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MEASUREMENT OF RESEARCH AND DEVELOPMENT IN NATIONAL ACCOUNTS

THE UNITED STATES RESEARCH AND DEVELOPMENT SATELLITE ACCOUNT: ESTIMATES AND CHALLENGES

Note by the Bureau of Economic Analysis, United States[1]

Summary

The Research and development (R&D) satellite account developed by the Bureau of Economic Analysis will provide means of exploring the impact of the new treatment of R&D spending on the economy and a framework through which various methodological and conceptual issues can be worked out. This paper presents a summary of the concepts, methods, and results from the 2007 R&D satellite account.

[1] This paper has been prepared by Brent R. Moulton, Carol A. Robbins and Carol E. Moylan (Bureau of Economic Analysis, U.S. Department of Commerce) at the invitation of the secretariat.

I. INTRODUCTION

1. The Bureau of Economic Analysis-National Science Foundation (BEA-NSF) research and development (R&D) satellite account provides detailed statistics designed to facilitate research into the effects of R&D on the economy.[2] The account shows how gross domestic product (GDP) and other measures would be affected if R&D spending were "capitalized," that is, if R&D spending were treated as gross fixed capital formation rather than as a current expense. A preliminary version of the account was published in 2006.[3] In 2007, BEA published revised national estimates and preliminary industry, international, and regional estimates and methodologies.[4]

2. The R&D satellite account format provides a means of exploring the impact of adjusting the treatment of R&D activity on the economy and a framework through which various methodological and conceptual issues can be worked out. The R&D account can be seen as prelude toward adjusting BEA's core economic accounts to better account for R&D. Currently, BEA plans to incorporate R&D spending as gross fixed capital formation into its core accounts around 2013.

3. This paper presents a summary of the concepts, methods, and results from the 2007 R&D satellite account. The paper consists of the following sections: a) motivation for the account, b) conceptual challenges faced in building the account, c) an overview of the estimation process, d) a summary of the results, and e) a discussion of next steps.

II. MOTIVATION

4. Currently, the national economic accounts do not treat R&D as fixed capital formation and thus cannot separately identify its contribution to U.S. economic growth. BEA's R&D satellite account is part of BEA's long-term efforts to better account for intangible assets.

5. Economic theory can be used to consider the classification of expenditures as capital formation or intermediate consumption. Corrado, Hulten, and Sichel (2005) conclude that *any* use of resources that reduces current final consumption in order to increase it in the future qualifies as capital formation, regardless of whether the capital is tangible or intangible. They note that this definition encompasses not only R&D and the intangible investments recognized by *System of National Accounts 1993* (computer software and databases, mineral exploration, and artistic originals), but also some types of advertising, worker training, and management reorganization and restructuring designed to improve productivity. For the 2008 update to the

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[2] The R&D account was developed with support from NSF's Division of Science Resource Statistics, which is responsible for national R&D statistics.

[3] See Okubo, Robbins, Moylan, Sliker, Schultz, and Mataloni (2006). The R&D satellite account built on earlier work at BEA by Carson, Grimm, and Moylan (1994) and Fraumeni and Okubo (2005).

[4] The main report is Robbins and Moylan (2007) and the methodological documents are Sliker (2007), Okubo (2007), Mataloni and Moylan (2007), Robbins, Candela, Fahim-Nader, and Medeiros (2007), Copeland, Medeiros, and Robbins (2007), Mead (2007), Yorgason (2007), and Bernat (2007).

System of National Accounts, only R&D has been considered for reclassification as capital formation.

6. *System of National 1993* treats R&D in a peculiar way, reflecting the lack of consensus at the time on whether it should be capitalized. On the one hand, *SNA 1993* treats R&D as current consumption and patented as nonproduced assets; on the other hand, it regards the income derived from royalty and license fees for use of the patented innovation as sale of a service, implicitly acknowledging that the innovation is really a produced asset and the resulting income flows represent a return to a produced asset. Nevertheless, the accounts show the anomaly of a nominally nonproduced asset producing services. Treating R&D like other fixed assets by capitalizing it removes this anomaly from the system and helps produce a more consistent set of accounts.

7. For decades, economists have focused on R&D as a driver of economic growth, but have lacked quantitative macroeconomic data on its value, volume, and prices or information on its contribution to the nation's productivity growth and wealth. By capitalizing R&D, we are contributing to the development of quantitative measures of innovation and identifying some of the important sources of economic growth that have heretofore not been measurable.

III. CONCEPTUAL CHALLENGES

8. Measuring R&D capital formation presents well-known conceptual and empirical challenges. Because most R&D is created by businesses, nonprofit institutions, and governmental agencies for their own use, data on market transactions are unavailable for most R&D output.

9. Not only are prices and quantities generally not observed, but their units are difficult to define. R&D, by its nature, produces unique products, whereas measurement of quantity and prices generally relies on standardized products with prices that are repeatedly observed. Consequently, it is not possible to construct traditional price indexes, and alternative approaches must be considered for the deflation of R&D output. One of the methods conventionally used for nonmarket output is to deflate using input price indexes. However, this approach seems ill-suited for R&D; deflation using input prices implies that the output prices are changing at the same rate as input costs, which precludes multifactor productivity growth from R&D.

10. Another unique feature of intangibles is that they do not suffer from the effects of damage and wear and tear that cause the efficiency of tangible fixed assets to decline as they age. Nevertheless, the value of R&D and other intangible assets does tend to decline as the asset ages, and thus they can be said to depreciate. This decline in value is due in part to the limited period of protection provided by patents and, more often, by obsolescence as it is replaced by new and and more efficient R&D assets. Thus, R&D depreciation exists and is defined by its obsolescence, but measuring R&D depreciation is difficult due to the lack of resale markets.

11. When a business invests in R&D, it generally tries to protect the innovation or knowledge that it has produced, either through legal mechanisms such as patents or through secrecy. In many cases, however, the new knowledge eventually becomes known outside the firm and allows competitors or other firms to benefit from the R&D of the investing firm without

incurring the costs. These benefits are known as *spillovers*. The BEA R&D satellite account is designed to measure only the direct impact of R&D investment and does not separately identify the effects of spillovers. (The effects of spillovers are implicitly included in the overall growth of GDP.)

IV. OVERVIEW OF THE ESTIMATION PROCESS

A. Estimates of capital formation

12. In the national income and product accounts (NIPAs), expenditures on R&D—whether actually purchased from others or carried out in-house—are treated as intermediate rather than final expenditures; they are treated as a current expense of production. These expenditures are currently only partly identifiable in BEA's NIPAs. Federal government purchases of R&D are identified and reflected in government consumption as an intermediate purchased service. Expenditures on R&D performed in-house by the federal government and state and local government purchases of R&D are also reflected in government consumption, but are not separately identified. Spending on R&D by nonprofit institutions serving households are in personal consumption expenditures (PCE), but are not separately identified. In addition, BEA's estimates of international trade in services provide measures of exports and imports of R&D services. BEA separately estimates royalties and licensing fees, which include payments for the use of R&D protected by patents.

13. For market producers, reclassifying R&D expenditures out of current expenses and into fixed capital formation would lead to an increase in GDP equal to the value of the R&D expenditures. For general government and for nonprofit institutions serving households, capitalizing R&D expenditures would shift the value of the expenditures from final consumption to fixed capital formation. This shift alone would not change the measure of GDP. However, capitalizing R&D spending would also lead to an increase in the value of capital services generated by the capital asset, reflecting the value of the use of the asset in production. Conceptually, that value is the amount a producer would be willing to pay to rent the asset for a given period. For the R&D satellite account, capital services are measured as the sum of consumption of fixed capital and net returns on R&D fixed assets. The inclusion in the R&D satellite account of net returns to nonprofits and general government is a departure from the calculation of non-market output in the NIPAs, which includes only consumption of fixed capital as a partial measure of capital services.

14. The treatment of R&D fixed capital formation in the R&D satellite account is similar to treatment of fixed capital formation in tangible fixed assets in the NIPAs. Fixed capital formation in R&D reflects purchases of R&D assets by business and by governments and their expenditures on own-account for R&D that will be used to generate future product and income streams for its owners. Conceptually, the investment should be recorded for the sector that owns the R&D asset.

15. The NSF survey of industrial R&D is the most important data source for the satellite account. It provides over 50 years of industry-level data on R&D expenditures. It collects data on R&D costs and expenditures for employees, materials, and depreciation. It has traditionally focused on the physical and life sciences and on engineering. It uses definitions and methods

that are largely consistent with the recommendations of the Organisation for Economic Co-operation and Development's *Frascati Manual*.

16. The satellite account provides estimates of R&D fixed capital formation that are derived from NSF data and measured by source of funding. Ownership of the R&D output is needed to properly assign income flows to the various economic sectors in the NIPAs. The existing R&D survey data do not completely identify ownership. Consequently, the funder of R&D activity is treated as the owner of the R&D output. This means that currently the satellite account treats R&D funding of a grant for the performance of R&D the same way that it treats a contract for the purchase of R&D. In this satellite account, the owner is assumed to be the sole entity with the direct economic benefit from the R&D activity. Although spillovers may exist, the R&D satellite account does not separately identify these impacts.

17. The satellite account provides two major disaggregations of R&D expenditures: 1) R&D output by performer and source of funding and 2) R&D fixed capital formation by type of funder. Although R&D fixed capital formation is based on source of funding, R&D output by performer is also an analytically useful measure that allows users to see each sector's contribution to the performance of R&D. In addition, performer-based R&D activity is the foundation for estimating R&D fixed capital formation in current prices because these estimates are based on the most detailed source data available.

18. To derive R&D fixed capital formation, the detailed performance-based R&D output by major sources of funding were re-aggregated to a funding basis, and then imports were added and exports were subtracted. In the R&D satellite account, five sources of funding are distinguished: Federal Government, state and local governments, business, universities and colleges, and other nonprofit institutions serving households.

19. The performer-based survey data were adjusted to match the scope of capitalized R&D. The satellite account uses the definition of R&D outlined in the OECD Frascati Manual 2002 that includes R&D activity in the social sciences and humanities, but excludes activities that are solely for commercialization and marketing. The manual presents an internationally accepted classification system and guidelines for internationally comparable data on R&D activity.

20. The cost of R&D activity in developing software that is to be marketed was subtracted to avoid a double count as both software and R&D fixed capital formation; the NSF source data include these costs. For the BEA satellite account, the double-counted R&D software was removed from the software estimate and retained in R&D gross fixed capital formation.

B. Price indexes for deflation

21. The R&D satellite account presents estimates of real R&D investment based on two price indexes: One is an input price index like those used in the current NIPA estimation process when no market prices are observable; the other is an output-based index that indirectly reflects the movement of R&D output prices.

22. The input price index was similar to those used for government and other hard-to-measure services in the national accounts. Thus, these estimates provide a baseline against which

other estimates can be evaluated. This input price index for R&D investment was based on an aggregation of detailed price indexes for the inputs used to create R&D output. Although this method is useful for estimating the impact of inflation on R&D inputs, it is less appropriate for R&D output because it rules out productivity growth; it leads to real output growing at the same rate as real inputs. Because of increases in computing power and other scientific advances, some argue that R&D productivity has increased, which would make the input price approach inappropriate.

23. The aggregate R&D output price index is a weighted average of the output prices of R&D-intensive industries. It assumes there are common factors in R&D production processes across industries. Such an index tends to average out the extreme effects of rapidly falling or rising output prices for particular industries.

24. The aggregate output price index was constructed using a Fisher-weighted combination of the output prices of 13 R&D-intensive industries.[5] The index was weighted according to each industry's share of annual business R&D gross fixed capital formation. For years before 1987, detailed industry investment measures were unavailable, and the aggregate output price index was a weighted average of the top five R&D industries based on NSF data.

C. Depreciation

25. The challenges in measuring deprecation of R&D assets were described above. For the 2007 R&D satellite account, industry-specific geometric depreciation rates were selected based on a review of the academic literature. The following rates were used: transportation equipment, 18 percent; computer and electronics, 16.5 percent; chemicals, 11 percent; all other, 15 percent.

D. Multinational and multi-unit firms

26. Capitalizing R&D raises several practical and conceptual issues in the case of multinational corporations. The first issue is conceptual. R&D—like some other intangible assets, but unlike conventional physical capital—can be shared without cost. A parent company that shares its R&D results with a foreign affiliate neither increases the MNC-wide stock of R&D capital nor lowers its own stock of R&D capital. However, it does raise the stock of R&D assets that the affiliate can use in its production processes. The sharing of R&D capital among different parts of an MNC satellite account raises the issue of whether and how to measure such sharing.

[5] The thirteen industries are pharmaceutical and medicine manufacturing, other chemical manufacturing, computer and peripheral equipment manufacturing, communications equipment manufacturing, semiconductor and other electronic components manufacturing, navigational, measuring, electro-medical, and control instruments manufacturing, other computer and electronic products manufacturing, motor vehicles, bodies and trailers, and parts manufacturing, aerospace products and parts manufacturing, other transportation equipment manufacturing, software publishers, computer systems design and related services, and scientific research and development services.

27. The second issue arises because of data limitations. In contrast to the domestic stock of R&D capital, which is acquired through R&D production activity, the stock of MNC R&D capital can also increase through the acquisition of firms that hold pre-existing R&D stocks. The result is that computing changes in MNC capital stocks is more complicated than simply summing up past investment and subtracting depreciation (that is, the perpetual inventory method). Conceptually, a solution would be to estimate the R&D stocks of entering firms and acquisitions. However, available data allow for only very rough estimates of the effects of entry.

28. Similar issues arise with respect to large multi-unit firms in deriving regional estimates of R&D activity and capital. R&D that is funded and performed in a company's headquarters in one state can be shared with the company's operating units throughout the country. Locating the R&D entirely in the state in which the R&D is performed or funded is conceptually problematic when the investment is shared with establishments in other states.

V. RESULTS OF THE 2007 R&D SATELLITE ACCOUNT

29. The contribution to real GDP growth from treating R&D as gross fixed capital formation would have been approximately 0.2 percentage point of the 3.3-percent growth, or about a 7-percent share of the growth rate from 1995 to 2004. (In comparison, the contribution of business growth fixed capital formation in the form of commercial and all other types of nonresidential building accounts for just of 2 percent of real GDP growth.) The contribution of R&D is almost as large as the contribution of computers to GDP growth.

30. Chart 1 illustrates the addition to GDP (in current prices) from R&D investment. If R&D had been capitalized, R&D investment would have been $316.6 billion in 2004, an increase of 5.7 percent from the $299.6 billion in 2003.

31. Treating R&D as capital formation raises industry gross output when the R&D is not sold; it also increases value added of industries that purchase R&D, by reducing their intermediate consumption. The magnitude of these effects varies across industries, but for some industries can be quite large. For example, the capitalization of R&D raised the level of industry value added by about 38 percent for pharmaceutical and medicine manufacturing, 30 percent for computer and peripheral equipment manufacturing, and 26 percent for semiconductor and other electronic component manufacturing (see Table 1).

VI. NEXT STEPS

32. In order to move toward BEA's goal of capitalizing R&D in the core accounts by 2013, additional work is needed. Capitalization of R&D needs to be extended to the full set of benchmark input output accounts. Problems in the regional and international aspects of R&D investment need to be addressed, including determining the location of the R&D asset for multi-unit and multinational firms. For application in the quarterly national accounts, we need to develop timely indicators of current R&D activity. Finally, BEA's research agenda includes looking at possible extensions of this analysis to other types of innovation through development of a prototype innovation satellite account.

33. BEA's plans are also being shaped by the recent report of the report to the Secretary of Commerce by the Advisory Committee on Measuring Innovation in the 21st Century Economy (2008). Some examples of the recommendations of this Committee that BEA is working to address include the following: BEA, working with the Bureau of Labor Statistics, will develop a production account to allow for consistent estimation of the contributions of innovation to growth in GDP and productivity. BEA is working with the Bureau of the Census to fill in gaps in measuring service sector activity, especially in sectors that are important contributors to national innovation. BEA also plans to design a prototype innovation satellite account in order to expand the categories of innovation inputs and allow those inputs to be tracked.

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Chart 1. Addition to GDP from R&D Investment

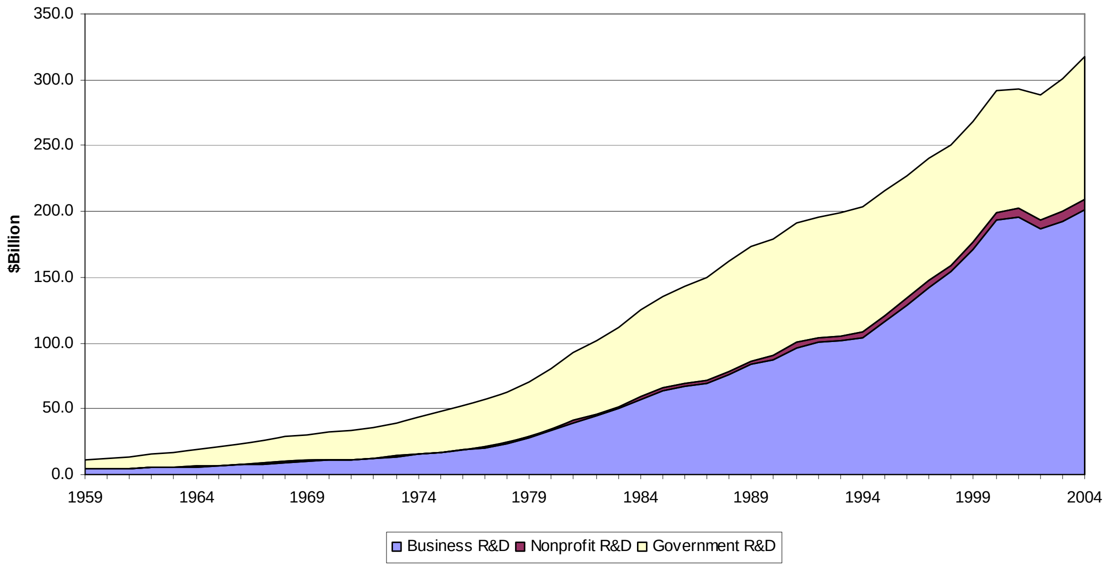

Table 1. Industry Impacts: Average Percent Change in the Level of Value Added, 1987-2004

Industry	Percent change
Pharmaceutical and medicine mfg	38.4
Chemicals minus pharmaceutical and medicine mfg	7.9
Computer and peripheral equipment mfg	29.8
Communications equipment mfg	22.1
Semiconductor and other electronic component mfg	25.7
Navigational, measuring, electro-medical, and control instruments mfg	12.2
Other computer and electronic products mfg	9.1
Motor vehicles, bodies and trailers, and parts mfg	14.5
Aerospace product and parts mfg	14.3
Other transportation equipment mfg	4.1
Software publishers	14.2
Computer systems design and related services	2.4
Scientific R&D services	12.7
All other industries	0.7

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