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STD/CSTAT/WPNA(2006)15

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

05-Oct-2006

English - Or. English

STATISTICS DIRECTORATE
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STD/CSTAT/WPNA(2006)15
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Working Party on National Accounts

CAPITALIZATION OF RESEARCH AND DEVELOPMENT:
Country experiences (satellite accounts, surveys, first estimates) - United States

To be held on 10-12 October 2006
Tour Europe - Paris la Défense
Beginning at 9:30 a.m. on the first day

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JT03215045

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I. Introduction

Economists have long sought a better understanding of research and development as a source of innovation and growth and therefore economic well-being. This interest was sparked in part by Robert Solow's path-breaking productivity work in the late 1950s, which showed that much of economic growth cannot be attributed to increases in capital and labor.[1] Since then, researchers have suggested various ways to account for the unexplained portion of economic growth. These efforts include developing improved theoretical underpinnings to growth models as well as better measures of technology-driven economic activity, intangible assets, real output of industries, and the so-called knowledge economy.

BEA's efforts have focused on improved measurement of economic output, prices, and growth. This paper provides a set of preliminary estimates of treating R&D as an investment (that is, as gross fixed capital formation), and details the potential impact of this treatment on the economy, notably on such measures as gross domestic product, investment, and saving. These estimates are presented as a satellite account—a set of economic estimates presented in a framework that provides detail about R&D activity that is not reflected in BEA's core economic accounts.

This satellite account adjusts the accounting conventions of BEA's core accounts to test the impact of changing the scope of investment—in this case, recognizing R&D as an asset. While this satellite account does not affect BEA's official measures of GDP, it provides an opportunity to work out new methodologies that may be incorporated into the accounts in the future. Using R&D expenditure data from the National Science Foundation (NSF), BEA has developed estimates of R&D investment, R&D capital stock, and the resulting macroeconomic impacts for 1959 to 2002. A series of revised estimates and a final report will be released in September of 2007.

These estimates measure solely the direct impact of R&D investment. They do not include the effect of R&D beyond those industries that conducted the R&D. For example, the increase in output and productivity of the computer industry associated with a new R&D-based innovation are included in the estimates, but the increase in output and productivity of the banking industry associated with using more efficient computers are not. The banking-industry effect is included in the GDP, but it is not attributed to R&D investment in these estimates.

[1] Robert Solow (1957).

Treating R&D as an investment, rather than an expense, has a substantial impact on the measures of GDP and its components. This paper provides preliminary estimates.[2] Highlights include the following:

- Recognizing R&D as investment increases the level of GDP by an average of 2.6 percent between 1959 and 2002.
- R&D investment and the income flows arising from accumulated R&D capital accounted for 4.6 percent of growth in real (adjusted for price change) GDP between 1959 and 2002, and between 1995 and 2002, its contribution to growth rose to 6.7 percent.
- Estimates of gross private domestic investment (in current dollars) in 2002 would be more than 11 percent, or $178 billion, higher after recognizing R&D as investment; and the 2002 national saving rate would be 16 percent, instead of 14 percent.

This paper marks another step in BEA's ongoing commitment to adapt its measures of economic activity to the changes in the structure of the economy. One of the first advances made was the result of work with IBM to develop hedonic, or quality-adjusted, prices for measuring real investment in computer products and measuring the impact on real output. The Bureau of Labor Statistics (BLS) has extended this work to a wide range of other goods and services. Currently, approximately twenty percent of real GDP is deflated using quality-adjusted price indexes that rely at least in part on hedonic methods.[3] This expanded coverage has been used by BEA to improve its estimates of real GDP and the value of real output of services industries that use information technology (IT).

A second advance was to begin to include one of the most important types of intangible investments into the national accounts; in 1999 BEA introduced into its estimate of GDP the investment flows of computer software. Inclusion of computer software helped explain a significant share of the resurgence in economic growth in the last decade. Between 1995 and 2002, software's contribution to the growth in real GDP was more than 5.1 percent. Between 1973 and 1994, its contribution was 3.0 percent.

These efforts have enabled researchers to decrease their estimates of the amount of economic growth that is not explained by the contributions of labor, capital, and intermediate inputs. In 1967, the unexplained portion of growth was approximated at 50 percent.[4] The work by BEA, BLS, and others has provided the basis for better measures of IT-related improvements and their contributions to growth. Indeed, researchers such as Triplett and Bosworth have used improved BEA data on real industry output (GDP by industry) to show that services-producing industries, "have emerged as engines of economic growth," during the resurgence in economic growth and productivity over the past decade.[5] Improved measures of IT have also been used by analysts of the sources of growth to reduce their estimates of multifactor productivity—the residual portion of growth after all the contributions of labor, capital, and intermediate inputs have been explained.[6]

Because intangible assets are increasingly important components of the knowledge economy, BEA is interested in expanding the available data that will allow analysts to understand their role in production and

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

[3] Moulton, (2001).

[4] Griliches and Jorgensen (1967).

[5] Triplett and Bosworth (2004).

[6] Jorgenson, Mun, and Stiroh (2005).

economic growth. BEA is currently engaging in research that might allow it to develop prototype accounts for health care, human capital, and education.

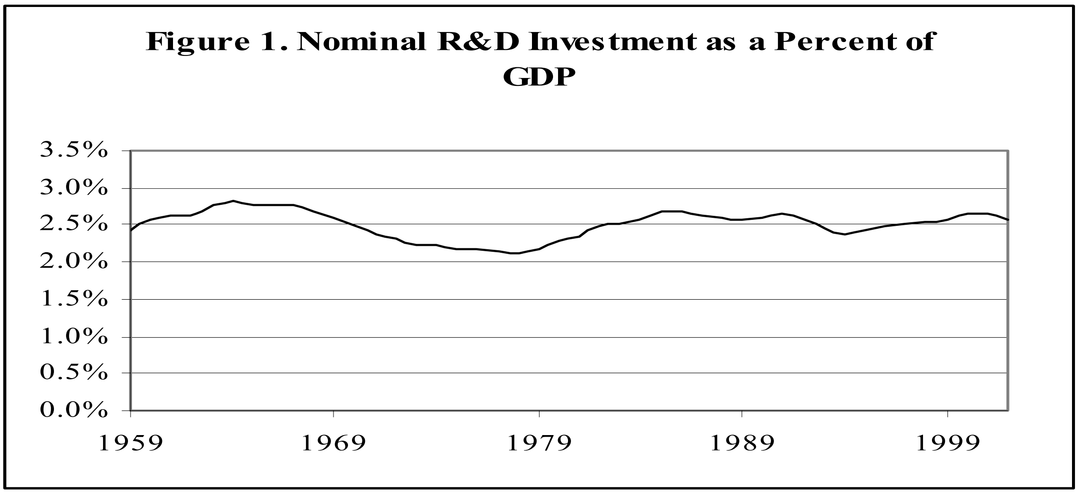
A logical next step for BEA is to consider recognizing R&D in addition to computer software in its measures of intangible fixed investment. Although R&D activities provide private and social benefits that can be long lasting, R&D expenditures are not currently recognized as investment in the national accounts of the United States or other nations. Spending for R&D is more like investment than like current consumption because it uses resources to create a future stream of benefits that extends beyond the current period. To the extent that the benefits of R&D can be appropriated by its owner, R&D expenditures have qualities of an economic asset.

As part of its commitment to improving measurement of intangibles and the knowledge economy, BEA plans to capitalize R&D in its core accounts in the future, if resources are available. Current plans call for BEA to incorporate R&D into the input-output (I-O) accounts in 2012 and into the national income and product accounts (NIPAs) around 2013.

This effort builds on the earlier work at BEA on developing R&D satellite accounts by Carson, Moylan, and Grimm (1994) and Fraumeni and Okubo (2005). However, an important innovation in BEA's current satellite account is the presentation of the investment flows and resulting stocks of R&D assets based on the funder of the R&D. This funder-based presentation differs from the earlier versions of BEA's R&D satellite accounts, which were based on the performer of the R&D. These earlier versions were created on the performer basis because the most detailed source data are available on this basis. However, in order to assign income flows to the appropriate sector in BEA's national accounts, BEA needs to identify the owners of these productive assets. Because existing R&D survey data are insufficient to completely identify ownership, BEA has two immediate choices, the funder and performer perspectives. In this satellite account, BEA adopts the funder perspective to represent ownership. This choice reflects the view that the funder of R&D gains the direct economic benefits.

A Brief Overview of R&D in the U.S. Economy

Domestic R&D expenditures by business (that is, by non-financial corporations, financial corporations, and household operated enterprises), which are currently treated as an expense, are only partially 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 (NAICS 5417). 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 output of colleges and universities in the I-O table, they are not separately identified. Similarly, only a portion of R&D expenditures is identifiable within the NIPAs; these are Federal purchases of R&D and expenditures of foundations and nonprofit research (which are presented in the NIPAs as part of "personal consumption expenditures," which consolidate final consumption expenditures of households and of nonprofit institutions serving households). BEA's estimates of international trade in services provide measures of exports and imports of R&D services; these data are described more fully in Section V.



The R&D satellite account presented in this paper enhances BEA's measures of R&D activity with more detailed information. The satellite account estimates show nominal investment in R&D totaled $276.5 billion dollars in 2002 and the ratio of this investment to GDP, adjusted for the effect of R&D, was 2.6 percent. Figure 1 shows this ratio between 1959 and 2002. The ratio of R&D to GDP rose in the 1960s, as the U.S. invested in space-related technologies, and fell in the 1970s. This ratio picks up again in the early 1980s, followed by another drop at the end of the century.

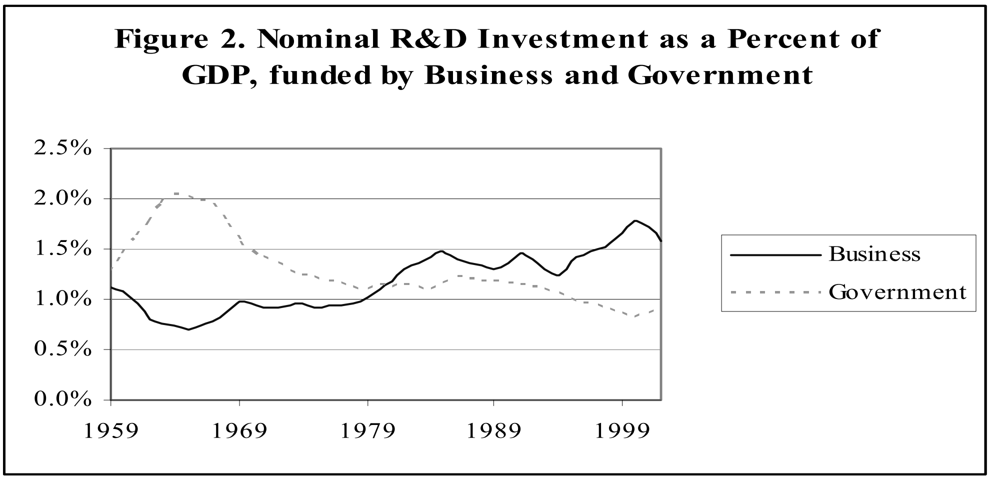


Figure 2 shows the ratio of R&D investment to GDP for R&D funded by business and by government. (The small share funded by private nonprofit institutions is not shown here.) The declining role of the government in the funding of R&D and the increasing importance of business funding of R&D are evident. During the early era of space exploration in the mid-1960s, the Federal government invested a value equivalent to more than 2 percent of GDP in R&D. The government's contribution to total R&D investment was at its highest in the middle of the 1960s, when it funded almost three-quarters of all R&D investment. Government investment has declined steadily since the 1960s, reaching its low in 2000, when government investment totaled about 0.8 percent of GDP. Business investment has been steadily increasing as a percentage of GDP; by 1982, business funded more investment in R&D than government. In 2000, the business sector investment in R&D equaled 1.8 percent of GDP.

The recent growth in business R&D expenditures has been driven by four of the most R&D intensive industries: Chemicals (including drugs and medicine), machinery (including computers), electrical equipment (including communication equipment) and transportation (including aircraft). The NSF report of Science and Engineering Indicators, 2006, provides an in-depth analysis of R&D trends by performers in these industries and many other dimensions of R&D activity.[7]

Table 1: Selected Summary Measures of R & D
(Percent base on current dollar measures)

	1960	1965	1970	1975	1980	1985	1990	1995	1998	1999	2000	2001	2002
R&D net fixed capital stock as a % of total R&D adjusted net fixed capital stock	3.3	4.1	4.2	3.4	2.8	3.3	3.7	3.3	3.0	2.9	2.9	2.9	2.9
Funder-based R&D investment as a % of R&D 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	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 % 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	33.3	30.8	32.4	35.5
Nonprofit Institutions	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 % of total R&D													
Business	76.8	70.0	68.9	67.6	69.9	73.6	72.5	71.4	74.3	74.8	75.2	73.3	70.9
Government	17.2	21.4	22.3	23.8	21.3	18.4	19.1	18.6	16.6	16.0	15.3	16.5	18.2
Nonprofit Institutions	6.0	8.6	8.8	8.6	9.4	8.0	8.4	10.0	9.1	9.2	9.5	10.2	10.9

Calculations based on:
Appendix tables 1.2, 3.1, 3.4, and 4.1
BEA fixed asset table 1.1 Current- Cost Net Stock of Fixed Assets and Consumer Durable Goods

Table 1 provides a summary of investment trends shown by BEA's estimates for funders and performers of R&D. In this table, public universities and colleges are included as part of government, and private universities and colleges are included as part of nonprofit institutions serving households. The share of total R&D investment by business and government, as estimated on a performer basis, has not changed as much as the funder-based view of investment indicates—the funder-based view shows the decline in government funded R&D relative to business and nonprofit funded R&D over the entire range of years.

7 These data are available based on expenditures for R&D: National Science Board (2006).

Measuring R&D as Investment

Measuring the output of R&D activity presents well-known challenges. For its core accounts, BEA's economic measures are primarily based on observable prices and quantities for goods sold in the market. With data on business revenues based on prices and quantities of goods sold, BEA develops measures of economic gross output. GDP, or value added by business, is estimated by subtracting measured input costs from these revenues.

For R&D and other intangibles, both prices and quantities are particularly challenging to estimate. While there are also difficulties associated with quality adjustments for cars, computers, or radios, these products at least have a quantifiable output. A unit of R&D, on the other hand, does not have any commonly agreed upon output measure. To further complicate the measurement issue, R&D investment, like many other types of intangibles, is created primarily by firms and institutions for internal use instead of sold on the open market. Thus, for much of the R&D conducted in the U.S., there is neither an observable market price nor a quantity of output.[8]

The approach BEA has taken in this report is to apply the estimating methods used in BEA's accounts for nonmarket output. This method, used in the accounts both for investment goods created internally for a firm's own use and for the output of government and nonprofit entities, is to measure output by the sum of costs expended to create it. The approach described in this paper as an input-cost method is readily applied to the detailed R&D expenditure data collected by the NSF for the United States.

How then would BEA adjust this output measure for changing prices? One of the methods conventionally used for nonmarket output is to apply input-cost price indexes to these aggregated costs, thereby producing a measure of real, or price-adjusted output. In working through the methodology for this R&D satellite account, detailed input-cost price indexes have been developed to deflate the output of R&D investment.

A well-known limitation of this input-cost approach to measuring nonmarket output is that it is unable to capture productivity gains. In order to develop a truer estimate of this hard-to-measure real R&D output in this paper, BEA develops three alternative output measures for R&D and compares the results with the more conventional input-cost based approach (see section IV for a detailed discussion).

Thus this paper provides estimates of R&D output for each of four scenarios:

- The input-cost based approach (scenario A),
- An output measure that takes the input-cost based approach and adjusts it to reflect a rapid rate of productivity improvement (scenario B).
- An output measure based on a group of high-productivity service industries (scenario C),
- An output measure based on four industries that perform the majority of domestic R&D (scenario D).

While the first of these methods is, as described earlier, consistent with national accounts methods for nonmarket output, the inability of this approach to measure productivity gains renders it of limited value for capturing the real impact of R&D investment in the economy. Estimates presented on that basis would underestimate R&D impact on the economy.

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

The other three measures produce a set of estimates with quite similar impacts on nominal GDP and contributions to the growth in real GDP. The preliminary estimates described in the introduction to this paper and presented in the appendix tables (3 and 4) are based on estimates that value real (price-adjusted) R&D at output prices of products produced by R&D intensive industries (scenario D).

Steps in Treating R&D as Investment

The estimates presented in this paper are prepared by 1) aggregating NSF expenditures on R&D by funder, 2) adjusting these expenditures to prevent double-counting with other forms of investment and to include the cost of additional inputs such as the use of structures, equipment, and software, 3) deflating the costs to develop real (price-adjusted) R&D investment, 4) cumulating this investment into a capital stock with an annual depreciation rate, and 5) estimating the resulting changes on GDP, investment, and contributions to the growth in real GDP.

Limitations of the Preliminary Estimates

To calculate the preliminary estimates for R&D, BEA had to address several substantial data gaps and unresolved conceptual issues in the treatment of R&D as investment. This required several assumptions about R&D that BEA plans to refine over the next several years. A partial list of these unresolved issues includes: 1) the absence of output measures for R&D, 2) incomplete information on the ownership of R&D, 3) limited information about market prices for R&D, 4) limited information about the rate at which R&D depreciates, 5) incomplete information about the full scope of R&D in the U.S, and 6) limited information about the rate of return earned on R&D investment.

These unresolved issues are addressed in two different ways—either with simplifying assumptions or with a range of alternatives that are designed to bracket the range of likely results. Developing improved methods for these issues forms the basis of a research agenda for BEA’s future work on R&D and other intangibles.

Effect of R&D on Gross Domestic Product (GDP)

Recognizing R&D as investment changes the measure of the gross domestic product (GDP). The specific impact of this treatment depends on the sector of the economy. The largest impact on GDP occurs in the business sector. Other sectors are also affected, that is, nonprofit institutions serving households and general government. These changes are shown in Table 2; Appendix Table 7 provides a detailed view of these impacts on the NIPAs for the year 2000.

Business sector. Reclassifying business R&D expenditures from intermediate consumption to investment leads to an increase in GDP equal to the value of the R&D expenditures. The recognition of R&D as investment also affects the operating surplus and private consumption of fixed capital (CFC) components of gross national income (GNI). Because R&D is no longer considered an expense, gross operating surplus (proprietors’ income and corporate profits) increases by the elimination of the deductions for R&D expenditures.

Table 2: How the National Accounts Change when R&D is treated as Investment

	Gross Domestic Product			Gross National Income	
R&D Imputations R&D Funded by:	Treatment in Current Measure GDP	Adjusted GDP	Change in Current Measure GDP	Adjusted GNI	Change in Current Measure GNI
Business	Intermediate consumption	Reclassify to investment	Increase	1) Increase in net operating surplus equal to R&D investment less CFC 2) Increase in CFC	Increase
Nonprofit institutions serving households	Consumption (PCE)	1) Reclassify to investment 2) R&D CFC added	Increase	Increase in returns to R&D capital	Increase
General government	Government consumption	1) Reclassify to investment 2) R&D CFC added	Increase	Increase in returns to R&D capital	Increase

Nonprofit institutions serving households and general government. In these two sectors, R&D expenditures are reclassified from consumption expenditures to investment; since consumption expenditures are already part of GDP, this shift alone does not change its measure. However, recognizing these expenditures as investment also increases the measure of consumption by nonprofit institutions and general government in an amount equal to the value of the CFC of the R&D, and thus GDP and GNI increase correspondingly. This treatment is consistent with current treatment of government and nonprofit investment in the NIPAs; government and nonprofit investment receives only consumption of fixed capital as a return. The featured estimates for this account also include a net return to government and nonprofit R&D capital in addition to consumption of fixed capital. Therefore GDP will rise by an amount equal to the value of CFC and the net return for government and nonprofit R&D investment.

Government enterprises. R&D expenditures by government enterprises are currently treated as costs of production and thus are deducted in the calculation of the current surplus of government enterprises. In recognizing R&D as investment, these expenditures are added to gross government investment and, as a result, to GDP. The effect on the current surplus of government enterprises is similar to that on business income described above; that is, the surplus will increase by the elimination of the deduction for the expenditures of R&D but will be offset partially by the deduction of the CFC on R&D.

The BEA-NSF Collaboration

BEA is producing this satellite account in collaboration with the NSF, the agency of the Federal government that has responsibility for producing R&D-related statistics for the United States. NSF provided funding for the R&D satellite account project, allowing BEA to assemble a team of researchers and analysts to work on the project. In addition to providing the expenditure data that BEA is using to develop estimates of R&D output, NSF staff has engaged in an analytical review of the data and methodology and has provided guidance on issues such as the scope of R&D.[9]

[9] NSF staff has also undertaken several investigative and research tasks to support the satellite account project. This support includes conducting informal surveys of R&D performers to help classify them correctly into performing sectors, analyzing micro-data to answer questions about industry coverage and types of R&D included in the

The remainder of this paper is organized as follows:

- Section II describes the conceptual issues involved in treating R&D as investment. A summary of the choices made in recent experimental satellite accounts by other countries concludes the section.
- Section III presents an overview of the methodology used to develop current-cost and constant-cost estimates of R&D investment.
- Section IV describes the assumptions used for the satellite account. Results are discussed for the range of estimates based on the alternative scenarios previously introduced.
- Section V discusses the additional issues that will be reviewed in preparation for the final version of the R&D satellite account to be released in the fall of 2007.
- Section VI concludes this paper.
- An appendix provides the data tables. The detailed methodology used to estimate the accounts and the data improvements needed for full implementation of capitalized R&D in the NIPAs will be released separately. Tables 1.1-1.4 presents the macroeconomic effects of the R&D capitalization on real GDP, nominal GDP, GNI and the national savings rate, by scenario. Table 1.5 presents the returns to R&D assets for each scenario. Table 2 summarizes the process required to transform the R&D survey data to the R&D investment used in the satellite account. Tables 3.1 – 3.8 construct a net stock of R&D assets. The investment, net stock and depreciation of the R&D asset are presented in historical-cost, current-cost and real terms. The tables are prepared on a funder basis using the assumptions defined in scenario D. Tables 4.1-4.2 show the R&D investments on a performer basis in historical-cost and real dollars.
- Table 5 show the price indices used each of the scenarios outlined in the satellite account. Table 5.1 constructs the cost-based price index used in scenario A. The indices used on the funder and performer basis are equal at the total R&D investment level. Table 5.2 shows the price indices for each scenario. Table 6 is a summary of the data and methods used for the deflation of R&D investment. Table 7 provides a detailed view of the impacts of the R&D treatment of R&D as an investment on the NIPAs for the year 2000. Table 8 presents information on the trade in R&D services, international royalties and licensing fees and the international funding of R&D.

II. Conceptual issues in the treatment of R&D as investment

In order to prepare this satellite account, several key analytical and conceptual issues had to be addressed. These issues include the following:

- Defining the scope of R&D investment—that is, the boundary used to distinguish activities within the scope of the R&D satellite account;
- Assigning ownership of R&D investment to economic sectors;
- Developing a measure of investment based on the available survey data on R&D expenditures;
- Choosing appropriate price indexes to create the real measures of R&D;
- Identifying patterns and rates of depreciation to use when building R&D capital stocks;
- Defining gestation lag periods; and

survey data, and developing a conceptual framework for improving the survey data on international R&D transactions (Moris (2006)).

- Identifying rates of return to be used for deriving income flows from R&D for scenarios B, C, and D that reflect a higher return to R&D compared to other assets.

This section concludes with a look at the experiences of other countries that have worked through these issues as they created R&D accounts.

Scope of R&D Activity

A fundamental issue BEA had to address was what activities to include as R&D investment and what activities to exclude. Should only scientific R&D be included, or should research in social sciences and the humanities be treated as investment as well? What about market research and other activities that help firms determine what types of new products to develop? How would BEA separate innovative expenditures from R&D expenditures?

All the estimates presented in the satellite account use the same definition of R&D; this is the definition used by NSF in its surveys. BEA evaluated two international standards, the System of National Accounts (SNA)[10] and the Frascati Manual,[11] the internationally accepted standard for R&D surveys. BEA selected the Frascati definition of R&D as currently implemented by NSF in its R&D surveys as the measure of R&D for the account because consistent data are available on this basis, and the resulting estimates will allow for international comparability.

The Frascati Manual defines research and experimental development as "…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."[12] The inclusion of knowledge about man, culture, and society in the definition makes it clear that, in addition to R&D in the natural sciences, it also covers R&D in the social sciences and the humanities. The quality that distinguishes Frascati-based R&D from related activity is "an appreciable element of novelty and the resolution of scientific and/or technical uncertainty."[13]

In contrast to the Frascati definition, the description of R&D according to the SNA can be interpreted somewhat differently.[14] The SNA emphasizes activities related to innovation that bring products and processes to market and can be interpreted more broadly than the Frascati definition. In other dimensions, the SNA definition can be interpreted more narrowly because it does not specifically include activities that increase knowledge without a resulting impact on economic activity. The latter type of activities would be within the scope of R&D according to the Frascati Manual. Innovative activity that does not involve novelty or technological uncertainty is not considered R&D in this definition.

The current implementation of the R&D satellite account includes all domestically performed, Frascati-defined R&D reported on NSF surveys. In practice the survey data used to develop the estimates in the R&D satellite account cover a somewhat narrower scope than the Frascati definition.. R&D in the social sciences and humanities are excluded from NSF's Survey of Industrial R&D, the primary source of

10 SNA (1993)

11 OECD (2002)

12 OECD (2002) par. 63.

13 Ibid paragraph 84.

14 In the SNA, the purpose of R&D is identified as follows: "Research and development by a market producer is an activity undertaken for the purpose of discovering or developing new products, including improved versions or qualities of existing products, or discovering or developing new or more efficient processes of production." (SNA 1993 par. 6.142)

time-series related data for business sector R&D. Consequently, reported business sector R&D is limited in practice to R&D in natural sciences and engineering.[15]

The estimates presented in this account are limited to those that affect GDP; a related concept, gross national product (GNP), would include receipts of factor income from the rest of the world, and subtract payments of factor income to the rest of the world (for additional discussion on international transactions in R&D, see section V).

A useful recent implementation for the U.S. economy of a broader definition of R&D is found in the work of Corrado, Hulten and Sichel (2006). Corrado, Hulten, and Sichel (CHS) characterize investment in innovative property as composed of two parts, scientific R&D and nonscientific R&D. The main difference between their definition of R&D and the one implemented in this paper is the inclusion of a broad set of activities characterized as non-scientific R&D. These include the cost of developing motion pictures and other forms of entertainment, licensing payments and royalties, and an estimate of spending for new product development by financial and insurance firms.

Ownership of R&D Assets

Recognizing R&D as investment implies that the satellite account must treat the R&D stock as a fixed intangible asset. Flows from the stocks of fixed assets located in the United States are presented in the NIPAs based on the sector that owns the assets. Although recognition of R&D as an asset requires a presentation of domestic R&D stocks on an ownership basis, the Frascati-based survey data used to estimate R&D investment do not provide all the information necessary to identify ownership. In large part because the most detailed survey data for R&D are available on a performer basis, as mentioned earlier, the two prior versions of BEA-produced R&D satellite accounts, Carson, Moylan and Grimm (1994) and Fraumeni and Okubo (2005), developed measures of R&D capital stocks based on the performer of the R&D.

The limitations of the data still require BEA to make ownership assumptions; in contrast with earlier satellite accounts, all of the capital stock and macroeconomic estimates in this satellite account assign ownership of R&D assets to the funder. Without complete information on transactions, BEA assumes that R&D funded by business is also owned by business. Although, for nonprofit- and government-funded R&D, the ownership is more ambiguous, BEA assumes that the R&D funded by them is owned by them. The Federal government currently funds about twice as much R&D as it performs. This amount funded by the Federal government is divided primarily between business and academic institutions. Based on existing data, one cannot tell with certainty whether the government bought this R&D, or whether ownership passes to the performer. Because the government pays for this R&D and therefore can be expected to gain some economic benefit from it, government funded R&D is currently considered an asset of the government in this satellite account.

The impacts on GDP from recognizing R&D as investment presented in this paper in Appendix Tables 1.1–1.4 are funder-based. Appendix Tables 3.1 and 3.2 provide estimates of real and historical cost R&D investment and price indexes by funder. Because many users will be interested in the performer-based data, BEA investment measures on both a funder and performer basis are presented in Appendix Tables 4.1 and 4.2. These tables provide estimates of real and historical cost investment and price indexes by performer.

[15] While for universities and colleges, R&D in the humanities is excluded from the expenditures used here, NSF has been collecting non-scientific R&D (including humanities) since 2003, allowing these expenditures to be included in future estimates.

Data for R&D Investment

As noted earlier, NSF data on R&D expenditures are used for the measurement of R&D investment. BEA has decided to build on data published by the NSF because NSF data provide the most comprehensive source for national level R&D expenditures for business, government, nonprofit institutions, and academic institutions.[16]

The NSF's Division of Science Resources Statistics coordinates the collection and reporting of survey data on R&D expenditures and consolidates these data in the annual publication, *National Patterns of Research and Development Resources* (NSF, various years). These data are based primarily on two annual surveys published by the NSF, the Survey of Industrial R&D (SIRD or RD-1) and the Survey of Research and Development Expenditures at Universities and Colleges. An abbreviated version of the latter survey is collected annually for Federally funded research and development centers. Two additional annual surveys provide information on outlays and obligations by the Federal government for R&D. These are the Survey of Federal Funds for R&D and the Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. The Scientific and Engineering Research Facilities Survey provides information on construction plans and capital spending and is conducted biennially. An NSF sponsored Gallup survey, Research and Development Funding and Performance by Nonprofit Organizations was last conducted in fiscal 1996 and 1997 and has been discontinued. A survey of state research and development expenditures was last collected for fiscal year 1995; an update of the survey will be fielded in the Fall of 2006.

Measurement of R&D Investment

Annual R&D investment is measured as the sum of the costs of R&D activities by all domestic performers. This investment measure implicitly treats all reported R&D expenditures equally, resulting in expenditures for unsuccessful R&D being considered as investment along with expenditures for highly valuable innovations. These R&D expenditures are then segmented by funder.

This method is used for two related reasons. First, there is currently no standard measure of R&D output, and second, most R&D conducted in the business sector is not sold on the market directly but is used instead within the firm that created it.[17] Appendix Table 2 provides a summary of the adjustments required to transform survey data on R&D expenditures into an annual investment measure in current dollars. These steps effectively link Frascati-based expenditures to the value of investment in current dollars.[18] The table provides a summary of the adjustments BEA has made to the data for the 2006 R&D satellite account as well as an indication of what remains to be completed for the 2007 R&D satellite account and beyond. An "x" indicates an adjustment has been made when necessary, an "NAN" indicates that no adjustment is necessary, and a blank indicates that the adjustment should be made in a future set of estimates as improved methodologies and data are developed. A review of Appendix Table 2 also provides a partial indication of BEA's agenda for future improvements to the methodology as well as the additional data requirements.

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[16] BEA in fact surveys multinational companies on their R&D expenditures, collecting data on R&D expenditures from U.S. parent companies as well as foreign-owned U.S. affiliates. However, the reported expenditures by the U.S. units of these multinational companies account for approximately 80 percent of industrial R&D performed in the U.S when compared to industrial expenditures reported by NSF. The reason for this narrower coverage is that BEA data exclude the domestic R&D expenditures of firms which are not classified as multinational companies.

[17] This treatment is similar to BEA's treatment of expenditures for mineral exploration; the successful discoveries pay for the unsuccessful ones. Moreover, knowledge gained by unsuccessful attempts is additional output.

[18] This procedure is laid out in detail in Robbins (2006).

The first section of the table describes adjustments to the performer-based survey data to match the scope of capitalized R&D. Since the Frascati-based definition is used here, it includes R&D in the social sciences and humanities but excludes expenditures solely for commercialization and marketing. Because the sum of current-period R&D production costs are used to develop current-period investment measures, expenditures for materials and supplies not used in the current period should be subtracted from the output measure. Also, because R&D is being treated as an intangible asset, R&D that is purchased for use in the production of further R&D is the purchase of an asset and not a current cost. However, payments for the use of R&D in the form of technology or patent licensing fees are a cost of production.

The next section of the table makes adjustments to the data to make it consistent with accounting conventions of the NIPAs. Following this, the next adjustments account for expenditures in the survey data that reflect capital expenditures rather than current costs. These include expenditures for structures, equipment, and software. Such expenditures are subtracted and accounted for separately in the stock of fixed capital.

Accounting for the full cost of production includes the costs associated with the use of that stock of fixed capital used to create R&D. This cost includes the economic depreciation on the structures, equipment, and software used in production. This cost is measured by the consumption of fixed capital (CFC) estimate. The full cost of production includes an adjustment for taxes and subsidies on production. Finally, investment must be adjusted to include imports of R&D and exclude exports.

Real Measures of R&D

Real (inflation-adjusted) R&D is difficult to measure largely because it is not bought and sold in markets. Normally, the companies that conduct the R&D are also the companies that use the R&D to produce new and better goods and services. Conceptually, the value of R&D is equal to the discounted present value of the future benefits that the company derives from R&D. However, the value of the R&D 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, contactors, and other costs of conducting R&D, but not the market price of R&D. For computers, communication equipment and other assets that are bought and sold in final goods markets, companies know the market price of the asset, its share of sales, as well as the share of profits that came from the difference between the sales price and cost of producing that asset. For these assets, it is relatively simple to estimate their real value and contribution to GDP by simply dividing the nominal value of these assets by a price index based on their sales. For R&D, the value of the assets and their contribution to sales are indistinguishably bundled with the companies overall assets. Thus, the only available nominal value is the cost of their production.

The conventional approach for estimating real goods and services that are not sold in markets is to deflate the cost of their production by a cost index based on the prices of the components of the costs. In the U.S. national accounts, this approach is used for computing the real value of the output of governments and nonprofits institutions serving households (NPISHs). The cost-based output and deflation approach is also used for estimating the real value of assets that companies build for their own use (these expenditures are called “own-account construction” in the language of national accountants).

While this approach produces a “real value” for the output of governments and NPISHs output and for the value of own account construction, it necessarily implies that real inputs grow at the same rate as real output and thus produces zero productivity growth (e.g. real output cannot grow faster than real inputs). Unfortunately, this “default” convention seems particularly inappropriate for measuring a dynamic sector like R&D, especially within the context of satellite accounts.

The dynamism of the R&D sector is clear. Firm level and indirect estimates of the rates of return to R&D are much higher than the rates of return to other investments. While rates of return are uncertain and variable, the returns from available studies suggest very high rates. The average private return from studies shown in Table 3 is 26 percent. Social returns—including the returns that "spillover" to industries beyond the direct returns to the companies conducting the R&D—are much higher, averaging 66 percent. Although comparing rates of returns is difficult, the high average returns to R&D shown in Table 3 probably reflect not only the reward-to-risk ratio but also the nature of technological innovation and the high-productivity of R&D investments.

For example, products that typically embody a high level of R&D, such as computers and communication equipment, have a short—and increasingly shorter—lifecycle as new R&D and new technologies are introduced. This technological obsolescence not only means that the time period over which the costs on R&D must be recovered is short, but the value of that R&D is being reduced each year as prices fall (the price of older models that embody previous R&D must be reduced to compete with newer models embodying more advanced R&D). This means that R&D must significantly raise the productivity of new products by lowering costs and/or increasing sales by enough to earn the very high rate of returns found in R&D. Companies must also try and maintain that productivity advantage over their competitors as long as possible by carefully protecting their intellectual property through trade secrets, patents, licensing and other methods.

Table 3. Summary of Estimated Rates of Return to Private R&D

Estimated Industry Rates of Return to Private R&D (%)		
Source	Private	
Minasian (1969)	54	
Griliches (1980)	27	
Mansfield (1980)	28	
Nadiri and Bitros (1980)	26	
Schankerman (1981)	24-73	
Griliches and Mairesse (1983)	19	
Link (1983)	5	
Clark and Griliches (1984)	18-20	
Griliches and Mairesse (1984)	30	
Griliches (1986)	33-39	
Griliches and Mairesse (1986)	25-41	
Jaffe (1986)	25	
Schankerman and Nadiri (1986)	10-15	
Griliches and Mairesse (1990)	27-41	
Lichtenberg and Siegel (1991)	13	
Source: Nadiri, (1993).		
Estimated Aggregate Rates of Return to Private R&D (%)		
Source	Private	Social
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(1)	56(1)
Goto and Suzuki (1989)	26	80
Terleckyj (1974)	29	48-78
Scherer (1982,1984)	29-43	64-147
Source: Table 8.1, 12. Fraumeni, Barbara M., and Okubo, Sumiye. “R&D in the National Accounts: A First Look at Its Effect on GDP.” National Bureau of Economic Research, Studies in Income and Wealth, Volume 65, *Measuring Capital in the New Economy*, Edited by Carol Corrado, John Haltiwanger, and Daniel Sichel, 2005. (1) These rates are median rates.		
Average Rates of Return to Private R&D from All Studies (%)		
Source	Private	Social
Average of Above	26	66

In constructing these initial R&D satellite account real estimates, the goal is to implement the simplest case, one consistent with existing national accounting conventions that would be used if R&D were to be capitalized and treated like government output; this is scenario A.

Scenario A. In this scenario, BEA uses input costs as a proxy for R&D output and then deflates this output measure with the price index created with information on the cost components for R&D. While this procedure is consistent with national accounts methodologies for other nonmarket output, by measuring output with inputs and then deflating this output by the costs of inputs, the procedure is unable to capture an increase in output per unit of input. Therefore, if there is productivity improvement in the conduct of R&D over time, this method will under-estimate real R&D output.

Beyond this scenario, three estimates based on proxies for the market price of the R&D sector are introduced in order to obtain an estimate of the order of magnitude of the effect of capitalizing R&D on real GDP. The challenge is to find proxy prices for the market value of R&D consistent with the very high returns earned by R&D and the characteristics of R&D without a direct link between the returns to R&D and the value of R&D.

Scenario B. This scenario, a variant of the cost-based deflation approach, assumes that the real value of R&D output is higher than the real value of R&D inputs by the amount of productivity growth recorded in higher-performing industries in the U.S. economy. This adjustment is implemented by subtracting average multifactor productivity (MFP) growth, estimated for a group of manufacturing industries with the highest MFP growth, from the increase in the cost-based price index from scenario A. The result is a cost-based index that incorporates a proxy for R&D productivity growth. The resulting R&D price index implies MFP growth in R&D conduct that averages 3.8 percent a year, but with the well-known downturn in 1973 and acceleration since the mid-1990s.

Scenario C. This scenario assumes that R&D, which is most similar to a service industry, is valued at the output prices of the most productive service industries. While service industries have traditionally had lower productivity growth and higher inflation than the industries in the goods sector, key industries have a good record in 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 service industries. These industries are air transportation, broadcasting and telecommunications, securities and commodity brokers, and information and data processing services.[19]

Scenario D. This scenario, the most closely linked to available R&D data, assumes that R&D is valued at the output prices of products produced by R&D-intensive industries. The prices of these products that have a high R&D content may be the best proxy for the value of the R&D embodied in these products. This R&D price index is developed using BEA's GDP by industry value-added price indexes for the four industries that perform the most R&D. Based on NSF industry performer data, these industries are: radio and tv receiving equipment; drugs and medicines; office, computing, and accounting machines; and aircraft and missiles. The weights used to combine these price indexes vary each year based on each industry's share of total performer-based R&D expenditures.

[19] These indexes were used instead of BLS indexes because in most cases, the time span for industry coverage by BLS is not long enough to enable using the BLS producers price indexes as deflators. For example, the BLS PPI for broadcast and telecom equipment – an industry that appears in the top five Productive Services index – is only available for the period 1991 forward. The R&D work requires having an index that covers the period 1959 forward.

Depreciation Rates

The satellite account uses two alternative measures for depreciation of R&D. Depreciation is "the decline in the value of the stock of assets due to wear and tear, obsolescence, accidental damage and aging."[20] While R&D capital does not wear out in the traditional sense, it does lose value due to obsolescence. It loses value over time as new innovations appear and earlier R&D becomes relatively less effective in the production process and therefore less valuable. An additional loss in value comes from the gradual leakage of information to competitors and the expiration of intellectual property protection that render the R&D asset less valuable to its owner.

The geometric depreciation patterns used by BEA for other assets are based, to the extent possible, on empirical studies of markets for used assets. Because most R&D is not sold on the market, this type of information is not directly available. Using econometric methods to develop depreciation rates for business R&D, economists have found the range of average annual depreciation rates to be between twelve and twenty-five percent.[21] A lower rate of depreciation is likely to be appropriate for R&D conducted by government and universities and colleges. More basic research is done by these performers, and this basic research is likely to obsolesce more slowly than the private sector R&D represented by the econometric studies noted above.

Scenario A's estimates of depreciation are based on a 15 percent geometric rate of depreciation; this rate was chosen as compromise between the results of the depreciation studies and the presumed slower depreciation of non-business R&D. A 15 percent rate is somewhat higher than the 11 percent depreciation rate that was used by Fraumeni and Okubo (2005) and Carson, Moylan and Grimm (1994).

As an alternative to the 15 percent depreciation rate, 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 a resulting increase in the rate of obsolescence. 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 incorporate this faster depreciation by using the depreciation pattern from the NIPAs information processing equipment and software between 1987 and 2002. Prior to 1987 the depreciation pattern is estimated with the rate of change in the depreciation pattern from the NIPA series for private fixed investment in nonresidential equipment and software. The resulting depreciation series accelerates in recent years based on the shorter service life of new types of equipment and software; it starts at about 16 percent in 1959 and ends up at about 23 percent in 2002.

Gestation Lags

These lags represent the time between beginning and completing an R&D project, while application lags are the period between its completion and commercial use. For R&D, a gestation lag implies that an expenditure made in one year becomes an investment in a subsequent year. BEA's earlier efforts to estimate the impact of R&D on the economy included a lag to account for the timing of the R&D expenditure and its impact on economic output.

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[20] BEA (2003)

[21] 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 percent to 20 percent and an average depreciation rate of 15 percent. Most recently Bernstein and Mamuneas (2004) calculated a 25 percent depreciation rate for the manufacturing sector.

Despite unarguable real-life lags between research activities and commercialized products or implemented processes, in the current set of estimates, a zero-year gestation lag is used, implying that the R&D investment will be added to the R&D capital stock at the time that the expenditure is made. Real-life lags are likely to vary by type of R&D, and the one-year lag implemented in earlier estimates is at best, an approximation of a heterogeneous process. The zero lag implemented here is a methodological simplification that consistent with both the current practice with tangible investment in the NIPAs and recent recommendations of the international group of experts responsible for developing revised SNA standards.

Rates of Return to R&D Assets

Recognizing business R&D as investment results in an increase in GDP equal to the value of the new investment. On the income side (GNI) this treatment results in matching additional profits and depreciation. These additional profits and depreciation are reflected in the NIPAs as gross operating surplus. This profit-like measure can be used to estimate before and after tax rates of return as a ratio of this surplus, less CFC, divided by the stock of produced assets. From 1960 to 2005, the before-tax rate of return (based on net operating surplus) for domestic nonfinancial corporations has had a median value of 9 percent.[22]

Scenarios B, C, and D make some preliminary proxy adjustments for the impact of higher net rates of return for R&D compared with other types of capital. These scenarios assume that R&D investment earns a higher rate of return than other types of investment because of the uncertainty or risk surrounding its future benefit. This is done by assuming that R&D capital earns an average net rate of return of 15 percent over the period 1959 to 2002. This is approximately four percentage points higher than the average rate of return to all private assets.

In contrast with business sector gross operating surplus, which implicitly includes depreciation and a net return, the current NIPA and SNA treatment of government and nonprofit capital is to recognize only CFC; implicitly assuming a zero net return to this investment. While scenario A of the R&D satellite account adopts this assumption, scenarios B, C, and D explore the impact on GDP of including a net return to government and nonprofit R&D capital. These scenarios include a return to government and nonprofit R&D that is estimated with a long-run average rate from ten-year government securities, boosted up to match the new ratio of the return from business R&D assets to other business assets.[23]

In their estimates of the impact of R&D on the economy, Fraumeni and Okubo (2005) included a set of estimates of the account with return to government and nonprofit R&D capital in excess of CFC (net returns). For consistency, they extended this treatment to all government and nonprofit fixed capital.

In this version of the satellite account, BEA chose to limit the addition of the return to government and nonprofit investment capital to only include a return to R&D capital (scenarios B, C, and D). The reason for this is that the additional return to non-R&D capital has a significant impact on the macroeconomic results, and would tend to blur the interpretation of the treatment of R&D as investment with the net returns to government and nonprofit investment capital.

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22 Lally (2006) pages 7

23 BEA's efforts to approximate ex ante real net rates of return—as the nominal rate on constant-maturity 10-year U.S. Treasury bonds, less a simple moving average of the rate of change of the R&D investment deflator—produced very bumpy series, owing to a spike in interest rates in the early 1980s unmatched by R&D inflation. The 1959–2002 average rate by this method is noticeably lower than the 15 percent average assigned to private-business R&D assets; the ratio of these two averages, times the year-to-year private-business R&D net rate, gives the smoother net rate that BEA actually used in scenarios B, C, and D.

To illustrate the impact, including a net return to all government and nonprofit capital would increase the level of nominal GDP by an average of 5.4 percent from 1959 to 2002 as compared with the average annual 2.6 percent increase in scenarios B, C, and D. Excluding the net return to government and nonprofit capital out of the estimates all together would have resulted in an average annual increase in the level of nominal GDP of 2.3 percent.

Including the net rate of return to government and nonprofit capital presented an additional challenge: What price index should be used to deflate these additional returns? These returns were deflated with the price index created for scenario B, the high-productivity service-sector industries. It is used here instead of a broader deflator in a first attempt at capturing the public benefits of government and nonprofit R&D investment.

Experiences of Other Countries with R&D Satellite Accounts

The national statistical agencies of several other countries have linked their R&D survey data to their national accounting system through bridge tables and have begun to develop satellite accounts to estimate the impact of R&D on GDP. These efforts required an exploration of conceptual issues described in earlier parts of this section, including specifying the scope of R&D, lags and depreciation rates for R&D assets, and the choice of input deflators for R&D investment. This section reviews some of the results of these efforts. Countries with relevant experimental work with R&D satellite accounts include Australia, Canada, France, Israel, the Netherlands, Sweden, and the United Kingdom. Table 4 compares some of the assumptions used.

In specifying the scope of R&D that should be considered as an asset, Israel, Australia, the Netherlands, and Canada consider somewhat different frameworks from each other. National accountants from Statistics Netherlands and Statistics Canada argue that the SNA definition of an economic asset should be understood to exclude some Frascati-defined R&D. De Haan and van Rooijen-Horsten of Statistics Netherlands propose that nonmarket R&D should be excluded unless it is patented or explicitly used in government production, as in the case of defense R&D.[24] Siddiqi and Salem of Statistics Canada include all business sector R&D but exclude R&D outside of the business sector that is not either patented or patentable.[25] Peleg of the Central Bureau of Statistics of Israel argues for the inclusion of nonmarket R&D, noting that its use is similar to that of roads and other public infrastructure.[26] The Australian Bureau of Statistics' satellite account handles this issue by providing estimates both with and without pure basic research.

[24] de Haan, et al (2004). page 19

[25] Siddiqi and Salem (2005).

[26] Peleg (2003).

Table 4: Comparison of Key Assumptions of R&D Satellite Accounts

Country	Average service life in years	R&D input price index	Depreciation rate of R&D capital	Source of net operating surplus estimate	Gestation lag	Impact on Level of Current GDP
Australia (Note 1)	9	component-based input price index	10 percent	based on a normal return to capital	0	1.5 percent
Canada (Note 2)	5 to 10	GDP deflator	10 and 25 percent	R&D Services Industry	NA	1.2 percent
Israel (Note 3, 5)	7	component-based input price index	15 percent	R&D Services Industry	2	3 percent
Netherlands (Note 4)	NA	component-based input price index	11 to 25 percent	Other business services industry	1	1.1–1.2 percent
UK (Note 6)	NA	GDP deflator	10 to 25 percent	NA	NA	NA
U.S.	13.3	input-cost based deflator and three high-productivity proxy price indexes	15 percent, information-processing equipment and software	none	0	2.3 to 2.6 percent

Note 1. Australia. Australian Bureau of Statistics. National Accounts Research Section. Capitalising Research and Development in the National Accounts. March 2004.

Note 2. Siddiqi, Yusuf and M. Salem: "Treating Research and Development as Capital Expenditure in the Canadian SNA." System of National Accounts Statistics Canada. March 2005.

Note 3. Brenner, Nava; Peleg, Soli; and Galit Zalewsky: Updated version of the exercise to examine the impact of capitalization of R&D in the national accounts." Prepared for the Canberra II Group: On the Measurement of Non-Financial Assets. August 2005.

Note 4. de Haan, Mark and Myriam van Rooijen –Horsten Measuring R&D Output and Knowledge Capital Formation in Open Economies. Conference paper, 28th General Conference of the International Association for Research in Income and Wealth, Cork, Ireland, August 22-24, 2004.

Note 5 Peleg, Soli: "Harmonization between R&D Statistics and the National Accounts." Central Bureau of Statistics, Israel. Paper presented at the NESTI/Canberra II meeting in Berlin, Germany, May 2006.

Note 6 Clayton, Tony and Prabhat Vaze. Capitalising Research and Development in the UK National Accounts, Undated Manuscript.

Because of the absence of output measures, output is obtained via deflation of input costs in most of these satellite accounts. Australia, Israel, and the Netherlands deflate cost components separately, using wage and salary indexes for R&D activity when available. By contrast, Canada and the UK use the GDP deflator, which has been found in many comparisons to perform similarly to component based input deflators for R&D. All the satellite account reports describe the need to improve their deflator measures in future work.

Based on these preliminary exercises, the impacts on the level of current-dollar GDP of these countries range between 1 and 3 percent. Of these international examples, the largest impact of 3 percent is found in Israel, where market R&D is a major industry and the satellite account includes all nonmarket R&D. Australia reports a 1.4 percent increase in GDP, excluding basic R&D, and a 1.6 percent increase, including basic R&D. The Netherlands total GDP is adjusted upwards by 1.1 percent to 1.2 percent. For Canada, total GDP increases by 1.2 percent.

Each satellite account estimates the value of R&D investment based on input costs, and R&D survey data are adjusted to include an estimate of the cost of capital used to produce the R&D. Similar to BEA's construction of its satellite account, these countries include an estimate of the value of CFC for the fixed capital used in the creation of R&D.

Since the fixed capital used to create R&D could have been used for another economic purpose and would have earned an average return that exceeds the CFC alone, some satellite accounts make an additional cost adjustment to the sum of costs to recognize this return. This adjustment is made with an estimate of the net operating surplus (a profit-like measure net of CFC). Israel and Canada use net operating surplus from the R&D services industry; the Netherlands uses the surplus from Other Business Services, and the Australians use the normal return on their aggregated capital stock. BEA does not use this practice in its national accounts methodology for own-account output, and therefore, this adjustment is not made in the satellite account.[27]

III. Estimation Methodology

This section provides a more detailed discussion of the transformation of NSF expenditure data into measures of real investment and capital stock. Readers who are interested primarily in the results of the alternative scenarios may wish to skip to Section IV.

In the new treatment of R&D as investment, BEA measures the value of R&D output by summing the costs of R&D activity. The methodology is similar to BEA's methods for estimating other types of own-account investment, for example software and construction. The aggregated investment measures for R&D are presented in the Appendix Tables, where they are shown by major performer and by major source of funding. The stocks of R&D, the accumulation of investment after adjusting for their loss in value over time, are presented by major source of funding.

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). [28] Government organizations consist of the Federal Government, state and local governments (excluding universities and 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.

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27 Since the industry survey data used for the U.S. estimates include an overhead measure, this overhead may also include profits for performers who sell R&D.

28 FFRDCs, which are R&D organizations financed almost entirely by the Federal Government, are shown separately and grouped with the entities that administer them in the performer-based presentation of investment (Appendix 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.

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 cumulating them based on methodologies which BEA uses for other types of fixed assets.

Changes from Previous BEA R&D Satellite Accounts

The methodologies used for this satellite account are largely similar to those used in the first version of the R&D satellite account presented in the November 1994 *Survey of Current Business* (Carson, Moylan, and Grimm (1994)). However, several important changes have been made to the account's current-dollar estimates, real estimates and the capital stock measures.

Important changes in current-dollar estimates include the following:

- Industry-administered FFRDCs are now shown separately.
- For the state and local government and nonprofit institutions sectors, indicator series have been improved for years when there are no NSF survey data.

Important changes to real estimates include the following:

- Improved chain-type price measures of real output and prices, 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.
- Within the input-cost price index (Scenario A), a new methodology for deflating business R&D that 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;
- Within the input-cost price index (Scenario A), a new methodology for deflating academic R&D that uses an academic R&D price index developed by the National Center for Education Statistics.[29]
- Real R&D investment by source of funding.

Important changes to the capital stock measures include the following:

- A new measure of R&D capital stocks based on the funder of the R&D that is performed; to better approximate the ownership assumed for R&D capital.
- A geometric rate of depreciation that replaces the depreciation pattern based a straight-line perpetual inventory method.

The key methodological issues faced in developing the R&D satellite account are outlined in the following sections.

Historical Cost (current-dollar) R&D investment

As noted earlier, although BEA's estimates of R&D stocks are presented on a funder basis, the investment estimates are built up from performer-based survey data. Current-dollar investment is based on performer-reported R&D expenditures from several NSF surveys. These expenditures include the cost of R&D personnel, materials and supplies, overhead (e.g., utilities, insurance, and taxes) and the depreciation

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[29] This series ends in 1995, BEA extrapolates with NIPA PCE for education and research between 1996 and 2002.

charges associated with the capital used in performing R&D. Expenditures for each performer are then disaggregated by any available detail on the sources of funding.

Constructing funder-based R&D stocks performer-based expenditures, rather than stocks from the source of R&D funding, attempts to avoid at least two problems. First, the data reported by source of funding would have to be adjusted in order to be consistent with the timing with which purchases of goods and services are generally recorded in the NIPAs.[30] Second, the data reported by source of funds would have to be adjusted to avoid double-counting for funds passed between sectors.

Where there are gaps in the coverage of the NSF survey data, BEA uses interpolation and extrapolation methods to fill in the missing data using time series of related data. R&D activities for state and local governments and for nonprofit organizations excluding universities and colleges are two categories where this method is used extensively. Some R&D expenditure estimates prior to 1987 use data previously estimated in Carson, Moylan, and Grimm (1994).

BEA performs a number of adjustments to the NSF survey-based expenditure data to make them statistically and conceptually consistent with the NIPAs. The statistical adjustments are for timing (to reflect calendar year expenditures), geographic coverage (to reflect only domestic R&D performed), and to estimate missing data, which were withheld to protect the confidentiality of NSF survey respondents. BEA also makes an adjustment to put the depreciation of structures and equipment used in the production of R&D on a basis appropriate for national economic accounting rather than tax accounting.

Real R&D investment

An important methodological change is the introduction of "chain-type" measures of real output and prices. This major methodological improvement was introduced into the NIPAs as part of the 1996 comprehensive revision of the accounts. The real R&D measures are "chain-type" measures that are based on the "Fisher ideal" formula that incorporates weights from the two adjacent years rather than the weights of a single base year.[31] Thus, when the base year is updated, the levels of the estimates change but the growth rates of the various components do not, and the revisions to the growth rates that result from updating the base period of a fix-weighted index are avoided.

The rest of this section has two parts. First, it describes the construction of the input-cost-based indexes used in scenario A. Next, it describes the construction of the three high-productivity proxy indexes used in scenarios B, C, and D.

Input-cost Price indexes

Ideally, BEA would develop measures of real R&D investment based on market prices for R&D. Without these market prices, BEA has developed a methodology similar to that used for other nonmarket output. This methodology uses input-cost price indexes to deflate output. BEA would like to deflate all R&D expenditures disaggregated by major cost components, such as compensation, materials and supplies,

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[30] This is an adjustment from the time of payment from the source of funding to the time of payment to the performer.

[31] The Fisher quantity index relative is geometric mean of Paasche and Laspeyres quantity relatives. The quantity index relative is calculated as $Fisher = \sqrt{L * P}$,where $Laspeyres = \frac{\sum P_{t-1}Q_t}{\sum P_{t-1}Q_{t-1}}$ and $Paasche = \frac{\sum P_t Q_t}{\sum P_t Q_{t-1}}$

CFC, and other overhead costs. In practice, only industry expenditures are deflated based on detailed cost components because the survey of industrial R&D performers is currently the only survey that provides the information needed to develop this detailed split of R&D costs. Consistent with NIPA practice, the estimates do not include any additional adjustment, such as an assumed rate of increase in productivity. Appendix Table 6 summarizes the main deflation measures used for each performer in the input cost indexes used in the 2006 preliminary R&D satellite account.

The procedure above results in the performer-based price indexes presented in Appendix Table 6.1. For funder-based estimates, since not all the detailed cost data are available in scenario A, the input cost-based price indexes require additional steps. Currently, BEA can identify only two of the necessary price indexes. One is a NIPA price index for total Federal defense and nondefense purchases of R&D. The other is for Federal intramural expenditures that are already derived as part of the performer-based calculations.[32] that are already derived as part of the performer-based calculations.

For funder-based estimates of investment, BEA uses the Federal price indexes described above and the total (performer-based) price index to derive a non-Federally funded price index. Thus, when the Federal price indexes are combined with this derived non-Federal index using a chain-type formula, the total funder-based price index will match the total performer-based index.

BEA has introduced some important improvements to the real measures of R&D output that were not available in the prior versions of BEA-produced R&D satellite accounts. For the business sector, salaries for engineers in R&D organizations are used to deflate compensation costs for R&D personnel (American Association of Engineering Societies Annual Salary Surveys, various years). Input price indexes from costs incurred by the Scientific Research and Development Services industry (NAICS 5417) are used to deflate materials and supplies, overhead, and R&D CFC. These prices are based on detailed data for intermediate input costs now available in BEA's industry accounts.[33]

For R&D performed by colleges and universities, BEA incorporates a new methodology for deflating academic R&D expenditures based on an academic R&D price developed by the National Center for Education Statistics for the years 1960–95.[34] This index is extrapolated for the other years based on the BEA price index for personal consumption expenditures on other education and research.[35]

High-Productivity Price Indexes

While scenario A uses three price indexes to deflate R&D investment, the other three alternative scenarios apply one price index to all investment. The price indexes used to deflate nominal investment in Scenarios B, C, and D are constructed in various ways.

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32 Intramural expenditures are expenditures for R&D performed within a sector of the economy, in this case within the Federal government. Extramural expenditures are expenditures for R&D performed by another sector.

33 BEA's earlier work assumed that intermediate inputs to business R&D had a pattern of price change more like that of the overall intermediate inputs used by the industry performing the R&D. The current choice assumes that intermediate inputs to business R&D have a pattern of price change more like that of the inputs to the R&D services industry. BEA and NSF plan to continue to work together to improve these measures.

34 Deflation of academic data in the 1994 satellite account relied heavily on the use of BEA's biomedical research and development price index (BIRDPI), which BEA and NSF believed was not a desirable price measure to use for the entire academic sector.

35 National Center for Education Statistics, *Digest of Education Statistics*, 2004, Table 35.

Direct High MFP (scenario B). The high MFP index is created by subtracting a gross-output weighted average of the top 5 MFP growth rates of 2-digit SIC manufacturing industries, as computed by the BLS , from the growth rate of the Fisher aggregate of the three input-cost based indexes of scenario A. To create this combined index, BLS multifactor productivity data for 2-digit manufacturing industries are compared for each year. In each year, annual productivity growth from the five industries that experienced that year's highest MFP growth are weighted by the share of gross output of each industry to the sum of the five industries' gross output. Two industries, "electronic and other electrical equipment, except computer equipment," and "industrial and commercial machinery and computer equipment" consistently appear in the top measures since 1974. The resulting productivity series is used to adjust the input-cost based price index used in scenario A. As noted earlier, the resulting R&D price index implies MFP growth in R&D conduct averaging 3.8 percent a year, and reflects the well-known downturn in 1973 and acceleration since the mid-1990s.

High-Productivity Service Industries (scenario C). Service industries with high average annual real value added growth over the period 1959–2002, (high-productivity service industries) are used to create a price index that replicates the output growth of R&D prices. The industries used for this index represent 5 of the 6 fastest growing services-producing industries during the period.[36] The value added price indexes from BEA's GDP-by-industry program are combined using Fisher aggregation (see footnote 29) of the price indexes for air transportation (NAICS 481); broadcasting and telecommunications (NAICS 513); securities and commodity brokers (NACIS 523); computer systems design and related services (NAICS 5415); and information and data processing services (NAICS 514). This index was constructed using published current-dollar value added and value added price indexes for 1977–2002.[37] Unpublished data for these industries was used to compute the series for 1959–1976.

R&D performing industries (scenario D). In this scenario, the output measure for R&D is based on the assumption that the unobserved R&D prices are similar to the prices of industries that perform R&D; it is constructed using BEA's GDP by industry value-added price indexes. The R&D performers price index is a Fisher aggregate consisting of the price indexes for four of the top industrial R&D performers, in terms of current-dollar expenditures. These top performers were identified based on NSF data on industry performance of R&D and weighted annually based on their shares of performed R&D.[38] The four industries that consistently make up the vast majority of industry spending are radio and TV receiving equipment (SIC 366,377); drugs and medicine (SIC 283); office, computing, and accounting machines (SIC 357); and aircraft and missiles (SIC 372, 376).[39]

36 Since the use of these industry price indexes is intended to proxy a pattern of output growth similar to R&D, one fast-growing industry was excluded; this was Social Assistance which was the fourth fasted growing industry over the period from 1959 to 2002.

37 Current-dollar value added can be found at: http://www.bea.gov/bea/industry/gpotables/gpo_action.cfm (lines 37, 48, 49, 53, 62). Chain-type price indexes for value added can be found at: http://www.bea.gov/bea/industry/gpotables/gpo_action.cfm (lines 37, 48, 49, 53, 62).

38 National Science Board (2006).

39 Average current-dollar weights for the R&D performers index are provided below.

Average weights per time period

	1959-1973	1973-1995	1995-2002
Radio and TV receiving equipment (SIC 366,377)	30.3	29.4	40.4
Drugs and medicine (SIC 283)	10.6	20.1	28.8
Office accounting and computer machinery (SIC 357)	30.8	29.5	18.3
Aircraft and missiles (SIC 372,376)	28.2	21.0	12.5

Stocks of R&D Capital

Estimates of net stocks of R&D capital and depreciation are calculated for each type of funder. Real net stocks for each institutional type are constructed using a perpetual inventory method: the constant-cost net stock at the end of a year is estimated as the stock at the end of the previous year, times one less a depreciation rate, plus constant-cost investment during the year, multiplied by one less half the depreciation rate. This *half* is a compromise between assuming all investment happens at the start of the year versus the end. The depreciation rate is a flat 15 percent in scenario A. In scenarios B, C, and D, the depreciation rate is a varying time series, using the NIPA-based rate for the basket of assets comprising information-processing equipment and software for 1987–2002, extrapolated using the NIPA-based rate for the basket comprising private fixed investment in nonresidential equipment and software for earlier years. This alternative depreciation series is intended to capture accelerated depreciation of R&D in recent years, consistent with faster technological change and shorter-lived assets.

Current-cost net stocks of R&D, which value the stock at the replacement cost, are derived by pricing the constant-cost net stocks by an end-of-year deflator. Historical-cost net stocks of R&D, which are analogous to estimates used on company reports, are constructed like constant-cost stocks, but with no deflation. Historical-cost and current-cost aggregates of net stocks and depreciation are obtained by directly summing the estimates. Aggregate real-cost estimates are derived using the Fisher chain formula.

IV. Assumptions for the Satellite Account and Alternative Scenarios

In developing its preliminary estimates of the impact on the U.S. economy of recognizing R&D as investment, BEA has balanced two distinct, but interrelated needs: 1) advancing the process of developing a methodology for repeatable estimates that will be both consistent with the NIPAs and internationally comparable and 2) capturing results that include the impact of R&D on the economy based on a set of macroeconomic results reflecting existing consensus about the characteristics of R&D activity. These needs are, of course, interrelated because the NIPAs are dynamic. The NIPA comprehensive revision process provides the means for incorporating new concepts into the national accounts after careful testing and the development of broad consensus among national accountants and users of the accounts.

The Input-Cost Approach and Three High-Productivity Scenarios

It is useful to compare the assumptions used in each of the alternative scenarios of the R&D satellite account as well as the results that other researchers have produced in their estimates of the impact of treating R&D as investment. Each scenario makes assumptions about: 1) the rate at which R&D depreciates; 2) the deflators used to estimate real (inflation-adjusted) R&D; 3) the treatment of capital services for R&D investment, 4) the scope of R&D considered investment; and 5) the assumptions made about externalities or spillovers from the conduct of R&D.

In general, the measure of GDP will rise by adding capital services for government and nonprofit R&D, broadening the scope for what is considered R&D, more rapidly decreasing deflators, and including positive spillovers in the conduct of R&D. All of the estimates in this paper are based on the same definition of R&D. They reflect only the direct effects of R&D investment and do not include any additional explicit impacts based on spillovers.

As this paper has described, BEA's current estimates have been constructed with a cost-based approach that starts by summing the expenditures for R&D and adjusting these expenditures to make the measure of output consistent with national accounting treatment of own-account, or internally-used investment. These cost-based nominal estimates are then deflated to develop real, or inflation-adjusted measures of R&D investment. Real R&D investment is transformed into stocks of R&D capital by depreciating the cumulative investments of prior years to account for the loss in value over time.

The two basic approaches used in this paper to produce measures of real R&D investment produce noticeably different results. The conceptually simplest approach is to deflate R&D investment with an input cost price index; this is the method used in Scenario A. Since this method has the effect of not recognizing any productivity improvement in the conduct of R&D, its results should be considered a lower bound on the measure of real R&D investment. The other approach is to find an appropriate way to estimate the real output of R&D. The three alternatives for this estimate; a high-productivity manufacturing industries price index, a high-productivity service sector price index, and a R&D performing industries price index, have been described in Sections II and III.

Table 5 summarizes the assumptions for each of the four scenarios reported on in this account. Scenario A is consistent with most of the current accounting conventions of the NIPAs. This scenario assumes a constant 15 percent geometric rate of depreciation for all types of R&D. It also incorporates a set of input deflators that are developed from the most detailed component costs available. As noted above, the use of these input price indexes has the effect of not recognizing any productivity improvement in the conduct of R&D, since the measure of R&D output is simply the sum of the inputs.

Table 5: Assumptions for the Scenarios in the R&D Satellite Account

Parameter	A	B	C	D
depreciation of R&D	15 percent	before 1987: change in private fixed investment in nonresidential equipment and software depreciation after 1987: information processing equipment depreciation	Same as B	Same as B
price index	Input cost-component based	cost-based price index adjusted to proxy high-productivity growth in manufacturing	composite price index based on the value added of five high-productivity service industries	composite price index based on the value added of the four industries that perform the most R&D
net return to business R&D (capital services)	same as to other fixed assets	average net rate of 15 percent	Same as B	Same as B
net return to government and nonprofit R&D (capital services)	none	estimated net return based on long-term average in the real 10-year treasury rate, plus a higher premium for R&D investment	Same as B	Same as B

Scenario A also reflects the current convention of the NIPAs that investment by governments and nonprofit institutions earn no net return to capital. Further, it assumes no additional net return to R&D relative to other types of assets. This scenario produces the smallest impact of GDP of all the alternatives tested. Over the period from 1959 to 2002, the average impact on the level of GDP is 2.3 percent for scenario A and the contribution to the growth in real GDP is 2.17 percent.

The High-Productivity Approach, Scenarios B, C, and D

Scenarios B, C, and D all share a set of assumptions about the characteristics of R&D as an investment good with a rapid pace of technological change that leads to an accelerating pattern of obsolescence and the quality of uncertainty surrounding its outcome that leads to a higher rate of return to R&D investments.

Scenarios B, C, and D each employ a different approach to estimate real R&D output using price indexes for related industries. Scenario B uses a high-MFP, manufacturing industry-based, price index. Scenario C uses a composite high-productivity service sector price index; scenario D uses a composite R&D performing industries price index.

These three high-productivity scenarios all include the depreciation profile consistent with accelerating obsolescence. As described in Section II, it is based on the NIPA depreciation series for information processing equipment after 1987 and the change in the depreciation series for private fixed investment in nonresidential equipment and software prior to 1987.

Scenarios B, C, and D each also incorporate a set of assumptions about rates of return to R&D for business, government, and nonprofit institutions: 1) The net rate of return to business sector R&D is assumed to be higher than the net return to non-R&D assets; 2) government and nonprofit R&D are assumed to earn a net rate of return in addition to simply the consumption of fixed capital; and 3) a a higher net rate of return to government and nonprofit R&D capital is assumed compared with what non-R&D government and nonprofit capital would earn.

Despite the different methods used to estimate the unobserved real measure of R&D, all three all yield similar results with respect to the level of GDP and other macroeconomic effects. The increase in nominal level of GDP is an average of 2.6 percent when R&D is treated as investment in each of the scenarios in table 6. The larger impact compared with scenario A (2.3 percent) is mainly due to the addition of a net return to government and nonprofit R&D capital.

Table 6: Overall Impact of Capitalized R&D on GDP Level

	NIPA treatment	with R&D capitalized					
GDP [billions of dollars]		Scenario B level	Scenario B percent difference	Scenario C	Scenario C percent difference	Scenario D level	Scenario D percent difference
1960	526.4	537.4	2.1	537.8	2.2	538.0	2.2
1970	1,038.5	1,068.6	2.9	1,067.1	2.8	1,069.0	2.9
1980	2,789.5	2,859.3	2.5	2,856.0	2.4	2,857.5	2.4
1990	5,803.1	5,963.3	2.8	5,961.6	2.7	5,961.9	2.7
2002	10,469.6	10,751.5	2.7	10,743.5	2.6	10,747.3	2.7
average change, all years			2.6		2.6		2.6

By recognizing a new class of assets, the satellite account shows a rise in the measured value of investment. The increase in private gross domestic investment ranges from 7.5 percent in 1960 to 11.3

percent in 2002 (table 7). The increase is the same for each scenario, because it is measured the same way in each scenario, is estimated in nominal dollars, and is not affected by the adjustments to net returns.

Table 7: Impact on Gross Private Domestic Investment and the Saving Rate

Gross Private Domestic Investment GPDI			National Saving Rate (Note 1)	
	NIPA treatment	With R&D as investment	NIPA treatment	with R&D as investment
Period	(millions)	All Scenarios	saving rate	Percentage point difference All Scenarios
1960	7,8891	7.5	21.0	2.1
1970	15,2378	7.1	18.6	2.0
1980	47,9252	6.8	19.7	1.8
1990	86,0968	9.8	16.3	2.2
2002	1,582,129	11.3	14.2	2.2

Note 1. Calculated as the Ratio of the sum of Gross Saving (NIPA Table 5.1) to the sum of GNI over the each time period, expressed as a percent

Similarly, the impact on the national savings rate is consistent across all the scenarios; it increases by approximately two percentage points over the period. This change is the result of recognizing business sector R&D expenditures as investment rather than as expenses, and for government and nonprofit institutions, the shift of R&D expenditures from consumption to investment.

Scenarios B, C, and D produce a relatively tight range of contributions to the real growth in GDP. The largest contribution to growth comes from scenario B, the high-MFP index; the contribution to growth was 4.9 percent over the period 1959 to 2002. In scenario C, the scenario that includes the composite price index from the high-productivity service industries, 1959 to 2002 is an average 4.3 percent. For the late 1990s, the contribution is 6.3 percent. Using the composite price index for R&D performing industries yields a similar overall contribution, 4.6 percent, as well as a similar contribution for the late 1990s, 6.7 percent. All three of these scenarios are characterized by a bump up in the contribution of R&D investment to growth in the late 1990s. These results are compared in the table below.

Table 8: Contribution of R&D investment to growth in adjusted real GDP

	Scenario B High-MFP adjustment to input cost price index	Scenario C High-productivity service industries price index	Scenario D R&D performing industries price index
Years	Contribution	Contribution	Contribution
1959-1973	4.46	3.88	4.03
1974-1994	4.68	3.86	4.33
1995-2002	6.77	6.25	6.69
1959-2002	4.94	4.28	4.61

BEA reports the estimates based on scenario D as the preliminary estimates for the 2006 R&D satellite account. These results represent a mid-range of the three high-productivity options. Line 6 of Appendix Tables 1.1 through 1.4 provide the annual estimates for real GDP, GDP (nominal), real GNI, and the saving rate based on scenario D.

V. Looking forward to the 2007 R&D Satellite Account

The discussion in the previous section suggested areas where alternative assumptions produce significantly different impacts on GDP and growth. BEA intends, with the support of NSF, to explore the more important issues related to R&D investment and capitalization in preparing the R&D satellite account in 2007 and in future work on R&D. These issues include the overlap between R&D and software investment, the international flows of R&D transactions, improved output measures, improved input deflators, the treatment of spillovers or externalities associated with R&D activities, and the ownership of R&D. Each of these issues is discussed briefly below.

Overlap Between R&D and Software

The NIPAs currently recognize software as investment that yields an intangible, produced fixed asset. This investment includes prepackaged software, custom software, and own-account software. Because software is currently treated as investment in the NIPAs, the treatment of R&D expenditures as investment implies that R&D used to create own-account software may be counted once as investment in an R&D asset, and again as part of a software asset. This overlap exists because the value of own-account software is built up from production costs, which primarily consist of the compensation costs of computer programmers and systems analysts. For computer programmers and systems analysts who work in R&D facilities, compensation is counted once as an input to own-account R&D and again as an input to own-account software, resulting in a double count.

R&D expenditures used to create software assets are currently included as investment in the R&D satellite account. In 2007, BEA plans to address this overlap between own-account software and R&D by first adjusting investment in software. This adjustment includes a subtraction and an addition. The subtraction to investment in software would be the compensation costs and intermediate expenses associated with the creation of own-account software by computer programmers and systems analysts in R&D facilities, or a reclassification of these expenditures from software investment to R&D investment. The addition to investment in software will be for the consumption of fixed capital of the new R&D asset used to create the software.

A second step is estimating the size of this overlap. BEA does not currently have a good measure of the overlap in part because of differences in definition of own-account software. The NIPA definition is somewhat different from the definition of own-use software in the Census Survey of Industrial R&D (SIRD). This survey includes R&D expenditures for software development produced for sale to others, and identifies it separately in a line item. The survey specifically excludes expenditures for software development intended for within-company use only. This latter category is defined differently from the own-account definition in the SNA and implemented in the NIPAs. In addition to software created for own use within an enterprise, the NIPA measure of own-account software includes own account originals. These are software originals created and retained within the same enterprise for use in further production.[40] R&D to create these software originals for further production is likely to be included in the R&D totals despite the exclusion of expenditures for software for within company use. For the 2007 R&D Satellite Account, BEA plans to create estimates of this overlap, based on data from Census and other sources on purchases of capitalized and expensed software by industry.

40 A software original is a unique piece of software created by computer programmers and systems analysts. Both this original and the copies that can be made from it and sold are treated as investment in software.

International Transactions in R&D

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, presented in a detailed table in Appendix Table 8. BEA's R&D satellite account presents estimates of the stock of R&D located in the U.S., regardless of the nationality of the owner. The satellite account treats all domestically-performed business R&D as 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 paper are not yet adjusted for R&D investment by U.S. and foreign multinationals, 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 collection of data not currently available, and is a longer term project.

The R&D surveys that provide the primary source data for the R&D satellite account do not currently measure exports and imports of R&D, but they do provide information on funding for foreign-performed R&D. Complete source data are not currently available, and the discussion below describes the existing data on international R&D transactions for the U.S., primarily available from BEA's international survey programs, and how they can be used in future versions of the R&D satellite account to adjust the domestic expenditures.

Currently, trade in R&D services represents a relatively small component of domestic R&D activity. Exports of R&D services (described in more detail below) of $7.6 billion dollars in 2002 is small compared to $170.8 billion dollars in business-funded investment in R&D in the U.S (Table 3.1) The production and sale of R&D services are a result of R&D activity, and thus, are not directly comparable to domestic R&D spending.[41] However, comparing the volume of trade in R&D services to R&D spending provides an indicator of its relative importance.

Data on international trade in R&D services between unaffiliated or unrelated firms are available beginning in 1986 from BEA; for trade in R&D services between affiliated entities (both are part of the same firm but are located in different countries), data are available since 2001.[42] Although these data represent trade in R&D services for all industries, not only the R&D services industry (NAICS 5417), they represent a somewhat broader scope of activities from Frascati based-R&D.

The greater magnitude of affiliated trade for imports and exports highlights the role of multinational corporations in the international exchange of R&D services. Affiliated trade is comprised of transactions between 1) U.S. parent companies and their foreign affiliates and 2) the U.S. affiliates of foreign parents. Most of the growth in exports of R&D services is transactions between the U.S. affiliates of foreign firms and their foreign parents; exports from U.S. parents to their foreign affiliates have been level during this 4-year period.

[41] Trade in research and development and testing services in the BEA international services data covers "laboratory and other physical research, product development services, and product testing services." The inclusion of product testing services may make its scope a somewhat broader than other measures of R&D activity collected by BEA and the National Science Foundation, where the Frascati-based definition is generally understood to exclude some types of testing services.

[42] Prior to 2001 affiliated trade in R&D services was included in larger aggregates; other private services between 1992–1996; and other business, professional, and technical services between 1997–2000.

Although trade in business R&D services from the U.S. is relatively small, R&D is increasingly an international activity. This growth is reflected in a number of dimensions of R&D-related activity, including R&D performed by multinational corporations outside of their home countries, international trade in R&D services, international transactions for the purchase and use of patents and other types of technology, and international collaboration on R&D. For BEA's R&D satellite account, isolating the transactions in R&D and identifying both the owner of the R&D investment and where the R&D is used are key pieces of information necessary to determine the impact of these international activities on the stock of U.S. R&D.

R&D performed outside of the U.S. that is ultimately used in the U.S. would be measured as domestic investment in a framework that recognizes R&D as investment. As shown in the last two columns of Appendix Table 9, BEA and NSF surveys currently provide information on R&D performed abroad that can be identified with U.S. ownership or funding; however, they do not include information on where this R&D is ultimately used. Without the latter information, the U.S. expenditures for foreign-performed R&D cannot be characterized as U.S. assets; the R&D may be used in the country where it is performed, and thus represent an asset for that country.

To include international transactions in R&D, additional data are needed on where R&D is used. Moris (2006) calls for collection of these international R&D data that would identify where the R&D is used. This information would be particularly valuable for developing stocks of capitalized R&D for the U.S. because this information about use would serve as a reasonable proxy for the location of the asset—a somewhat inexact concept when applied to intangibles.

Improved Output and Input Deflators

In 2007, BEA plans to refine its methodology for measuring R&D output. BEA expects to refine the approaches used in the 2006 preliminary R&D satellite account; in particular, developing 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.

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 makeup of R&D costs across industries, and correspondingly improved R&D deflators for compensation and the other input costs with an emphasis on certain key industries such as the manufacturing of computers, electronic products, and pharmaceuticals. For example, the makeup of R&D personnel (scientists, engineers, technicians, and clerical support) or the nature of R&D physical capital investment and its depreciation may vary significantly across industries. The makeup of an industry's R&D funding may also be used to develop improved R&D deflators, especially for those industries which have a high portion of their R&D funded by the Federal government.

Treatment of R&D Spillovers

Any additional impact of R&D investment beyond its share of nominal GDP would arise from spillovers or externalities. These spillovers or externalities exist when the social cost (or benefit) exceeds the private cost (or benefit). In the case of R&D, the gap between the private and social cost creates a spillover that consists of benefits or losses beyond the control of the R&D stocks' owner, or the effects of products using new technology and innovations, for example, production of products that use computers and software. The assumed existence of positive spillovers from R&D, and the inability of the owner to appropriate a payment for the R&D, has long been considered a justification for government support of R&D activity. The 2006 R&D satellite account does not consider any externalities from R&D activity, and in 2007, different techniques and methods will be tested and evaluated to determine the feasibility of including spillovers from R&D investment.

Ownership of R&D Assets

The estimates of R&D stocks and their macroeconomic impacts presented in the satellite account assume that the funder of R&D owns the R&D. As part of its work to develop improved concepts for treating R&D as investment, BEA plans to develop a standard that can be applied to the existing survey data. This standard would use existing information about the assignment of intellectual property rights—who has the right to patent and collect royalties— to adjust the funder-based estimates of ownership of R&D. This information about the assignment of intellectual property rights would then also be used to begin to develop a measure of "freely available" R&D.

The concept of "freely available" is currently not well defined and thus is difficult to apply to existing survey data. In the longer term, BEA will work with its data providers to align the survey questions to the economic concepts necessary to identify ownership and location of use. Since "freely available" R&D, often produced by governments, nonprofits, and academic institutions, is likely to have measurable impacts on economic activity, it is important that this type of R&D be reported separately.

VI. Summary and Conclusion

The recognition of R&D as investment in the NIPAs would represent a major change in BEA's treatment of intangible assets. The R&D satellite account, which can be seen as a step toward that goal, presents preliminary estimates for its impact on GDP, GNI, contributions to growth, and investment.

Several additional steps to refine the estimates are needed; some steps are slated for release in September of 2007, and others are long-term projects. Most significant among these additional steps are the following:

- An adjustment for imports and exports of R&D services and the overlap between R&D and software.
- Development of R&D stocks by type of R&D; that is basic research, applied research, and development of new products and processes. If BEA is 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.
- Improvement of the price indexes used for the estimates.
- Estimates of capital services for R&D. While this would enhance the usefulness of the R&D capital stocks for productivity analysis purposes, preliminary capital services estimates are likely to be somewhat speculative because of the limited availability of price data for the use of R&D. Given the future directions planned for BEA's national account in harmonizing BEA data with the productivity program of BLS and others, developing capital services estimates for R&D has a high priority. However, the public goods qualities of R&D and the potential for spillovers complicate the process of estimating the private rental value of R&D assets necessary from capital services. BEA staff members are currently engaged in research to develop econometric estimates of the private and social rates of return to domestic industrial R&D. Ongoing work at BEA and BLS will develop insights into the return received from R&D performed outside of the U.S. This work on social returns might form the basis of a set of approximations of the magnitude of the externalities or spillovers associated with R&D. These approximations could be presented as an overlay to the basic satellite account.

In the longer term, the enhancements that BEA is most interested in developing would require improved survey data. For example, the estimates of consumption of fixed capital used to create R&D would be greatly improved by survey data on expenditure 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.

As BEA considers incorporating R&D as intangible investment in the NIPAs, a series of estimating challenges emerge. One of the most immediate challenges will be the alignment of NSF and other data 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.

The additional dimensions of geographic and time measurement will need to be addressed before R&D can be fully incorporated into the NIPAs and other BEA accounts. Current R&D survey data are conducted annually or less frequently, and the publication lag is usually between 1 and 2 years. For the NIPAs, BEA needs to produce quarterly estimates with an initial lag of 1 month after the end of the quarter; quarterly R&D investment estimates will require a methodology based on higher frequency data with shorter lags than are currently available.

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