BEA's 2006 Research and Development Satellite Account

Preliminary Estimates of R&D for 1959–2002 Effect on GDP and Other Measures

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THE Bureau of Economic Analysis has been working on a research and development (R&D) satellite account since 2004 to help economists gain a better understanding of R&D activity and its effect on economic growth. This article introduces the 2006 satellite account, which provides preliminary estimates of R&D investment and the impact of R&D investment on such measures as gross domestic product (GDP), investment, and saving.

The full 2006 satellite account, released in September and accessible via <www.bea.gov/bea/newsrelarchive/2006/rdspend06.htm>, modifies the accounting conventions used in the national income and product accounts (NIPAs) in order to explore the impact of "capitalizing" R&D—that is, treating R&D spending as an investment rather than as an expense. The new account does not affect the official measure of GDP. Rather, the satellite account provides a framework to explore new methodologies and provide regularly updated estimates of R&D in preparation for future incorporation into the input-output (I-O) accounts and the NIPAs.

The R&D satellite account was developed in partnership with the National Science Foundation (NSF), the Federal agency that is responsible for producing R&D-related statistics for the United States. NSF provided funding for the R&D satellite account project, and its staff reviewed account methodologies and results. Using R&D expenditure data from the NSF, BEA developed estimates of R&D investment, the R&D, and the resulting macroeconomic effects for 1959–2002.[1] Revised estimates are scheduled to be released in September 2007.

The 2006 account measures the direct effect of R&D investment on final demand only; it does not include spillover effects. Spillovers—the economic benefits of R&D available to entities that did not pay to create the R&D—are not included in the national accounts framework because the national accounts value assets at their market value. This treatment is consistent with the treatment of other types of spillovers in the national accounts.

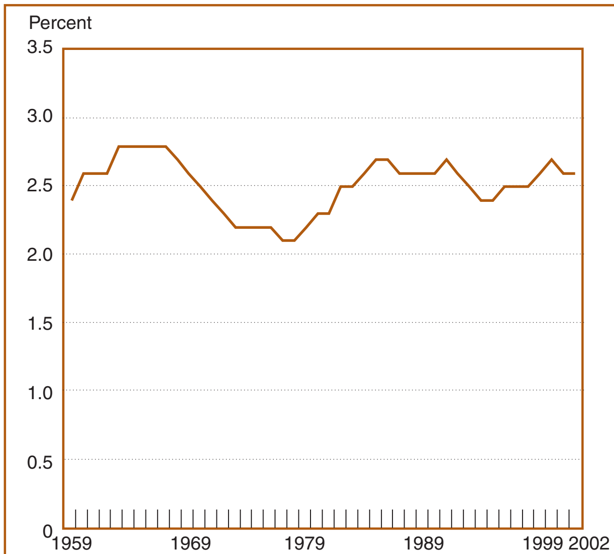
The new account makes clear that treating R&D as an investment would have a substantial impact on GDP and other measures. Highlights from the new satellite account include the following:

- Current-dollar investment in R&D totaled $276.5 billion in 2002.
- Recognizing R&D as investment would increase the level of current-dollar GDP by an average 2½ percent per year in 1959–2002 (chart 1).[2]

1. The NSF's Division of Science Resources Statistics annually publishes *National Patterns of Research and Development Resources*, which includes data based primarily on two annual NSF surveys: The Survey of Industrial R&D (SIRD or RD–1) and the Survey of Research and Development Expenditures at Universities and Colleges. Two additional annual surveys provide information on outlays and obligations by the Federal Government for R&D: The Survey of Federal Funds for R&D and the Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. The biennial Scientific and Engineering Research Facilities Survey provides information on construction plans and capital spending.

2. The results reported in the conclusions of this report are based on estimates that value real (inflation-adjusted) R&D at prices of products produced by R&D-intensive industries.

Chart 1. Current-Dollar R&D Investment as a Percent of Adjusted GDP, 1959–2002



NOTE. Adjusted GDP incorporates the impact of treating R&D as investment.

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- Businesses' investment in commercial and all other types of buildings would account for just over 2 percent of real GDP growth in 1995–2002.
- R&D investment and the income flows arising from accumulated R&D capital would account for about 4½ percent of real GDP growth in 1959–2002. In 1995–2002, R&D investment would account for about 6½ percent of growth.
- R&D investment would increase current-dollar gross private domestic investment in 2002 more than 11 percent, or $178 billion. The national saving rate in 2002 would be 16 percent, instead of 14 percent.
- Business investment in R&D as a percentage of GDP surpassed government investment as a percentage of GDP in 1981.
- Business investment accounted for just under 2 percent of current-dollar GDP in 2000, compared with just over 1 percent in 1960.

The release of the satellite account in September marks another step in BEA's efforts to adapt its measures of economic activity to structural changes in the economy (see the box "Previous NIPA Improvements Related to R&D"), particularly in the field of intangible assets. BEA plans several additional enhancements to the R&D satellite account in the near future: An improved treatment of the international aspects of R&D, improved measures of prices for R&D, and new industry-based estimates of R&D. Current plans, subject to available funding, call for the incorporation of R&D into the I-O accounts in 2012 and into the NIPAs in 2013.

The 2006 satellite account builds on the earlier work at BEA.[3] In 1994, BEA introduced the elements needed to translate R&D expenditures into investment, deflate investment, and develop R&D stock measures. In 2005, BEA went a step further and presented the general structure of the account along with rough estimates of the impact on GDP, gross domestic income (GDI), and national saving. The 2006 satellite account extends these previous efforts by exploring alternative scenarios that take into account the notable characteristics of R&D activity and by developing a more complete national accounts framework to estimate R&D activity.

In addition, BEA now recognizes the funder of R&D as the owner of R&D, that is, the entity that benefits from the activity; earlier versions focused on the performer of R&D. The change stems from the need to assign income flows to the economic sectors included in the national economic accounts. Assigning ownership from performer data is difficult because the performer is not necessarily the owner. Often, the original recipient of R&D funds may subcontract to others.

Measuring R&D as investment

Measuring the output of R&D activity presents well-known estimation challenges. Foremost among these challenges is the lack of market transactions for most R&D. Like other types of intangible investment, R&D investment is mainly created by firms and institutions for internal use; it is rarely sold on the open market. Therefore, for most of the R&D conducted in the United States, there is neither an observable market price nor a product that can be used to measure output.[4]

BEA's standard approach to estimating nonmarket activity—such as the output of government and nonprofit entities as well as goods that businesses create for their own use—is to measure the activity as the sum of input costs. In the case of R&D, this approach is made possible by detailed, 50-year time-series data collected by the NSF. However, the input-cost approach raises a critical issue: How to adjust this proxy measure of R&D output to account for changing prices? One of the methods conventionally used for nonmarket output is to apply input price indexes to these costs, thereby producing a measure of real output. Unfortunately, this approach seems ill-suited for measuring R&D: Deflation using input prices assumes that the output prices are changing at exactly the same rate as input costs, which precludes productivity gains that stem from R&D. In other words, this approach cannot account for multifactor productivity growth.

As a result, an input-price method would not reflect the dynamism of R&D activity. Products that embody a high level of R&D, such as computers and communication equipment, tend to have relatively short life cycles, paced by the rapid introduction of new, R&D-driven technologies. This relatively fast obsolescence means that the time period during which the costs of R&D must be recovered is short. In order to earn high rates of return, companies in R&D-intensive industries must raise the productivity of new products by lowering costs and increasing sales.

To account for these market dynamics, the 2006 R&D satellite account provides estimates for four R&D scenarios—scenarios A, B, C, and D. The scenarios differ in their assumptions in these areas: Price indexes, depreciation, rates of return to businesses, and rates of return to government and nonprofit institutions serving households.

3. See Carson, Grimm, and Moylan (1994). See also Fraumeni and Okubo (2005).

4. Census Bureau data for the R&D services industries provide estimates of market R&D, but this R&D is a relatively small share of total domestic R&D activity.

The rest of this article is organized as follows:

- The first section presents the new estimates of R&D investment activity and details the impact of R&D on such measures as real GDP. It introduces the four scenarios through which R&D is measured.
- The second section presents future initiatives to enhance the R&D satellite account.
- The third section discusses key conceptual and methodological issues that underlie the account.

This article also includes a list of references and tables of estimates from the 2006 R&D satellite account.

R&D and the Economy

This section discusses the current treatment of R&D in the NIPAs; new estimates of current-dollar R&D activity, the treatment of R&D in the 2006 satellite account, and the effect of R&D on key economic measures under the four scenarios.

Current treatment of R&D in BEA's accounts

Domestic R&D expenditures are currently only partly identifiable in BEA's accounts.

In the I-O accounts, the identifiable portion is based on data from the Census Bureau on establishments classified in the scientific research and development services industry. In BEA's GDP-by-industry accounts, estimates for the value added of this industry are included in a broader sector: Miscellaneous professional, scientific, and technical services. While Federal Government purchases of R&D are included in the I-O accounts, they are not separately identified.

In the NIPAs, Federal purchases of R&D are treated as government consumption, and spending on R&D by foundations and nonprofit institutions serving households are included in personal consumption expenditures (consumer spending). In addition, BEA's estimates of international trade in services provide measures of exports and imports of R&D services. BEA separately estimates royalties and licensing fees, which include transactions for the use of R&D protected by patents, considered payments for intermediate inputs.

Estimates of current-dollar R&D

To provide a more complete picture of R&D activity, the satellite account provides new R&D investment estimates derived from data from NSF (table A). The preliminary estimates shows that current-dollar investment in R&D totaled $276.5 billion in 2002, accounting for 2.6 percent of GDP (adjusted to include R&D as investment). Historically, the ratio of current-dollar R&D investment to current-dollar GDP rose in the mid-1960s, as the U.S. invested more in space-related technologies, and fell in the 1970s. The ratio trended upward again the early 1980s. Since 1990, the ratio has averaged 2.5 percent (chart 1).

Business and government. During the early era of space exploration in the mid-1960s, the R&D investment by government (Federal, state, and local governments) amounted to more than 2 percent of current-dollar GDP. Since 1960, Government R&D as a percentage of GDP has declined steadily since the 1960s, falling to a 0.8 percent of GDP in 2000. In that year, business-sector R&D investment equaled 1.8 percent of GDP.

Government's contribution to total R&D investment was also at its highest in the middle of the 1960s, when it funded almost three-quarters of all R&D investment (chart 2). By 1981, business funded more investment in R&D than government.

Funders and performers. The satellite account shows R&D activity by both funders and performers (table B). In the satellite account, government includes

Table A. NSF Survey Data on Expenditures and Methods Used for Current-Dollar R&D Investment

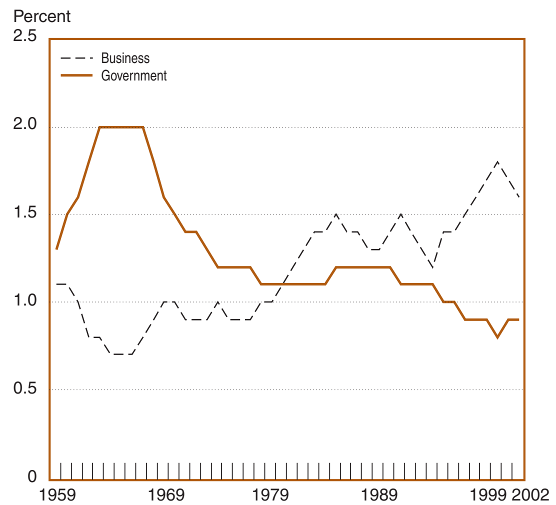
Steps		Method	Impact on investment
1	Align the survey data on expenditures for labor, material, and supplies with *Frascati*-defined R&D	Add expenditures for R&D in social sciences and the humanities. Subtract expenditures for commercialization	Increases Decreases
2	Adjust the survey data for consistency with the NIPAs	Convert data from a fiscal year to a calendar year Subtract expenditures for foreign performers	Increases or decreases Decreases
3	Adjust the data for the double-counting of capital	Subtract capital expenditures for purchase of structures, equipment, and software	Decreases
4	Adjust the data to move from expenditures to the full value of investment	Add the consumption of fixed capital on structures, equipment, and software Add other taxes on production less production-related subsidies	Increases Increases
5	Adjust the data for imports of R&D	Add imported R&D to domestic investment	Increases
6	Adjust the data for exports of R&D	Subtract exported R&D from domestic investment	Decreases

NIPAs National income and product accounts
NSF National Science Foundation

public universities and colleges, and nonprofit institutions serving households includes private universities and colleges. The 2006 satellite account shows the marked decline in government-funded R&D, compared with business- and nonprofit-funded R&D in 1960–2002; government-funded R&D accounted for 35.5 percent of total R&D in 2002, compared with 57 percent in 1960. In contrast, the performer-based share of total R&D investment by business and government has not changed nearly as much.

Investment and saving. R&D investment has had a progressively greater impact on gross private domestic investment since 1960. In 2002, domestic investment would have been 11.3 percent higher if R&D were included, compared with 9.8 percent in 1990 and 7.5 percent in 1960 (table C). The national saving rate would have been 2.1 percentage points higher in 2002.

Chart 2. Current-Dollar R&D Investment Funded by Business and Government as a Percent of Adjusted GDP, 1959–2002



NOTE. Adjusted GDP incorporates the impact of treating R&D as investment.
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Table C. Impact on Gross Private Domestic Investment and the Saving Rate When R&D is Treated as Investment

	Gross private domestic investment [1]			National saving rate [2]		
	Unadjusted (billions)	Adjusted (billions)	Impact (percent)	Unadjusted (percent)	Adjusted (percent)	Impact (percentage points)
1960	78.9	84.8	7.5	21.0	23.1	2.1
1970	152.4	163.1	7.1	18.6	20.5	1.9
1980	479.3	512.0	6.8	19.7	21.6	1.9
1990	861.0	945.4	9.8	16.3	18.5	2.2
2002	1,582.1	1,760.4	11.3	14.2	16.3	2.1

1. Applies to all scenarios.
2. Calculated as the ratio of the sum of gross saving (from NIPA table 5.1) to the sum of gross national income expressed as a percent. Implemented using assumptions in scenario D.

Proposed treatment to capitalize R&D investment

Treating R&D as an investment, rather than as an expense, in the calculation of GDP and other accounts would require significant changes to current NIPA concepts and methodologies (table D). The estimated impact is largest in the business sector, but nonprofit institutions serving households and general government are also affected.

Business sector. Reclassifying business R&D expenditures as investment would lead to an increase in GDP equal to the value of the R&D expenditures. Currently, business expenditures on R&D are considered intermediate input expenditures, which are not included in GDP. The recognition of R&D as investment also affects business income and private consumption of fixed capital (CFC), both components of gross domestic income (GDI). Because R&D would no longer be considered an expense, gross business income (proprietors' income and corporate profits) would increase

Table B. Selected Summary Measures of R&D

[Percent based on current-dollar measures]

	1960	1965	1970	1975	1980	1985	1990	1995	1998	1999	2000	2001	2002
Funder-based R&D investment as a percent of adjusted GDP													
Business	1.1	0.7	1.0	0.9	1.1	1.5	1.4	1.4	1.6	1.7	1.8	1.7	1.6
Government	1.5	2.0	1.5	1.2	1.1	1.2	1.2	1.0	0.9	0.9	0.8	0.9	0.9
Nonprofit institutions serving households	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Funder-based R&D investment as a percent of total R&D													
Business	42.0	25.4	38.9	42.4	48.4	55.1	52.5	56.3	61.8	64.2	66.7	65.1	61.8
Government	57.0	73.3	59.6	56.0	49.9	43.2	45.2	41.1	35.7	33.4	30.8	32.4	35.5
Nonprofit institutions serving households	1.0	1.3	1.5	1.6	1.7	1.7	2.3	2.5	2.5	2.5	2.4	2.5	2.7
Performer-based R&D investment as a percent of total R&D													
Business	76.8	70.0	68.8	67.6	69.9	73.6	71.2	71.4	74.3	74.8	75.2	73.3	70.9
Government	17.2	21.4	22.3	23.8	20.8	18.4	19.3	18.5	16.6	16.0	15.3	16.5	18.2
Nonprofit institutions serving households	6.0	8.7	8.8	8.6	9.3	8.0	9.5	10.0	9.1	9.2	9.5	10.2	11.0

NOTES. Calculations are based on tables 1.2, 2.1, and 3.1.
Implemented using assumptions defined in Scenario D.
Numbers do not sum to 100 because of rounding.

by the elimination of the deduction for R&D expenditures.

Nonprofit institutions serving households and general government. In these two sectors, R&D expenditures would be reclassified from consumption expenditures to investment; because consumption expenditures are already part of GDP, this shift alone would not change the measure of GDP. However, recognizing these expenditures as investment would increase the measure of consumption by nonprofit institutions and general government by an amount equal to the value of the CFC (depreciation) of the R&D. Thus, GDP and GDI would increase correspondingly. This treatment is consistent with the current NIPA treatment of government and nonprofit investment in which the CFC of those assets serves as a partial measure of the services they provide. The featured estimates for this account also include a net return to government and nonprofit R&D capital in addition to CFC. Therefore, GDP would rise by an amount equal to the value of CFC plus the net return for government and nonprofit R&D investment.

The four scenarios

To further explore the effect of R&D activity on the economy, BEA constructed four R&D scenarios—scenarios A, B, C, and D. Each scenario adopts the sector-specific methodological changes outlined above, but each also attempts to capture some specific characteristics of R&D activity, such as relatively high productivity, rapid depreciation, and high rates of return.

The scenarios differ in regard to assumptions in four areas: Price indexes, depreciation, rates of return to businesses, and rates of return to government and nonprofit institutions (table E).

Price indexes. R&D investment is difficult to measure largely because most R&D is not bought and sold in markets. Typically, the companies that conduct the R&D are also the companies that use the R&D to produce new and/or better goods and services. Conceptually, the value of R&D to a company is equal to the discounted present value of the future benefits that the company derives from the R&D.

However, this value is embedded in the value of all the goods and services the company sells, and there is no direct measure of either the contribution of R&D to those sales or the market price underlying R&D assets. Companies can normally report what they spent on wages, salaries, contractors, and other costs of conducting R&D but not the market price of R&D. For computers, communications equipment, and other assets that are bought and sold in final goods markets,

Table D. Effects of Treating R&D as Investment in the National Accounts

	Gross domestic product (GDP)			Gross domestic income (GDI)	
Sector	Treatment in GDP	Adjusted GDP [1]	Change in GDP	Adjusted GDI [2]	Change in GDI
Business	Intermediate consumption	Reclassify to investment	Increase	Increase in business income equal to R&D investment less CFC Increase in CFC	Increase
Nonprofit institutions serving households	PCE	Reclassify to investment	Increase	Increase in returns to R&D capital	Increase
General government	Government consumption	Reclassify to investment	Increase	Increase in returns to R&D capital	Increase

1. Adjusted GDP incorporates the impact of treating R&D as investment.
2. Adjusted GDI incorporates the impact of treating R&D as investment.
Note. This table applies to all scenarios.

CFC Consumption of fixed capital
PCE Personal consumption expenditures

Table E. Assumptions for the Scenarios in the R&D Satellite Account

Parameter	Depreciation of R&D	Price index	Net return to business R&D	Net return to government and nonprofit R&D
Scenario A	15 percent	Input cost-component based	Same as other fixed assets	None
Scenario B	Before 1987: Change in private fixed investment in nonresidential equipment and software depreciation. After 1987: Information processing equipment depreciation.	Input price index adjusted with BLS multifactor productivity to proxy high-productivity growth in manufacturing.	Average net rate of 15 percent	Estimated net return based on long-term average in the 10-year real Treasury rate, plus a higher premium for R&D investment.
Scenario C	Same as scenario B	Composite price index based on the value added of five high-productivity service industries.	Same as scenario B	Same as scenario B
Scenario D	Same as scenario B	Composite price index based on the value added of the four manufacturing industries that perform the most R&D.	Same as scenario B	Same as scenario B

BLS Bureau of Labor Statistics

companies know the market price of the asset and its share of sales as well as the share of profits that came from the difference between the sales price and the cost of producing such assets. For these assets, it is straightforward to estimate real (inflation-adjusted) values by simply dividing the current-dollar value of these assets by a price index based on their sales.

However, for R&D, the value of the assets and their contribution to sales are indistinguishably bundled with those of the companies' overall assets. Therefore, the only available current-dollar value is the cost of their production. The issue then becomes how to deflate this current-dollar value to produce an estimate of real investment. Each scenario embodies a different deflations method:

- **Scenario A.** This scenario is perhaps the most straightforward way to estimate real R&D. It bases the measure of current-dollar R&D output on input costs and then deflates this output measure with the price index created from information on the cost components for R&D. This method is currently used by BEA to measure the value of real investment that companies create for their own use. The obvious drawback to this approach is that it necessarily implies zero productivity growth because real output, by definition, grows at the same rate as real inputs. Thus, this approach seems particularly inappropriate for measuring a dynamic sector like R&D.
- **Scenario B.** This scenario assumes that the value of real R&D output is higher than the value of real R&D inputs by the amount of productivity growth recorded in higher productivity industries. The price index used to calculate real output is calculated by subtracting average multifactor productivity (MFP) growth for a group of manufacturing industries with the highest MFP growth from the increase in the price indexes used in scenario A. This adjustment provides a cost-based index that reflects the high productivity growth of R&D.
- **Scenario C.** This scenario assumes that the value of real R&D output is proportional to the output prices of the most productive services industries.

Previous NIPA Improvements Related to R&D

The Bureau of Economic Analysis (BEA) continues to update the U.S. economic accounts to better reflect the evolving economy, with a focus on high-technology-oriented goods and services. This box summarizes two previous important improvements.

Hedonic indexes

In the mid-1980s, BEA introduced hedonic, or quality-adjusted, price indexes for computers and peripherals into the national income and product accounts (NIPAs). Since then, it has gradually introduced quality-adjusted indexes for other goods, including semiconductors and digital telephone equipment. Currently, approximately 20 percent of real gross domestic product (GDP) is deflated using quality-adjusted price indexes that rely at least partly on hedonic methods. Use of such methods has improved the estimates of real GDP and the value of real output of services industries that use information technology (IT).

Intangibles

BEA has long recognized that so-called intangible assets play a significant role in the economy. Like tangible assets, intangible assets are created from production processes and tend to be used in other processes of production. Examples include R&D, software, business processes, and business-specific training.

In 1999, BEA capitalized spending on computer software, treating it as investment in its calculation of GDP. BEA's proposed treatment of R&D investment, outlined in this article, largely mirrors BEA's current treatment of software. The inclusion of computer software as an investment has helped economists better explain the resurgence in economic growth in the last decade. Between 1995 and 2002, software's average contribution to the growth in real GDP was 5.0 percent. Between 1973 and 1994, its average contribution was 2.7 percent.

These innovations have provided the basis for better measures of IT-related industries and their contributions to economic growth. Indeed, Triplett and Bosworth have used improved BEA data on real industry output (GDP by industry) to show that services-producing industries "have emerged as the dominant engines of U.S. economic growth" over the past decade (Triplett and Bosworth 2004).

Improved measures of IT have also been useful to researchers analyzing multifactor productivity—the unexplained portion of economic growth that remains after the contributions of labor, capital, and intermediate inputs have been measured. Improvements in both concepts and measurement have helped to both lower the unexplained portion of economic growth and to explain the contributions of information technology to the increase in growth and multifactor productivity in the last decade.

Because intangible assets are increasingly important components of the knowledge economy, BEA has begun preliminary research on prototype accounts for health care, human capital, and education.

While services industries traditionally have lower productivity growth and higher inflation than the industries in the goods sector, key industries have a good record of producing high-productivity, declining relative prices and ever-increasing real output per unit of input. In this scenario, real R&D output is estimated using a weighted average of BEA's GDP-by-industry value-added price indexes of these high-productivity services industries: Air transportation, broadcasting and telecommunications, securities and commodity brokers, and information-processing and data-processing services.[5]

- **Scenario D.** This scenario assumes that the value of real R&D output is proportional to the output prices of R&D-intensive products. The prices of such products may be the best proxies for the value of the R&D embodied in these products. This index is calculated from price indexes for the largest R&D-performing manufacturing industries. Based on NSF industry performer data, these industries are chemicals, computer and electronic products, machinery, and aerospace and defense.

Depreciation. R&D capital does not wear out the way tangible goods do, but it clearly loses value over time because of obsolescence. It loses value as new innovations appear and as earlier R&D becomes relatively less effective in the production process. An additional loss could stem from the gradual leakage of information to competitors and the expiration of intellectual property protection.

For tangible assets, BEA typically uses empirical studies of markets for used assets to determine depreciation rates. This type of information is not available for R&D, but economists have estimated the range of average annual depreciation rates for business R&D to be between 12 and 25 percent.[6] For government and public universities and colleges, the depreciation rate is likely to be lower because the R&D is often concentrated in basic research, which is likely to obsolesce more slowly.

The assumed depreciation rate for scenario A, the most straightforward scenario, is 15 percent a year. Scenarios B, C, and D incorporate an alternative method that proxies the effect of a more rapid pace of technological change in recent years and thus an accelerating rate of depreciation. This faster rate of obsolescence is consistent with the work of Caballero and Jaffe (1993), whose work with patents found an accelerating rate of obsolescence in the 1990s, compared with earlier decades. Scenarios B, C, and D assume a depreciation rate before 1987 that is equal to the depreciation rate of overall investment in equipment and software. After 1987, the rate is assumed to be equal to the depreciation rate for information-processing equipment and software.[7] The resulting depreciation series starts at about 16 percent in 1959 and reaches about 23 percent in 2002.

Business rates of return. Studies have shown a fairly wide range of estimates of the rate of return for R&D (table F). Despite the wide range, the private rates of return are high relative to other investments. The total returns, which include spillovers, are higher still—about twice the corresponding private returns to the originators of the R&D. Many of these studies were performed in the late 1970s and 1980s. More recently, higher returns have been necessary to offset the increasing rates of technical obsolescence, faster depreciation, volatility, and risk that have occurred for products that embody R&D, such as computers, software, and other information-communications-technology products.

Table F. Summary of Estimated Gross Private and Total Rates of Return to R&D

[Rate of return, percent]

Source	Gross private rates of return	Total rates of return, including spillovers
Sveikauskas 1981	7–25	50
Bernstein and Nadiri 1988	10–27	11–111
Bernstein and Nadiri 1991	15–28	20–110
Nadiri 1993	20–30	50
Mansfield et al. 1977	25	56
Goto and Suzuki 1989	26	80
Terleckyj 1974	29	48–78
Scherer 1982,1984	29–43	64–147

Note. The gross private rate of return to R&D includes depreciation.
Source. Table 8.1 in Fraumeni and Okubo (2005).

Scenario A, the most straightforward of the scenarios, assumes an average rate of return to business R&D investment of 11 percent in 1959–2002, the same return earned by other private fixed assets. However, scenarios B, C, and D assume a higher average net rate of return, 15 percent.

Returns to government and nonprofit institutions. The current NIPA treatment does not include any net returns to fixed assets owned by governments

5. These indexes were used instead of producer price indexes from the Bureau of Labor Statistics (BLS) because, in most cases, the timespan for industry coverage by BLS is not long enough to enable the use of BLS producer price indexes as deflators. For example, the BLS producer price index for broadcast and telecom equipment—an industry that appears in the top five productive services index—is only available for 1991 forward. The R&D work requires an index that covers 1959 forward.

6. Pakes and Schankerman (1984) found the average annual decay rate of R&D to be 25 percent; Nadiri and Prucha (1996) estimated the annual depreciation rate of industrial R&D capital stock to be 12 percent. In 1996, Lev and Sougiannis estimated decay rates of R&D in six industries, finding a range of 12 to 20 percent and an average depreciation rate of 15 percent. Most recently, Bernstein and Mamuneaus (2004) calculated a 25-percent depreciation rate for the manufacturing sector.

7. Table I compares this faster depreciation rate to the 15-percent depreciation rate used in scenario A.

and nonprofit institutions serving households. It treats CFC (depreciation) of those assets as a partial measure of the services they provide; thus, the net return is zero by construction.

Scenario A adopts the current treatment; it does not account for any net returns to R&D investment by governments and nonprofit institutions serving households. However, scenarios B, C, and D assume a net return to R&D spending by government and nonprofit institutions equal to the average real rate on 10-year Treasury securities, adjusted to reflect a higher return to R&D relative to other types of investments. The additional returns in scenarios B, C, and D were deflated with a price index created for scenario B, the high-productivity services-sector industries.

Impact of R&D on key NIPA measures

BEA reports the estimates based on scenario D as the preliminary estimates for the 2006 R&D satellite account. These estimates approximate a midrange of the three high-productivity options. Estimates based on scenario D for real GDP, current-dollar GDP, real GDI, and the saving rate are presented in tables 1.1–1.4.

Scenario comparison

For analytical purposes, a look at each scenario's estimates is instructive, especially estimates of contributions to real GDP and real GDP growth.

Scenario A, which assumes no productivity growth, produces the smallest impact on GDP of the alternatives tested; in 1959–2002, R&D boosted current-dollar GDP by an annual average 2.3 percent (table G).

Table G. Impact on Current-Dollar GDP When R&D is Treated as Investment

	1960	1970	1980	1990	2002	Average in 1959–2002
	Billions of dollars					
GDP	526	1,039	2,790	5,803	10,470	
GDP in scenario A	536	1,064	2,852	5,944	10,734	
GDP in scenario B	537	1,069	2,859	5,963	10,751	
GDP in scenario C	538	1,067	2,856	5,962	10,744	
GDP in scenario D	538	1,069	2,857	5,962	10,747	
	Percent change in GDP					
Scenario A	1.8	2.5	2.3	2.4	2.5	2.3
Scenario B	2.1	2.9	2.5	2.8	2.7	2.6
Scenario C	2.2	2.8	2.4	2.7	2.6	2.6
Scenario D	2.2	2.9	2.4	2.7	2.7	2.6

NOTES. Scenario A uses an input price index.
Scenario B uses a multifactor productivity-adjusted price index.
Scenario C uses a high-productivity service industries price index.
Scenario D uses a top four R&D performers price index.
Source: Table 1.2.

The average contribution to real GDP growth was 2.2 percent (table H).

Table H. Average Percent of Real GDP Growth Attributed to Treating R&D as Investment Selected Periods

	1959–73	1974–94	1995–2002	1959–2002
Scenario A	2.3	1.8	2.7	2.2
Scenario B	4.5	4.7	6.8	4.9
Scenario C	3.9	3.9	6.3	4.3
Scenario D	4.0	4.3	6.7	4.6

NOTES. Scenario A uses an input price index.
Scenario B uses a multifactor productivity-adjusted price index.
Scenario C uses a high-productivity service industries price index.
Scenario D uses a top four R&D performers price index.

In scenarios B, C, and D—the high-productivity-growth scenarios—the average increase in the level of current-dollar GDP was 2.6 percent each. Scenarios B, C, and D also produce a relatively tight range of contributions to the growth in real GDP (table H). The largest contribution to growth (4.9 percent) in 1959–2002 comes from scenario B, which uses the high-MFP index. In scenario C, which uses the composite price index from the high-productivity services industries, the contribution in 1959–2002 averages 4.3 percent, and the contribution in 1995–2002 is 6.3 percent. Scenario D, which uses a composite price index for R&D performing industries, yields a similar overall contribution, 4.6 percent, and a similar contribution in 1995–2002, 6.7 percent.

Step-by-step comparisons

To get a clearer picture of the step-by-step impact of specific assumptions in each scenario, table I provides a decomposition of R&D's contribution to average real GDP growth for each scenario for 1995–2002 and 1959–2002. By looking down the columns and across the rows, the cumulative impact of each assumption can be seen.

Table I. Average Percent of Real GDP Growth Attributed to Treating R&D as Investment Decomposition, Selected Periods

	Depreciation		Depreciation and net return	
	1995–2002	1959–2002	1995–2002	1959–2002
Scenario A	2.7	2.2	n.a.	n.a.
Scenario A with accelerated depreciation rate[1]	2.8	2.4	n.a.	n.a.
Scenario B	6.5	4.4	6.8	4.9
Scenario C	6.1	3.8	6.3	4.3
Scenario D	6.5	4.1	6.7	4.6

n.a. Not available
1. Scenario A with accelerated depreciation is presented as an intermediate step to scenarios B, C, and D.
NOTES. Scenario A uses an input price index.
Scenario B uses a multifactor productivity-adjusted price index.
Scenario C uses a high-productivity service industries price index.
Scenario D uses a top four R&D performers price index.

Table I shows the contribution of R&D to real GDP growth for scenario A in two cases: (1) When the depreciation rate is assumed to be 15 percent and (2) when the depreciation rate is accelerated. Accelerating the depreciation rate results in a higher contribution to the average contribution to GDP growth in 1959–2002 and 1995–2002.

Scenarios B, C, and D also assume an accelerated depreciation rate; however, they include other changed assumptions as well: (1) Different output price indexes for deflation purposes and (2) a return for government and nonprofit institution capital services. The return for capital services includes both CFC and a net return, which are both deflated with the high-productivity services industries price index.

The average contributions for scenarios B,C, and D, given all assumptions, are shown in table I in the far right columns.

For scenario D, the featured estimates of the average R&D-related contributions to the average real GDP growth rate combine (1) the price-index impact that raises the contribution of R&D from 2.4 percent (scenario A) to 4.1 percent and (2) the impact of the net return component of capital services that raises the estimate from 4.1 percent to 4.6 percent in 1959–2002. Thus, the total increase in the contribution of R&D, 2.2 percentage points, is largely due to the selection of the output price index.

Future Initiatives

In the near future, BEA intends to explore a variety of issues related to R&D investment. These issues include international flows of R&D transactions, improved output measures, improved input deflators, the treatment of R&D spillovers, the ownership of R&D assets, and improved estimates of capital services for R&D.

International flows of R&D transactions

There are two dimensions of international transactions for R&D and a related category of payments for the use of R&D: International trade in research, development, and testing services; business funding of foreign-performed R&D; and royalties and licensing fees for the use of industrial processes.

BEA's R&D satellite account presents estimates of the stock of R&D located in the United States, regardless of the residence of the owner. The satellite account treats all domestically performed business R&D as producing U.S. assets and excludes R&D performed abroad by foreign affiliates of U.S. companies. This treatment implicitly assumes that the private benefits of R&D are obtained in the country where the R&D is performed. The stock estimates presented in this article are not adjusted for R&D investment by U.S. and foreign multinational companies or the exports and imports of research, development, and testing services. Adjustment for exports and imports of research, development, and testing services is planned for the 2007 R&D satellite account. Including R&D investment by multinationals requires data not currently available and remains a longer-term project.

Improved output measures, input deflators

In 2007, BEA plans to refine its methodology for measuring real R&D output. In particular, BEA intends to develop a methodology for weighting the relative importance of high R&D-performing industries. BEA also plans to develop improved R&D price deflators for the largest input cost: Compensation of R&D personnel in business. (These price deflators were used in scenario A.)

Over the longer term, a framework for including R&D in the U.S. industry accounts needs to be constructed. The goal is to develop a more detailed look at the composition of R&D costs across industries and to develop improved R&D deflators for compensation and the other input costs, with an emphasis on certain key industries such as computer manufacturing, electronic products, and pharmaceuticals. For example, the makeup of R&D personnel (scientists, engineers, technicians, and administrative support) or the nature of R&D physical capital investment and its depreciation may vary significantly across industries. The composition of an industry's R&D funding may also be used to develop improved R&D deflators, especially for those industries that have a high portion of their R&D funded by the Federal Government.

Treatment of R&D spillovers

Spillovers (externalities) exist when the social benefit (or cost) of an economic activity exceeds the private benefit (or cost). These spillovers are not currently included within the existing framework of the U.S. national accounts or the System of National Accounts (SNA), the internationally accepted national-accounts guidelines issued by the United Nations.

However, a satellite account—because it allows for the adjustment of national accounting conventions without changing the core accounts—can provide a means of exploring the effects of spillovers. Any potential experimental estimates of R&D spillovers will be included in the R&D satellite account—not the core GDP accounts.

Explicit identification of spillovers have not been included in the national accounting framework, because those accounts value assets at their private value, that is, the value of the asset to the owner.[8] The effects of spillovers are implicitly reflected in those market prices, but the national accounts do not attempt to estimate, for example, what share of economic growth is determined by the market value of computers. It does not include the efficiencies and value added (over and above the price paid for the computers) that accrue to the financial and other industries that use the computers. These spillovers form part of the unexplained multifactor residual in economic growth. Nonetheless, national economic accounting agencies, including BEA, recognize the interest in the value of R&D to society as a whole.

Although no attempt has been made to estimate the total impact of R&D, including spillovers, on economic growth, it is possible to infer the relative impact using studies of rates of return. If, as earlier studies have suggested, spillovers to other industries (and other firms in the same industry) are at least as large as the returns to the original investor, then R&D might account for a fifth of the 33 percent of economic growth between 1995 and 2002 that cannot be accounted for by conventional inputs and is described as multifactor or total factor productivity.

BEA's role in growth accounting continues to be to provide the data that other economists use to analyze the sources of economic growth. BEA intends to continue to explore the issue within the satellite account framework.

Ownership of R&D assets

The estimates presented in this satellite account assume that the funder of R&D owns the R&D. BEA plans to develop guidelines that can be applied to the existing survey data and that would use available information about the assignment of intellectual property rights—who has the right to patent and collect royalties—to refine its funder-based estimates of ownership of R&D. BEA also intends to refine the definition of R&D as an asset.

In the longer term, BEA will work with its data providers to align survey questions to the economic concepts necessary to identify ownership and location of use. Although some R&D produced by governments, nonprofits, and academic institutions may not be considered an economic asset in the final analysis, it is likely to have a measurable impact on economic activity; it is important that this type of R&D be reported separately.

Estimates of capital services for R&D

Capital services estimates would enhance the usefulness of the R&D capital stocks for productivity analysis purposes, but preliminary capital services estimates would likely be somewhat speculative because of the limited availability of price data for the use of R&D. Given the efforts to harmonize BEA statistics with those of the productivity program of BLS, developing capital services estimates for R&D is a high priority.

Other long-term improvements

R&D stocks by type. Estimating R&D stocks by basic research, applied research, and development of new products and processes would enhance the usefulness of the R&D satellite account. If BEA were able to create consistent time series of these stocks, an improved set of estimates could include depreciation rates that differ by type of R&D asset. BEA is exploring the issue.

Enhanced source data. Several long-term improvements to the R&D satellite accounts require improved survey data. For example, the estimates of CFC used in the production of R&D would be greatly improved by survey data on expenditures for structures, equipment, and software used in the production of R&D. Similarly, better data on the nature of the transaction between the funder and the performer of R&D would improve the assignment of R&D to sectors and the separation of domestic R&D investment from foreign R&D investment.

Alignment of data. As BEA considers incorporating R&D as investment in the NIPAs, an immediate challenge will be the alignment of NSF data and data from other sources with the industry classification systems used for enterprise and establishment data at BEA. BEA is currently working on developing an industry framework for R&D that will lead to industry-based estimates for R&D.

Timing. Currently, R&D surveys are conducted annually or less frequently, and the publication lag is usually between 1 and 2 years. For the NIPAs, quarterly estimates with a lag of 1 month after the end of the quarter are required.

Conceptual and Methodological Issues

For a more detailed discussion of the methodology, see "R&D Satellite Account: Preliminary Estimates" on BEA's Web site at <www.bea.gov/bea/newsrelarchive/2006/rdreport06.pdf>. Various highlights are discussed in this section.

Changes from previous versions

The methodologies used for the 2006 satellite account extend the methodologies used in the R&D estimates published in 1994 and the prototype account published in 2005. The 2006 satellite account includes R&D capital stocks and places R&D investment flows

8. Spillovers are not included in the value of investment in the NIPAs. However, their effects on production are captured in GDP.

and the income it generates within the accounts for GDP and the NIPA sectors.

Important methodological changes to real estimates over the period include the following:

- Chain-type price measures of real output and prices have been implemented, eliminating the overstatement of real R&D growth for periods after the base year and the understatement of real R&D growth for periods before the base year.
- For the input price index approach (scenario A), a new methodology for deflating business R&D has been developed; it uses price measures based on unpublished BEA industry accounts data from the scientific research and development services industry (NAICS 5417) instead of price measures for each industry. Also, a new methodology for deflating academic R&D has been developed; it uses an academic R&D price index developed by the National Center for Education Statistics.[9]
- Real R&D investment by source of funding is now presented.

Important changes to the capital stock measures include the following:

- A new measure of R&D capital stocks has been developed; it is based on the funder of the R&D that is performed, and it better approximates the ownership assumed for R&D capital.
- A geometric rate of depreciation is now used; it replaces the depreciation pattern based on a straight-line perpetual inventory method.

Scope of R&D investment

To define the scope of R&D investment, BEA evaluated two international standards: The United Nations System of National Accounts (SNA) and the Organisation for Economic Co-operation and Development's *Frascati Manual*. BEA selected the *Frascati* definition of R&D as currently implemented by NSF in its R&D surveys mainly because BEA relies on NSF source data. In addition, the *Frascati* definition is closely related to the new proposed international standard, making it easier to compare BEA's estimates with other countries' estimates. The quality that distinguishes the *Frascati* definition from the SNA definition is the requirement that R&D include "an appreciable element of novelty and the resolution of scientific and/or technical uncertainty" (OECD 2002). Innovative activity that does not involve novelty or technological uncertainty is not considered R&D in this definition.

Funders and performers

The aggregated investment measures for R&D are presented in the tables by major performer and major funder. The stocks of R&D are presented by funders.

The data are disaggregated into two major institutional categories: Private and government ("public") organizations. Several subcategories are also included. Private organizations consist of businesses; private universities and colleges; private hospitals, charitable foundations, and other nonprofit institutions serving households; and most Federally funded research and development centers (FFRDCs).[10] Government organizations consist of the Federal Government, state and local governments excluding universities and

9. This series ends in 1995; BEA extrapolates this academic R&D price index with NIPA personal consumption expenditures for education and research in 1996–2002 as the indicator.

10. FFRDCs are R&D organizations financed almost entirely by the Federal Government. They are shown separately and grouped with the entities that administer them in the performer-based presentation of investment (table 4.1). Grouping FFRDCs in the performing sector that administers them is consistent with the NIPAs. However, NSF reports that all FFRDC activities are more similar to Federal Government laboratories and classifies them as such. Since these institutions are by definition Federally funded, they are included with the government-funded investments and stocks of R&D.

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colleges, public universities and colleges, and FFRDCs administered by state and local governments, primarily public universities and colleges.

All estimates of current-dollar R&D investment are prepared by first compiling data available from the various NSF surveys and then by adjusting these data to be statistically and conceptually consistent with BEA definitions in the NIPAs. Performer-based estimates of real R&D expenditures are derived by deflating the most detailed current-dollar expenditures by appropriate price indexes. BEA develops real R&D capital stocks by treating the R&D expenditures as investment and aggregating them based on methodologies that BEA uses for other types of fixed assets.

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Tables 1.1 through 4.2 follow.