**	**56,896**	**59,352**	**61,864**	**65,704**	**69,938**	**74,906**	**79,189**
Cumulative research and development expenditures [1]	997,847	1,053,931	1,108,447	1,165,343	1,224,695	1,286,559	1,352,263	1,422,201	1,497,107	1,576,296
Change in research and development inventories	62,859	56,463	46,604	56,896	27,251	61,864	58,151	39,258	75,093	71,277
Research and development fixed investment	55,451	56,262	56,084	54,516	56,896	59,352	61,864	65,704	69,938	74,906
Consumption of research and development fixed intangible capital	47,190	48,787	50,233	51,454	52,521	53,560	54,581	55,636	56,796	58,112
Gross stock of research and development fixed intangible capital	838,230	867,638	894,101	915,897	937,072	957,757	977,862	999,069	1,022,102	1,047,870
Net stock of research and development fixed intangible capital	476,027	483,483	489,358	492,428	496,810	502,612	509,876	519,950	533,057	549,858
Government research and development expenditures	**18,511**	**18,446**	**18,406**	**18,580**	**18,580**	**19,203**	**19,799**	**19,722**	**19,841**	**20,123**
Cumulative research and development expenditures [1]	319,265	337,711	356,117	374,697	393,277	412,480	432,279	452,001	471,842	491,965
Change in research and development inventories	10,023	18,008	17,830	18,580	15,854	19,203	19,302	17,371	19,864	19,547
Research and development fixed investment	18,519	18,511	18,446	18,406	18,580	18,580	19,203	19,799	19,722	19,841
Consumption of research and development fixed intangible capital	14,614	15,167	15,682	16,148	16,571	16,954	17,307	17,650	17,962	18,233
Gross stock of research and development fixed intangible capital	260,477	270,183	279,242	287,456	295,180	302,170	309,030	315,669	321,472	326,625
Net stock of research and development fixed intangible capital	150,012	153,360	156,128	158,371	160,392	162,013	163,916	166,050	167,819	169,430
Addenda:										
Average age, in years, of R&D gross fixed intangible capital	7.8	8.0	8.3	8.5	8.6	8.8	8.9	8.9	9.0	9.0
Private	7.8	8.1	8.3	8.5	8.7	8.8	8.9	9.0	9.0	8.9
Government	7.8	7.9	8.1	8.3	8.4	8.6	8.7	8.8	8.9	9.0
Government and business net fixed reproducible tangible capital [2]	7,715,000	7,944,800	8,099,500	8,277,200	8,511,100	8,791,700	9,088,600	9,320,700	9,532,000	9,665,800

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Research and development expenditures	**104,707**	**113,433**	**121,871**	**124,769**	**127,390**	**130,427**	**132,253**	**136,493**	**140,435**	**141,410**
Cumulative research and development expenditures [1]	2,172,968	2,286,401	2,408,272	2,533,041	2,660,431	2,790,858	2,923,111	3,059,604	3,200,039	3,341,449
Change in research and development inventories	104,269	112,857	121,871	122,043	127,390	129,930	129,902	136,516	139,859	141,331
Research and development fixed investment	99,312	104,707	113,433	121,871	124,769	127,390	130,427	132,253	136,493	140,435
Consumption of research and development fixed intangible capital	78,080	80,004	82,266	84,962	87,923	90,991	94,179	97,463	100,868	104,450
Gross stock of research and development fixed intangible capital	1,407,407	1,443,719	1,486,946	1,536,885	1,588,302	1,641,320	1,696,480	1,752,683	1,812,302	1,874,989
Net stock of research and development fixed intangible capital	740,530	765,220	796,389	833,320	870,166	906,578	942,794	977,584	1,013,185	1,049,195
Private research and development expenditures	**83,704**	**91,444**	**98,881**	**100,935**	**103,336**	**105,700**	**106,732**	**110,545**	**114,508**	**115,186**
Cumulative research and development expenditures [1]	1,660,000	1,751,444	1,850,325	1,951,260	2,054,596	2,160,296	2,267,028	2,377,573	2,492,081	2,607,267
Change in research and development inventories	83,345	90,868	98,881	98,209	103,336	105,203	104,381	110,568	113,932	115,107
Research and development fixed investment	79,189	83,704	91,444	98,881	100,935	103,336	105,700	106,732	110,545	114,508
Consumption of research and development fixed intangible capital	59,603	61,283	63,275	65,668	68,295	71,016	73,845	76,736	79,720	82,877
Gross stock of research and development fixed intangible capital	1,076,064	1,107,406	1,145,278	1,189,429	1,234,684	1,281,684	1,330,414	1,379,599	1,431,891	1,487,428
Net stock of research and development fixed intangible capital	569,459	591,878	620,050	653,290	685,930	718,264	750,086	780,075	810,869	842,526
Government research and development expenditures	**21,003**	**21,989**	**22,990**	**23,834**	**24,054**	**24,727**	**25,521**	**25,948**	**25,927**	**26,224**
Cumulative research and development expenditures [1]	512,968	534,957	557,947	581,781	605,835	630,562	656,083	682,031	707,958	734,182
Change in research and development inventories	20,924	21,989	22,990	23,834	24,054	24,727	25,521	25,948	25,927	26,224
Research and development fixed investment	20,123	21,003	21,989	22,990	23,834	24,054	24,727	25,521	25,948	25,927
Consumption of research and development fixed intangible capital	18,477	18,721	18,991	19,294	19,628	19,975	20,334	20,727	21,148	21,573
Gross stock of research and development fixed intangible capital	331,343	336,313	341,668	347,456	353,618	359,636	366,066	373,084	380,411	387,561
Net stock of research and development fixed intangible capital	171,071	173,342	176,339	180,030	184,236	188,314	192,708	197,509	202,316	206,669
Addenda:										
Average age, in years, of R&D gross fixed intangible capital	8.9	8.9	8.8	8.6	8.5	8.4	8.4	8.3	8.2	8.2
Private	8.9	8.8	8.7	8.5	8.4	8.3	8.2	8.1	8.1	8.1
Government	9.1	9.1	9.1	9.1	9.1	9.0	9.0	8.9	8.8	8.8
Government and business net fixed reproducible tangible capital [2]	9,833,800	10,088,700	10,381,100	10,666,800	10,937,900	11,203,700	11,462,000	11,696,700	11,856,200	12,019,600

n.a. Not available.

1. Cumulative since 1929.

2. Business fixed reproducible tangible capital includes capital owned by nonprofit institutions.

Table 2.1.—Research and Development Expenditures by Performer, Showing Source of Funds

[Millions of dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**13,735**	**20,343**	**26,765**	**36,794**	**65,185**	**115,435**	**127,390**	**134,880**	**142,918**	**153,448**	**162,818**	**169,308**
Private	**11,440**	**16,026**	**20,715**	**28,160**	**51,587**	**94,146**	**103,336**	**109,042**	**115,098**	**123,782**	**131,774**	**136,922**
By industry	10,606	13,883	17,858	24,124	44,507	83,663	90,898	95,590	100,679	108,246	115,328	119,508
From industry [1]	4,465	6,473	10,425	15,975	31,293	57,839	62,033	67,322	74,293	82,444	91,321	97,296
From Federal Government	6,137	7,406	7,420	8,114	13,155	25,748	28,766	28,153	26,273	25,690	23,898	22,105
From State and local governments	4	4	13	35	59	76	99	115	113	112	109	107
By FFRDC's administered by industry	n.a.	373	473	727	1,277	1,863	2,351	2,538	2,632	2,764	2,722	2,746
From Federal Government	n.a.	373	473	727	1,277	1,863	2,351	2,538	2,632	2,764	2,722	2,746
By private universities and colleges	335	674	987	1,333	2,296	3,398	4,212	4,639	5,044	5,440	5,773	6,169
From industry	16	17	27	47	102	230	303	335	370	400	424	453
From Federal Government	261	558	788	1,030	1,803	2,537	3,093	3,383	3,635	3,882	4,083	4,386
From State and local governments	7	11	24	35	46	73	100	115	128	137	141	136
From private universities and colleges	17	37	63	83	173	297	374	414	464	523	591	631
From other [2]	34	51	85	138	172	261	342	392	447	498	534	563
By FFRDC's administered by private universities and colleges [3]	208	375	462	662	1,380	1,936	2,383	2,585	2,683	2,750	2,849	2,844
From Federal Government	206	375	459	658	1,377	1,919	2,370	2,572	2,672	2,739	2,834	2,827
From other	2	0	3	4	3	17	13	13	11	11	15	17
By FFRDC's administered by private nonprofit institutions	68	202	261	241	476	707	590	567	584	652	740	821
From Federal Government	67	200	248	224	443	657	549	527	543	607	688	764
From other	1	2	13	17	33	50	41	40	41	45	52	57
By other nonprofit institutions [4]	223	519	674	1,073	1,651	2,579	2,902	3,123	3,476	3,930	4,362	4,834
From industry	48	62	92	123	198	356	467	517	587	655	717	752
From Federal Government	107	335	421	687	1,062	1,569	1,624	1,681	1,849	2,133	2,403	2,752
From State and local governments	2	2	4	14	17	19	35	43	39	35	35	35
From other	66	120	157	249	374	635	776	882	1,001	1,107	1,207	1,295
Government	**2,295**	**4,317**	**6,050**	**8,634**	**13,598**	**21,289**	**24,054**	**25,838**	**27,820**	**29,666**	**31,044**	**32,386**
By Federal Government [5]	1,746	3,149	4,170	5,616	8,098	12,513	13,334	14,005	14,818	15,542	15,856	16,340
By State and local governments (excluding universities and colleges)	54	87	176	297	446	613	710	816	866	909	946	991
From Federal Government	26	38	82	131	157	175	140	192	234	245	255	267
From State and local governments	26	47	90	156	274	426	557	611	615	646	672	704
From other	2	2	4	10	15	12	13	13	17	18	19	20
By State and local universities and colleges	335	834	1,411	2,287	4,076	6,432	8,020	8,937	9,973	10,958	11,886	12,740
From industry	23	23	37	73	157	372	507	570	663	752	811	874
From Federal Government	167	545	893	1,405	2,475	3,517	4,242	4,752	5,230	5,666	6,129	6,707
From State and local governments	79	131	205	313	466	718	931	1,015	1,122	1,234	1,336	1,360
From State and local universities and colleges	47	91	191	356	729	1,385	1,827	2,019	2,301	2,577	2,807	2,928
From other [2]	19	44	85	140	249	440	513	581	657	729	803	871
By FFRDC's administered by governments	160	247	293	434	978	1,731	1,990	2,080	2,163	2,257	2,356	2,315
From Federal Government	160	247	293	432	967	1,706	1,971	2,059	2,135	2,226	2,325	2,285
From other	0	0	0	2	11	25	19	21	28	31	31	30

n.a. Not separately available, included in industry.

1. Includes funds from nonprofit institutions and from the rest of the world.
2. Includes funds from nonprofit institutions.
3. Includes FFRDC's administered by consortia of public and private universities and colleges.
4. Nonprofit institutions are divided into four subgroups: Private universities and colleges, FFRDC's administered by universities and colleges, FFRDC's administered by nonprofit institutions, and other nonprofit institutions.
5. Includes R&D performed at Federal universities and colleges.

NOTE.—This table shows R&D expenditures and the breakdown of expenditures by private organizations and government organizations. Within the "private" and "government" categories, lines preceded by the word "by" are "performers." Within "performer" categories, lines preceded by the word "from" are "sources."

FFRDC Federally funded research and development center

Table 2.2.—Domestically Funded Research and Development Expenditures by Source of Funds, Showing Performer

[Millions of dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Domestically funded research and development expenditures, total	**13,788**	**20,375**	**26,813**	**38,312**	**68,658**	**119,316**	**132,922**	**141,607**	**150,382**	**161,659**	**172,314**	**179,573**
Private expenditures [1]	**4,693**	**6,831**	**10,991**	**18,315**	**36,045**	**64,184**	**70,627**	**77,395**	**85,393**	**94,940**	**105,672**	**112,840**
From industry	4,552	6,575	10,581	17,672	35,015	62,447	68,536	75,039	82,727	91,978	102,420	109,356
To industry	4,465	6,473	10,425	15,975	31,293	57,839	62,033	67,322	74,293	82,444	91,321	97,296
To State and local universities and colleges	23	23	37	73	157	372	507	570	663	752	811	874
To private universities and colleges	16	17	27	47	102	230	303	335	370	400	424	453
To other private nonprofit institutions [2]	48	62	92	123	198	356	467	517	587	655	717	752
To foreign affiliates	n.a.	n.a.	n.a.	1,454	3,265	3,650	5,226	6,295	6,814	7,727	9,147	9,981
From private universities and colleges	17	37	63	83	173	297	374	414	464	523	591	631
To private universities and colleges	17	37	63	83	173	297	374	414	464	523	591	631
From other	124	219	347	560	857	1,440	1,717	1,942	2,202	2,439	2,661	2,853
To State and local universities and colleges	19	44	85	140	249	440	513	581	657	729	803	871
To private universities and colleges	34	51	85	138	172	261	342	392	447	498	534	563
To other private nonprofit institutions	66	120	157	249	374	635	776	882	1,001	1,107	1,207	1,295
To State and local governments	2	2	4	10	15	12	13	13	17	18	19	20
To FFRDC's	3	2	16	23	47	92	73	74	80	87	98	104
Government expenditures	**9,095**	**13,544**	**15,822**	**19,997**	**32,613**	**55,132**	**62,295**	**64,212**	**64,989**	**66,719**	**66,642**	**66,733**
From Federal	8,930	13,258	15,295	19,088	31,022	52,435	58,746	60,294	60,671	61,978	61,542	61,463
To industry	6,137	7,406	7,420	8,114	13,155	25,748	28,766	28,153	26,273	25,690	23,898	22,105
To Federal Government	1,746	3,149	4,170	5,616	8,098	12,513	13,334	14,005	14,818	15,542	15,856	16,340
To State and local governments	26	38	82	131	157	175	140	192	234	245	255	267
To State and local universities and colleges	167	545	893	1,405	2,475	3,517	4,242	4,752	5,230	5,666	6,129	6,707
To private universities and colleges	261	558	788	1,030	1,803	2,537	3,093	3,383	3,635	3,882	4,083	4,386
To FFRDC's	433	1,195	1,473	2,041	4,064	6,145	7,241	7,696	7,982	8,336	8,569	8,622
To other private nonprofit institutions	107	335	421	687	1,062	1,569	1,624	1,681	1,849	2,133	2,403	2,752
To foreign	53	32	48	64	208	231	306	432	650	484	349	284
From State and local [3]	165	286	527	909	1,591	2,697	3,549	3,918	4,318	4,741	5,100	5,270
To industry	4	4	13	35	59	76	99	115	113	112	109	107
To State and local governments	26	47	90	156	274	426	557	611	615	646	672	704
To State and local universities and colleges	126	222	396	669	1,195	2,103	2,758	3,034	3,423	3,811	4,143	4,288
To private universities and colleges	7	11	24	35	46	73	100	115	128	137	141	136
To other private nonprofit institutions	2	2	4	14	17	19	35	43	39	35	35	35
Addenda:												
Total domestic performers	13,735	20,343	26,765	36,794	65,185	115,435	127,390	134,880	142,918	153,448	162,818	169,308
Total foreign performers	53	32	48	1,518	3,473	3,881	5,532	6,727	7,464	8,211	9,496	10,265
Final expenditures	9,183	13,768	16,184	20,576	33,435	56,638	64,080	66,136	67,005	69,197	69,545	69,933
Intermediate expenditures	4,552	6,575	10,581	16,218	31,750	58,797	63,310	68,744	75,913	84,251	93,273	99,375
Gross domestic product	513,400	702,700	1,010,700	1,585,900	2,708,000	4,038,700	4,539,900	4,900,400	5,250,800	5,546,100	5,724,800	6,020,200
Final expenditures as a percent of gross domestic product	1.79	1.96	1.60	1.30	1.23	1.40	1.41	1.35	1.28	1.25	1.21	1.16
Intermediate expenditures as a percent of gross domestic product	0.89	0.94	1.05	1.02	1.17	1.46	1.39	1.40	1.45	1.52	1.63	1.65

n.a. Not available.

1. Includes funds from the rest of world.

2. Nonprofit institutions are divided into four subgroups: Private universities and colleges, FFRDC's administered by universities and colleges, FFRDC's administered by nonprofit institutions, and other nonprofit institutions.

3. Includes State and local universities and colleges.

NOTE.—This table shows R&D expenditures and the breakdown of expenditures by private organizations and government organizations. Within the "private" and "government" categories, lines preceded by the word "from" are "sources." Within "source" categories, lines preceded by the word "to" are "performers."

FFRDC Federally funded research and development center

Table 2.3.—Research and Development Expenditures by Type, Showing Performer

[Millions of dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**13,735**	**20,343**	**26,765**	**36,794**	**65,185**	**115,435**	**127,390**	**134,880**	**142,918**	**153,448**	**162,818**	**169,308**
Private	**11,440**	**16,026**	**20,715**	**28,160**	**51,587**	**94,146**	**103,336**	**109,042**	**115,098**	**123,782**	**131,774**	**136,922**
Industry	10,606	13,883	17,858	24,124	44,507	83,663	90,898	95,590	100,679	108,246	115,328	119,508
Private universities and colleges	335	674	987	1,333	2,296	3,398	4,212	4,639	5,044	5,440	5,773	6,169
FFRDC's not administered by governments	276	950	1,196	1,630	3,133	4,506	5,324	5,690	5,899	6,166	6,311	6,411
Other nonprofit institutions [1]	223	519	674	1,073	1,651	2,579	2,902	3,123	3,476	3,930	4,362	4,834
Government	**2,295**	**4,317**	**6,050**	**8,634**	**13,598**	**21,289**	**24,054**	**25,838**	**27,820**	**29,666**	**31,044**	**32,386**
Federal Government	1,746	3,149	4,170	5,616	8,098	12,513	13,334	14,005	14,818	15,542	15,856	16,340
State and local governments (excluding universities and colleges)	54	87	176	297	446	613	710	816	866	909	946	991
State and local universities and colleges	335	834	1,411	2,287	4,076	6,432	8,020	8,937	9,973	10,958	11,886	12,740
FFRDC's administered by governments	160	247	293	434	978	1,731	1,990	2,080	2,163	2,257	2,356	2,315
Basic research	**1,221**	**2,540**	**3,532**	**4,908**	**8,685**	**14,309**	**18,064**	**18,914**	**21,673**	**24,671**	**28,346**	**29,308**
Private	768	1,458	1,810	2,442	4,333	7,414	9,843	10,061	12,042	14,254	17,104	17,287
Industry	380	565	574	698	1,244	2,777	4,231	3,922	5,346	6,928	9,290	9,000
Private universities and colleges	255	577	840	1,091	1,723	2,589	3,147	3,198	3,444	3,712	3,952	4,212
FFRDC's not administered by governments	57	160	209	359	828	1,098	1,319	1,644	1,777	1,948	2,013	2,025
Other nonprofit institutions	76	156	187	294	538	950	1,146	1,297	1,475	1,666	1,849	2,050
Government	453	1,082	1,722	2,466	4,352	6,895	8,221	8,853	9,631	10,417	11,242	12,021
Federal Government	193	386	568	757	1,232	1,860	2,021	2,081	2,238	2,386	2,491	2,600
State and local governments	14	30	44	73	89	93	88	96	110	119	127	137
State and local universities and colleges	202	581	1,003	1,442	2,535	4,089	5,142	5,644	6,203	6,772	7,395	8,077
FFRDC's administered by governments	44	85	107	194	496	853	970	1,032	1,080	1,140	1,229	1,207
Applied research	**2,966**	**4,333**	**5,882**	**8,368**	**14,305**	**25,892**	**28,467**	**30,139**	**32,930**	**36,054**	**39,896**	**40,205**
Private	2,282	3,105	4,045	5,515	10,052	20,394	22,266	23,437	25,612	28,248	31,406	31,210
Industry	2,048	2,626	3,380	4,555	8,419	17,903	19,344	20,337	22,233	24,589	27,562	27,005
Private universities and colleges	67	79	117	207	435	623	823	1,117	1,249	1,343	1,427	1,543
FFRDC's not administered by governments	83	205	287	328	592	1,029	1,085	852	894	917	864	941
Other nonprofit institutions	84	195	261	425	606	839	1,014	1,131	1,236	1,399	1,553	1,721
Government	684	1,228	1,837	2,853	4,253	5,498	6,201	6,702	7,318	7,806	8,490	8,995
Federal Government	491	903	1,339	1,885	2,646	3,022	3,238	3,339	3,514	3,658	4,064	4,392
State and local governments	27	38	86	156	259	396	491	558	583	609	631	657
State and local universities and colleges	112	207	326	723	1,170	1,804	2,224	2,553	2,943	3,254	3,520	3,676
FFRDC's administered by governments	54	80	86	89	178	276	248	252	278	285	275	270
Development	**9,548**	**13,470**	**17,351**	**23,518**	**42,195**	**75,234**	**80,859**	**85,827**	**88,315**	**92,723**	**94,576**	**99,795**
Private	8,390	11,463	14,860	20,203	37,202	66,338	71,227	75,544	77,444	81,280	83,264	88,425
Industry	8,178	10,692	13,904	18,871	34,844	62,983	67,323	71,331	73,100	76,729	78,476	83,503
Private universities and colleges	13	18	30	35	138	186	242	324	351	385	394	414
FFRDC's not administered by governments	136	585	700	943	1,713	2,379	2,920	3,194	3,228	3,301	3,434	3,445
Other nonprofit institutions	63	168	226	354	507	790	742	695	765	865	960	1,063
Government	1,158	2,007	2,491	3,315	4,993	8,896	9,632	10,283	10,871	11,443	11,312	11,370
Federal Government	1,062	1,860	2,263	2,974	4,220	7,631	8,075	8,585	9,066	9,498	9,301	9,348
State and local governments	13	19	46	68	98	124	131	162	173	181	188	197
State and local universities and colleges	21	46	82	122	371	539	654	740	827	932	971	987
FFRDC's administered by governments	62	82	100	151	304	602	772	796	805	832	852	838

1. Nonprofit institutions are divided into four subgroups: Private universities and colleges, FFRDC's administered by universities and colleges, FFRDC's administered by nonprofit institutions, and other nonprofit institutions.

FFRDC Federally funded research and development center

Table 2.4.—Research and Development Expenditures by Performer, Showing Type

[Millions of dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**13,735**	**20,343**	**26,765**	**36,794**	**65,185**	**115,435**	**127,390**	**134,880**	**142,918**	**153,448**	**162,818**	**169,308**
Basic research	1,221	2,540	3,532	4,908	8,685	14,309	18,064	18,914	21,673	24,671	28,346	29,308
Applied research	2,966	4,333	5,882	8,368	14,305	25,892	28,467	30,139	32,930	36,054	39,896	40,205
Development	9,548	13,470	17,351	23,518	42,195	75,234	80,859	85,827	88,315	92,723	94,576	99,795
Private	**11,440**	**16,026**	**20,715**	**28,160**	**51,587**	**94,146**	**103,336**	**109,042**	**115,098**	**123,782**	**131,774**	**136,922**
Basic research	768	1,458	1,810	2,442	4,333	7,414	9,843	10,061	12,042	14,254	17,104	17,287
Applied research	2,282	3,105	4,045	5,515	10,052	20,394	22,266	23,437	25,612	28,248	31,406	31,210
Development	8,390	11,463	14,860	20,203	37,202	66,338	71,227	75,544	77,444	81,280	83,264	88,425
Industry	10,606	13,883	17,858	24,124	44,507	83,663	90,898	95,590	100,679	108,246	115,328	119,508
Basic research	380	565	574	698	1,244	2,777	4,231	3,922	5,346	6,928	9,290	9,000
Applied research	2,048	2,626	3,380	4,555	8,419	17,903	19,344	20,337	22,233	24,589	27,562	27,005
Development	8,178	10,692	13,904	18,871	34,844	62,983	67,323	71,331	73,100	76,729	78,476	83,503
Private universities and colleges	335	674	987	1,333	2,296	3,398	4,212	4,639	5,044	5,440	5,773	6,169
Basic research	255	577	840	1,091	1,723	2,589	3,147	3,198	3,444	3,712	3,952	4,212
Applied research	67	79	117	207	435	623	823	1,117	1,249	1,343	1,427	1,543
Development	13	18	30	35	138	186	242	324	351	385	394	414
FFRDC's not administered by governments	276	950	1,196	1,630	3,133	4,506	5,324	5,690	5,899	6,166	6,311	6,411
Basic research	57	160	209	359	828	1,098	1,319	1,644	1,777	1,948	2,013	2,025
Applied research	83	205	287	328	592	1,029	1,085	852	894	917	864	941
Development	136	585	700	943	1,713	2,379	2,920	3,194	3,228	3,301	3,434	3,445
Other nonprofit institutions [1]	223	519	674	1,073	1,651	2,579	2,902	3,123	3,476	3,930	4,362	4,834
Basic research	76	156	187	294	538	950	1,146	1,297	1,475	1,666	1,849	2,050
Applied research	84	195	261	425	606	839	1,014	1,131	1,236	1,399	1,553	1,721
Development	63	168	226	354	507	790	742	695	765	865	960	1,063
Government	**2,295**	**4,317**	**6,050**	**8,634**	**13,598**	**21,289**	**24,054**	**25,838**	**27,820**	**29,666**	**31,044**	**32,386**
Basic research	453	1,082	1,722	2,466	4,352	6,895	8,221	8,853	9,631	10,417	11,242	12,021
Applied research	684	1,228	1,837	2,853	4,253	5,498	6,201	6,702	7,318	7,806	8,490	8,995
Development	1,158	2,007	2,491	3,315	4,993	8,896	9,632	10,283	10,871	11,443	11,312	11,370
Federal Government	1,746	3,149	4,170	5,616	8,098	12,513	13,334	14,005	14,818	15,542	15,856	16,340
Basic research	193	386	568	757	1,232	1,860	2,021	2,081	2,238	2,386	2,491	2,600
Applied research	491	903	1,339	1,885	2,646	3,022	3,238	3,339	3,514	3,658	4,064	4,392
Development	1,062	1,860	2,263	2,974	4,220	7,631	8,075	8,585	9,066	9,498	9,301	9,348
State and local governments (excluding universities and colleges)	54	87	176	297	446	613	710	816	866	909	946	991
Basic research	14	30	44	73	89	93	88	96	110	119	127	137
Applied research	27	38	86	156	259	396	491	558	583	609	631	657
Development	13	19	46	68	98	124	131	162	173	181	188	197
State and local universities and colleges	335	834	1,411	2,287	4,076	6,432	8,020	8,937	9,973	10,958	11,886	12,740
Basic research	202	581	1,003	1,442	2,535	4,089	5,142	5,644	6,203	6,772	7,395	8,077
Applied research	112	207	326	723	1,170	1,804	2,224	2,553	2,943	3,254	3,520	3,676
Development	21	46	82	122	371	539	654	740	827	932	971	987
FFRDC's administered by governments	160	247	293	434	978	1,731	1,990	2,080	2,163	2,257	2,356	2,315
Basic research	44	85	107	194	496	853	970	1,032	1,080	1,140	1,229	1,207
Applied research	54	80	86	89	178	276	248	252	278	285	275	270
Development	62	82	100	151	304	602	772	796	805	832	852	838

1. Nonprofit institutions are divided into four subgroups: Private universities and colleges, FFRDC's administered by universities and colleges, FFRDC's administered by nonprofit institutions, and other nonprofit institutions.

FFRDC Federally funded research and development center

Table 3.1.—Industry Research and Development Expenditures by Performing Industry

[Millions of dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Industry research and development expenditures, total [1]	**10,606**	**14,256**	**18,331**	**24,851**	**45,784**	**85,526**	**93,249**	**98,128**	**103,311**	**111,010**	**118,050**	**122,254**
Manufacturing industries	10,436	13,870	17,613	24,092	43,908	77,092	85,292	87,471	89,079	89,941	89,311	91,897
Food and kindred products	105	158	235	347	645	1,131	1,196	1,163	1,236	1,230	1,259	1,385
Chemicals and allied products	993	1,366	1,808	2,817	4,779	8,677	9,758	11,201	12,222	13,447	14,782	16,835
Petroleum refining and extraction [2]	300	400	528	727	1,636	2,296	1,942	2,042	2,232	2,357	2,541	2,372
Rubber and miscellaneous plastics products	122	163	281	483	678	717	635	854	1,073	1,493	1,394	1,511
Stone, clay, and glass products	89	113	170	243	424	852	1,014	720	633	557	471	499
Primary metal industries	179	214	280	455	747	798	738	643	693	746	719	558
Fabricated metal products	147	145	210	332	563	839	791	889	913	947	981	1,063
Industrial machinery and equipment	956	1,070	1,758	3,312	6,150	12,508	11,980	13,477	14,645	14,698	14,975	15,303
Electronic and other electric equipment	2,555	3,216	4,279	5,236	9,414	14,635	16,025	14,278	13,466	13,537	13,522	13,634
Transportation equipment	4,432	6,404	6,881	8,289	14,557	28,146	34,481	35,002	34,094	31,562	27,567	26,574
Aircraft and missiles	3,541	5,169	5,271	5,807	9,336	22,403	24,609	24,309	22,468	20,752	16,702	16,178
Other transportation equipment	891	1,235	1,610	2,482	5,221	7,341	9,872	10,693	11,626	10,810	10,865	10,396
Instruments and related products	333	406	759	1,218	3,152	5,125	5,314	5,623	6,097	7,170	8,815	9,752
Other manufacturing industries	225	215	424	633	1,163	1,368	1,418	1,579	1,775	2,197	2,285	2,411
Nonmanufacturing industries	170	386	718	759	1,876	6,836	7,957	10,657	14,232	21,069	28,739	30,357
Federal funding	**6,137**	**7,779**	**7,893**	**8,841**	**14,432**	**27,611**	**31,117**	**30,691**	**28,905**	**28,454**	**26,620**	**24,851**
Manufacturing industries	6,026	7,509	7,405	8,521	13,628	25,265	28,378	27,390	25,123	23,951	21,057	18,909
Food and kindred products	9	1	3	1	1	1	2	2	2	2	0	0
Chemicals and allied products	174	192	184	244	383	234	192	242	128	124	211	293
Petroleum refining and extraction [2]	20	48	23	47	159	36	14	22	18	17	11	9
Rubber and miscellaneous plastics products	38	22	72	163	217	46	30	109	150	378	279	162
Stone, clay, and glass products	8	3	11	20	5	7	10	10	6	9	10	15
Primary metal industries	15	8	10	22	139	58	19	17	20	22	8	13
Fabricated metal products	36	15	7	28	50	50	152	164	180	205	228	295
Industrial machinery and equipment	394	240	266	527	674	1,531	1,202	1,333	1,051	886	1,069	1,074
Electronic and other electric equipment	1,700	1,993	2,242	2,366	3,842	5,234	5,459	4,197	3,785	4,175	4,586	3,882
Transportation equipment	3,392	4,844	4,364	4,880	7,481	15,946	20,927	21,001	19,397	17,207	12,634	10,783
Aircraft and missiles	3,174	4,517	4,045	4,501	6,727	15,100	18,633	18,509	16,931	15,334	11,145	9,908
Other transportation equipment	218	326	318	375	744	829	2,284	2,483	2,456	1,863	1,483	870
Instruments and related products	155	133	198	179	596	400	277	194	268	749	1,889	2,249
Other manufacturing industries	79	6	9	5	6	10	2	9	26	97	88	104
Nonmanufacturing industries	111	269	489	320	805	2,355	2,739	3,301	3,782	4,501	5,562	5,942
Other funding	**4,469**	**6,477**	**10,438**	**16,010**	**31,352**	**57,915**	**62,132**	**67,437**	**74,406**	**82,556**	**91,430**	**97,403**
Manufacturing industries	4,410	6,361	10,208	15,571	30,280	51,827	56,914	60,081	63,956	65,990	68,254	72,988
Food and kindred products	96	157	232	346	644	1,130	1,194	1,161	1,234	1,228	1,259	1,385
Chemicals and allied products	819	1,174	1,624	2,573	4,396	8,443	9,566	10,959	12,094	13,323	14,571	16,542
Petroleum refining and extraction [2]	280	352	505	680	1,477	2,260	1,928	2,020	2,214	2,340	2,530	2,363
Rubber and miscellaneous plastics products	84	141	209	320	461	671	605	745	923	1,115	1,115	1,349
Stone, clay, and glass products	81	110	159	223	419	845	1,004	710	627	548	461	484
Primary metal industries	164	206	270	433	608	740	719	626	673	724	711	545
Fabricated metal products	111	130	203	304	513	789	639	725	733	742	753	768
Industrial machinery and equipment	562	830	1,492	2,785	5,476	10,977	10,778	12,144	13,594	13,812	13,906	14,229
Electronic and other electric equipment	855	1,223	2,037	2,870	5,572	9,401	10,566	10,081	9,681	9,362	8,936	9,752
Transportation equipment	1,040	1,560	2,517	3,409	7,076	12,200	13,554	14,001	14,697	14,355	14,933	15,791
Aircraft and missiles	367	652	1,226	1,306	2,609	7,303	5,976	5,800	5,537	5,418	5,557	6,270
Other transportation equipment	673	909	1,292	2,107	4,477	6,512	7,588	8,210	9,170	8,947	9,382	9,526
Instruments and related products	178	273	561	1,039	2,556	4,725	5,037	5,429	5,829	6,421	6,926	7,503
Other manufacturing industries	146	209	415	628	1,157	1,358	1,416	1,570	1,749	2,100	2,197	2,307
Nonmanufacturing industries	59	117	229	439	1,071	4,481	5,218	7,356	10,450	16,568	23,177	24,415

1. Includes research and development expenditures by FFRDC's administered by industry.
2. Petroleum refining and extraction includes oil and gas extraction, normally included under mining.
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Table 3.2.—Industry Expenditures on Research and Development Performed Outside the United States by U.S. Companies and Their Foreign Subsidiaries

[Millions of dollars]

	1974	1975	1980	1985	1987	1988	1989	1990	1991	1992
Total	**1,300**	**1,454**	**3,265**	**3,650**	**5,226**	**6,295**	**6,814**	**7,727**	**9,147**	**9,981**
Manufacturing industries	**1,297**	**1,450**	**3,258**	**3,632**	**5,162**	**6,200**	**6,706**	**7,613**	**8,369**	**9,121**
Food and kindred products	27	23	54	75	37	27	41	40	66	68
Chemicals and allied products	208	269	603	843	1,243	1,501	1,504	1,990	2,401	2,683
Petroleum refining and extraction	(1)	(1)	141	47	47	58	45	71	107	119
Stone, clay, and glass products	7	7	21	(D)	(D)	(D)	(D)	263	38	41
Primary metal industries	3	9	11	(D)	18	24	26	30	20	20
Fabricated metal products	(1)	(1)	33	21	40	(D)	46	65	86	98
Industrial machinery and equipment	258	331	599	689	1,233	1,364	1,515	1,580	1,476	1,450
Electronic and other electric equipment	238	245	451	591	432	669	574	671	651	554
Transportation equipment	406	412	1,020	1,025	(D)	1,801	(D)	2,153	2,402	(D)
Instruments and related products	39	49	186	169	317	393	449	563	656	700
Other manufacturing industries	111	105	139	125	138	145	179	187	467	(D)
Nonmanufacturing industries	**3**	**4**	**7**	**18**	**64**	**95**	**108**	**114**	**778**	**860**

1. Estimates included in "other manufacturing industries" for these years.
D Data are suppressed in order to avoid the disclosure of confidential information; estimates are included in totals.

NOTE.—Data on research and development performed outside the United States are not available prior to 1974.

Table 4.1.—Research and Development Expenditures by Performer in Constant Dollars

[Millions of 1987 dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**55,697**	**73,327**	**75,668**	**72,922**	**89,660**	**121,871**	**127,390**	**130,427**	**132,253**	**136,493**	**140,435**	**141,410**
Private	**44,373**	**55,441**	**56,987**	**54,516**	**69,938**	**98,881**	**103,336**	**105,700**	**106,732**	**110,545**	**114,508**	**115,186**
Industry [1]	40,489	47,942	49,101	47,134	61,364	89,550	93,249	95,252	95,959	99,392	103,045	103,405
Private universities and colleges	2,149	3,968	4,183	3,615	3,934	3,814	4,212	4,394	4,505	4,571	4,583	4,643
FFRDC's administered by private universities and colleges	679	1,147	1,117	1,144	1,796	2,025	2,383	2,526	2,517	2,492	2,494	2,414
FFRDC's administered by private nonprofit institutions	213	556	604	406	598	730	590	562	562	612	673	726
Other nonprofit institutions [2]	843	1,828	1,982	2,217	2,246	2,762	2,902	2,966	3,189	3,478	3,713	3,998
Government	**11,324**	**17,886**	**18,681**	**18,406**	**19,722**	**22,990**	**24,054**	**24,727**	**25,521**	**25,948**	**25,927**	**26,224**
Federal Government	8,720	12,539	12,118	11,286	11,138	13,202	13,334	13,494	13,803	13,905	13,684	13,763
State and local governments (excluding universities and colleges)	206	308	516	615	607	657	710	775	795	805	805	819
State and local universities and colleges	1,895	4,356	5,388	5,802	6,742	7,318	8,020	8,406	8,847	9,138	9,304	9,602
FFRDC's administered by governments	503	683	659	703	1,235	1,813	1,990	2,052	2,076	2,100	2,134	2,040

1. Includes FFRDC's administered by industry.
2. Nonprofit institutions are divided into four subgroups: Private universities and colleges, FFRDC's administered by universities and colleges, FFRDC's administered by nonprofit institutions, and other nonprofit institutions.
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Table 4.2.—Industry Research and Development Expenditures by Performing Industry in Constant Dollars

[Millions of 1987 dollars]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Industry research and development expenditures, total [1]	**40,489**	**47,942**	**49,101**	**47,134**	**61,364**	**89,550**	**93,249**	**95,252**	**95,959**	**99,392**	**103,045**	**103,405**
Manufacturing industries	**39,814**	**46,581**	**47,086**	**45,614**	**58,696**	**82,427**	**85,292**	**84,909**	**82,683**	**80,327**	**77,762**	**77,602**
Food and kindred products	429	561	659	700	908	1,176	1,197	1,131	1,159	1,123	1,115	1,186
Chemicals and allied products	3,849	4,703	4,971	5,507	6,532	9,212	9,758	10,886	11,380	11,998	12,784	14,087
Petroleum refining and extraction [2]	1,247	1,449	1,473	1,421	2,240	2,375	1,942	1,991	2,078	2,111	2,220	1,928
Rubber and miscellaneous plastics products	496	578	792	968	953	746	635	827	1,002	1,354	1,231	1,290
Stone, clay, and glass products	362	405	483	487	590	885	1,014	699	593	507	418	429
Primary metal industries	670	718	763	867	991	830	738	631	656	686	644	487
Fabricated metal products	555	489	567	643	763	874	791	871	863	869	878	926
Industrial machinery and equipment	3,530	3,433	4,451	5,918	7,791	13,016	11,980	13,098	13,320	12,712	12,834	12,881
Electronic and other electric equipment	9,480	10,399	11,077	9,658	12,444	15,470	16,025	13,804	12,371	11,901	11,711	11,507
Transportation equipment	17,018	21,709	18,629	15,859	19,592	31,028	34,481	33,950	31,818	28,480	24,099	22,404
Aircraft and missiles	13,298	17,221	13,901	10,796	12,296	23,424	24,609	23,626	21,012	18,697	14,547	13,514
Other transportation equipment	3,720	4,488	4,728	5,063	7,296	7,604	9,872	10,324	10,806	9,783	9,552	8,890
Instruments and related products	1,264	1,357	2,017	2,307	4,248	5,392	5,314	5,488	5,778	6,584	7,809	8,417
Other manufacturing industries	914	780	1,204	1,279	1,644	1,423	1,417	1,533	1,665	2,002	2,019	2,060
Nonmanufacturing industries	**675**	**1,361**	**2,015**	**1,520**	**2,668**	**7,123**	**7,957**	**10,343**	**13,276**	**19,065**	**25,283**	**25,803**

1. Includes research and development expenditures by FFRDC's administered by industry.
2. Petroleum refining and extraction includes oil and gas extraction, normally included under mining.
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Table 4.3.—Annual Average Full-Time-Equivalent Number of Research and Development Scientists and Engineers by Industry

[Thousands]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Total [1]	**302.1**	**348.4**	**375.6**	**363.9**	**469.2**	**646.8**	**702.2**	**714.4**	**725.6**	**717.5**	**741.7**	**783.2**
Manufacturing industries	(T)	**337.7**	**359.6**	**349.1**	**448.2**	**575.8**	**603.0**	(T)	(T)	(T)	(T)	**576.4**
Food and kindred products	5.0	6.2	6.4	6.9	7.3	(S)	(S)	(S)	(S)	8.0	9.6	9.9
Chemicals and allied products	36.6	37.9	41.4	44.8	53.1	73.5	75.5	76.7	78.3	78.9	82.2	87.4
Petroleum refining and extraction	9.1	8.8	9.6	8.5	11.9	12.0	9.7	9.9	10.3	10.1	10.8	11.5
Rubber and miscellaneous plastics products	5.4	5.8	6.9	8.5	(T)	(T)	(S)	(S)	(S)	(S)	(S)	14.9
Stone, clay, and glass products	(T)	3.3	4.4	4.6	5.5	7.1	8.6	8.6	8.6	8.5	6.8	5.3
Primary metal industries	6.9	5.5	6.5	7.2	8.0	6.4	5.6	5.7	(S)	(S)	(S)	5.0
Fabricated metal products	8.0	6.5	6.5	7.1	7.8	(S)	10.2	10.1	(S)	(S)	(S)	8.5
Industrial machinery and equipment	32.6	29.9	42.5	54.2	65.7	85.7	97.1	99.1	106.1	109.8	103.3	99.4
Electronic and other electric equipment	75.8	89.8	96.2	81.3	100.7	115.6	131.5	136.6	139.3	137.9	114.8	91.2
Transportation equipment	94.0	123.6	112.0	94.5	128.6	169.8	187.8	190.6	188.4	175.8	154.5	142.9
Aircraft and missiles	75.5	99.3	85.2	67.2	90.6	137.5	136.4	139.4	135.4	123.2	105.4	94.0
Other transportation equipment	18.5	24.4	26.8	27.4	38.1	32.3	51.4	51.2	53.0	52.6	49.1	49.0
Instruments and related products	10.6	12.0	15.1	18.4	33.8	(S)	(S)	(S)	(S)	(S)	(S)	79.4
Other manufacturing industries	(T)	8.4	12.1	13.1	(S)	(S)	16.2	15.5	(S)	(S)	(S)	21.3
Nonmanufacturing industries	(T)	**10.7**	**16.0**	**14.8**	**21.0**	**71.0**	**99.2**	(S)	(S)	(S)	(S)	**206.8**

1. Annual average.
S Data are not shown separately because more than 50 percent were imputed by National Science Foundation; estimates included in total.
T Data are not shown separately; estimates included in total.
n.a. Not available.

Table 5.1.—Implicit Price Deflators for Research and Development Expenditures by Performing Group

[Index numbers, 1987=100]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Research and development expenditures, total	**24.7**	**27.7**	**35.4**	**50.5**	**72.7**	**94.7**	**100.0**	**103.4**	**108.1**	**112.4**	**115.9**	**119.7**
Private	**25.8**	**28.9**	**36.4**	**51.7**	**73.8**	**95.2**	**100.0**	**103.2**	**107.8**	**112.0**	**115.1**	**118.9**
Industry [1]	26.2	29.7	37.3	52.7	74.6	95.5	100.0	103.0	107.7	111.7	114.6	118.2
Private universities and colleges	15.6	17.0	23.6	36.9	58.4	89.1	100.0	105.6	112.0	119.0	126.0	132.9
FFRDC's administered by private universities and colleges	30.7	32.7	41.4	57.9	76.8	95.6	100.0	102.3	106.6	110.4	114.3	117.8
FFRDC's administered by private nonprofit institutions	32.0	36.3	43.2	59.4	79.6	96.9	100.0	100.7	103.8	106.5	109.9	113.1
Other nonprofit institutions	27.5	30.2	36.1	50.1	74.8	94.1	100.0	104.6	108.2	112.0	116.3	119.7
Government	**20.3**	**24.1**	**32.4**	**46.9**	**69.0**	**92.6**	**100.0**	**104.5**	**109.0**	**114.3**	**119.7**	**123.5**
Federal Government	20.0	25.1	34.4	49.8	72.7	94.8	100.0	103.8	107.4	111.8	115.9	118.7
State and local governments (excluding universities and colleges)	26.4	28.4	34.0	48.4	73.5	93.4	100.0	105.3	109.0	113.0	117.5	120.9
State and local universities and colleges	17.7	19.1	26.2	39.4	60.5	87.9	100.0	106.3	112.7	119.9	127.7	132.7
FFRDC's administered by governments	31.8	36.1	44.5	61.7	79.2	95.4	100.0	101.3	104.2	107.5	110.4	113.5
Addendum:												
Gross domestic product	26.0	28.4	35.2	49.2	71.7	94.4	100	103.9	108.5	113.3	117.6	120.9

1. Includes research and development expenditures by FFRDC's administered by industry.
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Table 5.2.—Implicit Price Deflators for Industry Research and Development

[Index numbers, 1987=100]

	1960	1965	1970	1975	1980	1985	1987	1988	1989	1990	1991	1992
Industry research and development expenditures, total [1]	**26.2**	**29.7**	**37.3**	**52.7**	**74.6**	**95.5**	**100.0**	**103.0**	**107.7**	**111.7**	**114.6**	**118.2**
Manufacturing industries	**26.2**	**29.8**	**37.4**	**52.8**	**74.8**	**95.5**	**100.0**	**103.0**	**107.7**	**112.0**	**114.9**	**118.4**
Food and kindred products	24.5	28.2	35.7	49.6	71.0	96.2	100.0	102.8	106.6	109.5	112.9	116.8
Chemicals and allied products	25.8	29.0	36.4	51.2	73.2	94.2	100.0	102.9	107.4	112.1	115.6	119.5
Petroleum refining and extraction [2]	24.1	27.6	35.8	51.2	73.0	96.7	100.0	102.6	107.4	111.7	114.5	123.0
Rubber and miscellaneous plastics products	24.6	28.2	35.5	49.9	71.1	96.1	100.0	103.3	107.1	110.3	113.2	117.1
Stone, clay, and glass products	24.6	27.9	35.2	49.9	71.9	96.3	100.0	103.0	106.7	109.9	112.7	116.3
Primary metal industries	26.7	29.8	36.7	52.5	75.4	96.1	100.0	101.9	105.6	108.7	111.6	114.6
Fabricated metal products	26.5	29.7	37.0	51.6	73.8	96.0	100.0	102.1	105.8	109.0	111.7	114.8
Industrial machinery and equipment	27.1	31.2	39.5	56.0	78.9	96.1	100.0	102.9	109.9	115.6	116.7	118.8
Electronic and other electric equipment	27.0	30.9	38.6	54.2	75.7	94.6	100.0	103.4	108.9	113.7	115.5	118.5
Transportation equipment	26.0	29.5	36.9	52.3	74.3	95.9	100.0	103.1	107.2	110.8	114.4	118.6
Aircraft and missiles	26.6	30.0	37.9	53.8	75.9	95.6	100.0	102.9	106.9	111.0	114.8	119.7
Other transportation equipment	24.0	27.5	34.1	49.0	71.6	96.5	100.0	103.6	107.6	110.5	113.7	116.9
Instruments and related products	26.3	29.9	37.6	52.8	74.2	95.0	100.0	102.5	105.5	108.9	112.9	115.9
Other manufacturing industries	24.6	27.6	35.2	49.5	70.7	96.1	100.0	103.0	106.6	109.7	113.2	117.0
Nonmanufacturing industries	**25.2**	**28.4**	**35.6**	**49.9**	**70.3**	**96.0**	**100.0**	**103.0**	**107.2**	**110.5**	**113.7**	**117.6**

1. Includes research and development expenditures by FFRDC's administered by industry.
2. Petroleum refining and extraction includes oil and gas extraction, normally included under mining.
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