Concepts, Data, and Methods for Preparing Experimental National and State-Level R&D Production Statistics

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1. Introduction

The U.S. Bureau of Economic Analysis (BEA), in partnership with the U.S. National Science Foundation's (NSF's) National Center for Science and Engineering Statistics (NCSES), is developing an exploratory research and development (R&D) satellite account that measures the contribution of R&D activities to domestic production. The new R&D production measures in this account include value-added, compensation, and employment that stem from the R&D investment and exports already captured in the National Income and Product Accounts (NIPAs). This document outlines relevant concepts, data, and methods used to prepare the experimental national and state-level statistics for this account.

BEA's satellite accounts are supplemental accounts that are linked to BEA's core accounts and expand on their analytical capability by exploring new concepts and methodologies. In addition, satellite accounts provide enhanced, complementary statistics on key sectors of the U.S. economy. They are particularly useful to measure economic activity like R&D that is spread across multiple industries as defined by the North American Industry Classification System (NAICS) used for BEA's official statistics. This satellite account includes not only the R&D produced by the scientific R&D services industry (NAICS 5417) but also the R&D produced by other industries in the business sector, including manufacturing. In addition, it includes the R&D produced by the nonprofit and government sectors.

The economic activity in the R&D satellite account is embedded in BEA's core statistics including national and regional data on gross domestic product (GDP), employment, and compensation. With this satellite account, using the latest data on R&D performance, BEA is exploring new methodologies within the GDP framework to identify and explicitly measure detailed components of R&D production at the national and state levels.

Among other insights, the experimental statistics can be used to show the contribution of the R&D sector to the national economy and to each state's economy. They can also be used to show the contribution of individual industries to R&D production or to directly compare the activity of the R&D sector to the economic activity of NAICS-defined sectors such as mining, construction, chemical manufacturing, accommodation, and food services. The contribution of the R&D sector is also measured in terms of the number of R&D jobs and the compensation for R&D work.

This new R&D satellite account builds on nearly two decades of collaborative work between BEA and NSF that laid out the foundation for BEA to expand its asset boundary within its core accounts by recognizing R&D expenditures as investment.¹ The work on R&D investment also began as a satellite account that served as a testing ground for R&D investment as a new concept and provided a means to explore the effect of this change and a framework to examine various methodological and conceptual issues. A detailed review and full references on BEA's prior collaborative work on R&D is provided in

¹ R&D expenditures were initially treated as a current expense and not included in GDP.



"The Evolving Treatment of R&D in the U.S. National Economic Accounts."²

2. Description of new statistics available in the R&D satellite account

The <u>experimental R&D satellite account statistics</u> are now available on the BEA website. There are four Excel files available for download—one each for value added, compensation, and employment as well as a bulk download file that contains all the statistics in a machine-readable format.

Each file contains statistics on R&D activity at the national level and for each of the 50 states and the District of Columbia from 2017–2021. For each geography, R&D activity is presented at the aggregate level and by producing sector—business, nonprofit institutions serving households (NPISHs), and government. The business statistics show the R&D produced by all for-profit enterprises. The nonprofit statistics show the R&D produced by private universities and colleges and nonacademic nonprofits. The government statistics show the R&D produced by federal and state and local governments including public universities. The R&D produced by federally funded research and development centers (FFRDCs) is attributed to the sector of the administrator of the FFRDC.

For value added, some industry detail is provided for R&D-intensive industries. For employment and compensation, statistics are published separately for the manufacturing sector and the nonmanufacturing sector. An addendum combines the R&D activity of private nonprofit universities and colleges (LineCode 14) and public universities and colleges under state and local government (LineCode 20).

In the state statistics, to ensure data quality standards, values below a certain threshold are suppressed and replaced with (L).

3. Definitions, concepts, and geography

This section provides definitions of key concepts relevant to the R&D satellite account. In addition, it discusses various aspects of R&D measurement including the relationship between R&D value added and R&D investment in BEA's economic accounts as well as the geography of R&D production.

3.1. Definitions

Research and (experimental) development comprises creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture, and society—and to

² A series of working papers on the first <u>R&D satellite account</u> are available on the BEA website.



devise new applications of available knowledge.³

Gross output is the broadest measure of economic activity. It includes both market-based economic activity and some nonmarket economic activity. The *market-based* economic activity is typically measured through sales/revenue generated from production and includes the value of goods and services purchased by industries for use in production (intermediate inputs) and the value of goods and services purchased by final users. *Nonmarket* activity refers to the production of goods and services that are either provided free of charge or for prices that do not significantly influence the amounts that producers supply or that purchasers demand. In the NIPAs, most of the production of nonprofit institutions and of government agencies is nonmarket production. The nonmarket economic activity is typically measured through expenses. Gross output double-counts some industry output because it includes output that is purchased by other industries for use as intermediate inputs.

Value added is the difference between gross output and intermediate inputs and measures the contribution of an industry to GDP. Value added can also be measured as the sum of an industry's compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. The sum of value added across all industries equals GDP.

R&D value added consists of the value that an industry generates as part of R&D production after it has accounted for its costs of energy, materials, and services used up in R&D production.

R&D employment consists of all full-time and part-time wage and salary jobs in which workers are engaged in the production of R&D. Self-employed individuals and temporary workers are not included. R&D workers include researchers and technicians. Included are also support staff that directly and indirectly support production of R&D.

R&D compensation consists of the pay to employees (including wages and salaries as well as supplements to wages and salaries, such as employer contributions to pension funds and health insurance) for their R&D work during a given year. Earnings of self-employed individuals and temporary workers are not included.

3.2. Relevant concepts

R&D value added and R&D investment in BEA's economic accounts

BEA publishes some measures of R&D production at the national level in detailed supply and use tables (SUTs). The principal measure of production in the SUTs is gross output. The SUTs show which industries

³ Organisation for Economic Co-operation and Development (OECD), *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development* (Paris: OECD Publishing, 2015); <u>https://doi.org/10.1787/9789264239012-en</u>.



produce R&D commodities as well as the intermediate and final uses of these commodities.⁴ This framework highlights the interdependencies between R&D and the rest of the economy, as it allows for a detailed look at the composition of R&D production and use across industries.

With the 2013 comprehensive update of the NIPAs, BEA changed the treatment of R&D to investment, and adjusted all historical GDP data to reflect this new treatment, known as "capitalization" of R&D.⁵ Prior to the capitalization of R&D, R&D expenditures were treated as intermediate inputs and not included in GDP.

There are conceptual differences between R&D production (R&D value added) and R&D investment. The relationship between total domestic R&D production in BEA's SUTs and total domestic R&D investment in BEA's NIPA investment tables is as follows:⁶

$$Total \ domestic \ R\&D \ supply = \ Total \ domestic \ R\&D \ investment$$
(1)

where total domestic R&D supply is computed from the SUTs as:

Total domestic R&D supply

 $= Total \ domestic \ R\&D \ gross \ output \ + \ R\&D \ imports \ - \ R\&D \ exports$ (2)

Furthermore,

 $Total \ domestic \ R\&D \ gross \ output = \ R\&D \ value \ added \ + \ R\&D \ intermediate \ inputs$ (3)

Thus,

 $R\&D \ value \ added = \ Total \ domestic \ R\&D \ investment - R\&D \ imports \ + \ R\&D \ exports$ $- R\&D \ intermediate \ inputs$ (4)

BEA currently publishes R&D production statistics (including value added and compensation) in the benchmark after-redefinitions use table. As in the R&D satellite account, statistics in the after-redefinitions use table include not only the R&D produced by NAICS 5417 but also the R&D produced by industries outside of NAICS 5417, which is assigned to NAICS 5417 in the redefinition process. The experimental statistics published in the R&D satellite account, however, differ in important ways. The first difference is that the after-redefinitions statistics have a broader scope, including non-R&D items as well as noncapitalized items, such as licensing of R&D. The second difference is that the after-redefinitions statistics as source data, whereas the

⁴ An example of an R&D commodity would be the R&D performed by private universities and funded by the federal government.

⁵ See Stephanie H. McCulla, Alyssa E. Holdren, and Shelly Smith, "<u>Improved Estimates of the National Income and</u> <u>Product Accounts Results of the 2013 Comprehensive Revision</u>," *Survey of Current Business* 93 (September 2013): 14–45.

⁶ Total R&D investment is the sum of private investment (<u>NIPA table 5.6.5</u>) and government investment (<u>NIPA table 5.9.5</u>).



satellite account measures rely on R&D survey data wherever possible.⁷

This satellite account provides an opportunity to test new measurements of underlying detail of R&D in the NIPAs, which can improve the national statistics and, importantly, allow for the development of more accurate regional data.

Measurement of value added

Value added can be measured as the difference between gross output and intermediate inputs. It can also be measured using the income approach as the sum of factor incomes earned. The R&D satellite account uses the income approach to estimate value added. With this approach, value added is measured as:

Value added = Compensation of employees + Gross operating surplus + Taxes on production and imports less subsidies

Compensation of employees consists of the income accruing to employees as remuneration for their work for domestic production. It includes wages and salaries and supplements to wages and salaries. Gross operating surplus consists of the consumption of fixed capital (CFC)—the depreciation in the value of capital due to wear and tear, obsolescence, accidental damage, and aging—and profits.⁸ Taxes on production and imports consist primarily of excise, sales, and property taxes. Subsidies are production-related monetary grants paid by government agencies to businesses.

For government and NPISHs, CFC serves as a measure of the value of the current service of the capital (fixed assets) owned and used by these entities. Thus, the value added in the government and nonprofit sectors consists only of compensation of employees and CFC.

R&D performance and funding

As mentioned above, there is an important conceptual distinction between R&D value added and R&D investment. Beyond the conceptual distinction, R&D production and R&D investment are attributed differently to sectors of the economy. For R&D production, BEA attributes the activity to the sector that performed the R&D. For R&D investment, BEA attributes the activity to the sector that funded the R&D.⁹ For example, the R&D performed by businesses but funded by the federal government would be attributed to the private sector on a production (or performance) basis but to the federal government

⁷ While R&D survey data from NSF are used as a foundation for the estimation of R&D gross output, the estimation of R&D value added and compensation in the after-redefinitions use table rely on the redefinition process. This process assumes the R&D inputs are similar to the inputs within the R&D industry (NAICS 5417), regardless of the industry in which the R&D is produced.

⁸ Profits include proprietors' income, corporate profits, and business current transfer payments (net).

⁹ To measure R&D investment, BEA assigns ownership to the R&D funder. For a more detailed discussion of R&D ownership, see Marissa J. Crawford, Jennifer Lee, John E. Jankowski, and Francisco A. Moris, "<u>Measuring R&D in</u> <u>the National Economic Accounting System</u>," *Survey* 94 (November 2014).



on an investment (or funding) basis.

To measure R&D production, only federal intramural R&D and state and local intramural R&D—the R&D performed in facilities owned and operated by the federal government or state and local governments— are attributed to the government sector. The R&D performed at a federally funded research and development center (FFRDC) is attributed to the sector that administers the FFRDC. FFRDCs are research institutions that are funded by the federal government but administered by businesses, universities, and other nonprofit organizations. For example, the R&D performed by FFRDCs administered FFRDCs is assigned to the business sector, whereas the R&D performed by FFRDCs administered by private nonprofit higher education institutions is assigned to the nonprofit sector. This is to ensure consistency with other production measures.

For R&D investment, BEA attributes the R&D funded by the federal government to the federal government regardless of the performer and the funding mechanism (contracts or grants).¹⁰ BEA also treats the R&D performed at FFRDCs as investment by the federal government. This treatment captures the outsized role of the federal government in funding R&D, where the economic benefits to the federal government include the benefits that the government obtains on behalf of the general public.

Lastly, for both R&D production and R&D investment measures, the R&D performed and/or funded by higher education institutions in BEA's data is split between the three R&D-producing sectors: business, NPISHs, and government. Private for-profit academic institutions are included in the business sector, private nonprofit academic institutions are included in the NPISH sector, and public universities and colleges are included in state and local government.

The results of the conceptual and sectoral differences between R&D value added and R&D investment are shown in table 1. The experimental statistics show R&D value added was \$542.7 billion dollars in 2021. This compares with \$837.1 billion in R&D investment. This difference is explained by the conceptual differences outlined in equation (4) above as well as differences in source data and methodologies between the two measures. The approximate \$300 billion difference is mostly accounted for by intermediate inputs in the production of R&D. Smaller portions of the difference are due to net exports of R&D. The business sector is the predominant sector in both R&D production (\$463.5 billion in R&D value added) and R&D investment (\$608.7 billion). The table also shows the outsized role of the federal government in funding R&D (\$172.4 billion in R&D investment) and its much smaller role in R&D performance (\$12.1 billion in R&D value added). The R&D value added for NPISHs and state and local government sectors is larger than the R&D investment by these sectors, indicating the external R&D

¹⁰ With a contract, the federal government usually retains ownership of the outcome of the purchased R&D activity. With a grant, the ownership typically transfers to the grantee; however, both the federal government and the grantee can benefit from the outcome of the R&D activity. BEA treats both R&D federal contracts and grants as R&D investment by the federal sector because the federal government is assumed to receive the primary economic benefit of this investment. Most of the R&D that is funded by the federal government, regardless of the funding mechanism, is performed in support of the missions of the individual funding agencies.



funding these sectors receive, in particular from the federal government.

Table 1. R&D Value Added and R&D Investment, 2021

[Millions of current dollars]

Sector	R&D value added (RDSA)	R&D investment (NIPA)
Research and development (R&D)	542,724	837,067
Private	500,630	642,138
Business	463,509	608,661
Nonprofit institutions serving households	37,122	33,477
Government	42,094	194,929
Federal	12,081	172,367
State and local	30,012	22,562

NIPA National income and product accounts

RDSA Research and development satellite account

U.S. Bureau of Economic Analysis

Own-account R&D versus for-sale R&D

Own-account production is production performed by an entity (e.g., business or government) for its own use. This is in contrast to production that is performed by the entity but funded by another entity (known as "for-sale"). This distinction is important in the context of R&D because these need to be measured differently. Own-account R&D is nonmarket activity, and it is estimated as the sum of production costs, whereas for-sale R&D is measured through receipts.

While detailed estimates are generated for own-account R&D separately from for-sale R&D, given their measurement differences, the R&D satellite account statistics aggregate the two.

3.3. Geography of R&D

One important and unique feature of the R&D satellite account is it includes R&D production statistics (R&D value added and corresponding R&D employment and compensation) for each state and the District of Columbia. These R&D production by state statistics are based on the state in which the R&D is performed. For example, the R&D activity of a multiunit pharmaceutical company that is headquartered in New Jersey but has R&D facilities in Pennsylvania is attributed to Pennsylvania. R&D performed in U.S. territories is not included.

4. Source data

Two types of data are used to prepare the experimental national and regional statistics for this satellite account: (1) data that are collected on an enterprise basis and (2) data that are collected on an



establishment basis.¹¹ This distinction is relevant because BEA's industry statistics are prepared on an establishment basis. Thus, the enterprise data need to be converted to an establishment basis to ensure comparability. The methodology for this conversion is described in some detail in the methodology section.

Enterprise basis. The enterprise data consists of NSF annual surveys of R&D expenditures covering all major R&D performing and funding sectors in the United States. These include the Business Enterprise Research and Development Survey (BERD), the Annual Business Survey (ABS), the Higher Education Research and Development Survey (HERD), the Survey of Federal Funds for Research and Development, the FFRDCs Research and Development Survey, the Nonprofit Research Activities Survey (NPRA), and the Survey of State Government Research and Development. The NSF surveys are also a principal source for BEA's estimates of national R&D investment.

The BERD survey collects data on industry R&D expenditures and R&D employment, wages and salaries, and benefits for for-profit nonfarm businesses with 10 or more employees. Data on R&D activities of microbusinesses—businesses with less than 10 employees—are collected in the ABS. The HERD survey collects data from U.S. colleges and universities that spent at least \$150,000 in separately accounted for R&D in the fiscal year. The three government surveys—federal funds for R&D, state government R&D, and FFRDCs R&D survey—collect data on R&D activity performed and funded by federal agencies; by departments and agencies in each state, the District of Columbia, and Puerto Rico; and by FFRDCs, respectively. The NPRA survey collects information on R&D performed by 501© nonprofit organizations.

Establishment basis. The establishment data includes the U.S. Census Bureau's Economic Census (EC), the U.S. Bureau of Labor Statistics' (BLS') Quarterly Census of Employment and Wages (QCEW) and Occupational Employment and Wage Statistics (OEWS), and BEA's SUTs and regional data on compensation and employment. The EC collects and publishes data on the scientific R&D services industry (NAICS 5417) and aggregate R&D expenditures for the R&D performed by the corporate, subsidiary, and regional managing offices industry (NAICS 55114). The BEA data reflect the results of the 2023 comprehensive update of the National Economic Accounts and Regional Economic Accounts.

The main source data are summarized in table 2 by R&D producing sector.

¹¹ An establishment is an economic unit—business or industrial—at a single geographic location where business is conducted or where services or industrial operations are performed. An establishment is not necessarily identical to an <u>enterprise</u> or company, which may consist of one or more establishments.



Table 2. Summary of Source Data

R&D producing sector	Source data				
Business	R&D performed by businesses (including for-profit private universities and colleges): BERD, ABS, state-level special tabulations of BERD data R&D performed by FFRDCs administered by businesses: FFRDC R&D survey Supplemental sources: QCEW, OEWS, BEA SUTs				
Nonprofit institutions serving households	R&D performed by private nonprofit universities and colleges: HERD R&D performed by nonacademic nonprofits: NPRA R&D performed by FFRDCs administered by nonprofits: FFRDC R&D survey Supplemental sources: EC, QCEW, BEA SUTs				
Government	Federal intramural R&D: Federal funds for R&D survey State and local intramural R&D: State government R&D survey, HERD For-sale R&D performed by public universities and colleges: HERD Supplemental sources: BEA SUTs				
ABS Annual Business Survey NPRA Nonprofit Research Activities Survey BERD Business Enterprise Research and Development Survey OEWS Occupational Wage and Employment Statisti EC Economic Census QCEW Quarterly Census of Employment and Wages FFRDCs Federally funded R&D centers R&D Research and development					

SUTs Supply and use tables

HERD Higher Education Research and Development Survey

NIPA National income and product accounts

U.S. Bureau of Economic Analysis

5. Methodology

The general methodology for the experimental statistics in the R&D satellite account consists of three main steps.

The first step is to determine the scope of the account and identify national and state-level source data on R&D. Determining the scope of the account involves identifying the domestic R&D commodities within BEA's SUTs that are capitalized and account for R&D investment or R&D exports in GDP.

The second step is to prepare detailed national statistics on R&D value added, employment, and compensation by R&D commodity and detailed industry. These detailed estimates are prepared by R&D performing sector reported in each of the NSF R&D surveys. The R&D survey data are adjusted and supplemented with internal BEA data and data from other sources.

The third step is to develop detailed allocator series to distribute the national values of R&D value added, employment, and compensation by R&D commodity and detailed industry to states. This step



requires closely aligning the detail in the national statistics with the detail available in the state source data that is used for the allocator series.

The detailed national and state-level estimates are aggregated to the publication level described in section 2. The publication statistics show three major R&D producing sectors reported in BEA's statistics: (1) business, (2) NPISHs, and (3) government. These three sectors also include R&D by higher education institutions: private for-profit academic institutions are included in the business sector, private nonprofit academic institutions are included in the NPISHs sector, and public universities and colleges are included in state and local government.

The rest of this section discusses in some detail the methodology used to prepare the experimental national and state statistics. The methodology discussion is organized by R&D performing sector as reported in the NSF R&D surveys.

5.1 Business sector

The business sector survey data cover R&D activity performed by for-profit enterprises, excluding business-administered FFRDCs.

5.1.1 Employment and compensation

At the national level, total R&D employment for the business sector is estimated using R&D employment headcounts, while total R&D compensation is estimated as the sum of wages, salaries, and fringe benefits and stock-based compensation from BERD and ABS. Because these headcounts and compensation include only employees whose primary responsibility is R&D, the BERD data is augmented with an estimate of incidental employment—a measure of employment for employees indirectly related to the production of R&D—to align with BEA's measure of employment and compensation, which is broader in scope. BEA's estimates of R&D employment do not include temporary employees, as those under contract and from temporary agencies are captured as purchases of intermediate services in national accounting.

Incidental employment is calculated as a share of nonincidental employment using OEWS data on occupations in the scientific R&D services industry (NAICS 5417). Incidental employment is calculated based on a selection of non-R&D occupations (such as cafeteria workers and cleaning staff) that are employed by NAICS 5417 establishments. Based on this data, in the establishments that perform for-sale R&D, incidental employment was 4.8 percent of total non-incidental employment. For establishments that perform own-account and auxiliary R&D, incidental employment was 2.8 percent of total non-incidental employment. This translates to roughly a 3.5 percent increase on average over BERD employment to account for incidental employment and compensation.

Total R&D employment and compensation is broken down by R&D commodity as well as by detailed



industry. Because the survey data is on an enterprise basis and all BEA statistics are reported on an establishment basis, a company-to-establishment adjustment is made to the survey data. This process is described in detail in section 5.1.3.

At the state level, the estimates of business R&D employment and compensation are also based on data from the BERD and ABS surveys. The data from these surveys, however, are more limited compared to the national level. Therefore, the state methodology discussion is shaped by the availability of the state-specific data.

R&D compensation is estimated first. Compensation for own-account R&D is estimated using a special tabulation of R&D compensation (wages, salaries, and fringe benefits and stock-based compensation) by state and industry from the BERD survey for the R&D that is paid for and performed by the company.¹² Two adjustments are made to these compensation values. First, an adjustment based on state R&D expenditures for own-account R&D from the ABS is made to account for microbusiness R&D.¹³ A second adjustment is made to account for incidental employment, with the same adjustment factor used at the national level.

R&D compensation for for-sale R&D is estimated by applying an industry-level compensation-toexpenditures ratio for own-account R&D to total expenditures for for-sale R&D. The use of this ratio assumes the same production process for own-account R&D and for-sale R&D within each industry. The same two adjustments made to compensation for own-account R&D are also made to compensation for for-sale R&D. The microbusiness adjustment, however, is based on state ABS R&D expenditure data for for-sale R&D. Total business R&D compensation is then generated as the sum of the compensation for own-account R&D and for-sale R&D.

R&D employment in the business sector is estimated using a special tabulation of R&D employment by state and industry from the BERD survey. These data are only available for 3 years, 2018–2020. The R&D employment series is extended back to 2017 by applying an average employment-to-compensation ratio for the period that employment is available to the estimated total business R&D compensation for 2017. Microbusiness adjustments based on state ABS expenditures for own-account R&D and for-sale R&D are applied to the respective R&D employment values. An adjustment for incidental employment is also made to employment using the same adjustment factor used at the national level.

The methodology described above is used to estimate most of the R&D that is performed by the

¹² The special tabulations provide data by state that are not available in the BERD public tables. The industry data available in the special tabulations, however, is more aggregated than the industry detail available in the BERD public tables on own-account R&D expenditures by state and industry. Thus, industry information from the public BERD tables is used to expand the industry detail in the special tabulations.

¹³ R&D expenditures from the ABS are available by state for own-account R&D and for-sale R&D for the 2017–2020 period. These data, however, are not available by industry. The industry breakdown of the ABS data is based on the industry breakdown in the BERD survey.



business sector. An exception is the portion of business R&D that is performed by the auxiliary establishments of larger companies. This portion is treated as for-sale R&D, even though it is not technically sold on the market; it is classified this way due to BEA's general establishment-based method of economic measurement. The most recent public state-level data on auxiliary establishments come from the 1997 economic census of auxiliary establishments, which provides data on employment, payroll (compensation), and receipts for the auxiliary establishments. State-by-industry QCEW data on employment and wages for the scientific R&D services industry (NAICS 5417) are used to extrapolate forward the economic census data on auxiliary establishments.

Lastly, the state R&D employment and compensation estimates that are based on the R&D survey data are adjusted to reflect R&D activity on an establishment basis. The methodology for the company-to-establishment adjustment is described in section 5.1.3. All state R&D employment and compensation estimates are then used to allocate the corresponding national R&D employment and compensation estimates to states.

5.1.2 Value added

For both national and state estimates, value added is measured additively from its components compensation, gross operating surplus (GOS), and taxes on production and imports less subsidies (TOPI). GOS and TOPI are estimated separately and then added to the compensation estimate to derive value added.

At the national level, to compute GOS, the first step is estimating the CFC used in R&D production. To compute CFC, data from the BERD survey on depreciation of property, plant, equipment, and intangible assets are used to compute ratios of depreciation to compensation. These ratios are then applied to the previously computed compensation estimates to generate CFC estimates. On average, the CFC ratios hover at around 6 percent of the compensation total.

GOS is computed one of two ways depending on whether the R&D produced is for sale or whether it is own-account or auxiliary R&D. Production of for-sale R&D is measured through receipts, while production of own-account or auxiliary R&D is measured through expenses, and GOS measures need to reflect this. In addition to CFC, receipt-based measures of GOS conceptually include a host of subcomponents, like profits from the sale of R&D, while expense-based measures of GOS conceptually only include a capital services measure.¹⁴ Capital services measure the services capital provides, similar to the way compensation measures the services labor provides.

¹⁴ The inclusion of capital services in own-account measures was introduced in the <u>System of National Accounts</u> <u>2008</u>: "A3.41 The 2008 SNA recommends that when estimating the value of the output of goods and services produced by households and corporations for own final use, it is appropriate to include a return to capital as part of the sum of costs when this approach is used for estimating output in the absence of comparable market prices. However, no return to capital should be included when production for own final use is undertaken by non-market producers."



To estimate GOS in for-sale R&D commodities, a GOS-to-compensation ratio from BEA's SUTs is applied to the previously estimated compensation for these commodities. For own-account or auxiliary R&D, GOS is equal to a capital services measure. This measure is imputed based on a ratio of capital services to CFC and the CFC estimates based on the BERD survey. This ratio is based on internal BEA research that was used to estimate capital services for the 2018 comprehensive revision of the NIPAs.

TOPI is estimated using underlying BEA SUTs data. A ratio of TOPI to compensation is derived and applied to the previously computed compensation estimate to derive an estimate of TOPI.

At the state level, state R&D expenditures from the BERD survey are used to allocate the national estimates of GOS and TOPI to states. The state GOS and TOPI estimates are then added to the state compensation estimates described above to generate R&D value added.

5.1.3 Company-to-establishment adjustment

In addition to the adjustments to the NSF enterprise data for coverage, scope, and alignment with the NIPA framework and concepts described above, an important adjustment involves reclassifying the enterprise R&D data to an establishment basis.

With an enterprise approach, all of a company's R&D activity is assigned to the company's primary industry. With an establishment-based approach, the R&D activities performed at different establishments within a company are assigned separately. For example, a pharmaceutical company might perform R&D in an establishment with manufacturing (the company's primary industry) as its main activity and in another establishment with R&D services as its main activity. With the establishment-based approach, the R&D activity of this company would be split between the manufacturing industry and the R&D services industry. In contrast, the NSF source data assign all of the example company's R&D activity to the manufacturing industry.

For the national R&D investment estimates, BEA adjusts the NSF data based on a reconciliation of the EC establishment-based data for the scientific R&D services industry (NAICS 5417) with the NSF's enterprise-based data.¹⁵ This reconciliation results in an estimate of the R&D expenditures for the NAICS 5417 industry that include the expenditures on a company basis as reported by NSF and the expenditures for scientific R&D services by multiunit companies outside of the NAICS 5417 industry.¹⁶

¹⁵ For noneconomic census years, data from the Service Annual Survey (SAS) are used to interpolate between economic census years. For more information on the estimating methods and source data underlying BEA's R&D investment statistics, including the company-to-establishment adjustment for these statistics, see Marissa J. Crawford, Jennifer Lee, John E. Jankowski, and Francisco A. Moris, "<u>Measuring R&D in the National Economic</u> <u>Accounting System</u>," *Survey* 94 (November 2014).

¹⁶ All establishments of a scientific R&D services company are assumed to be scientific R&D services establishments.



To make this adjustment, BEA assumes half of the NSF NAICS 5417 industry R&D expenditures are associated with the production of own-account R&D and the other half with the R&D produced for sale. Furthermore, BEA assumes NSF NAICS 5417 sales, estimated as half of its R&D expenditures, are included in the EC.¹⁷ Subtracting the NSF sales from the EC sales results in an estimate of R&D sales for establishments that are part of multiunit companies. This amount is taken out proportionally from the primary industries (for example, the pharmaceutical manufacturing industry) in the enterprise data and moved to the NAICS 5417 industry. Note that this adjustment results in an adjustment ratio that does not vary by industry. An adjustment is also made for the state estimates of R&D investment in GDP by state, but the ratio is assumed to be the same as the national ratio.

A similar broad company-to-establishment adjustment is also made to the experimental R&D production statistics in this satellite account. However, the reconciliation is made with the QCEW for NAICS 5417. Note the important assumption here that the entirety of the economic activity in NAICS 5417 is in scope—in other words, the business-sector employment captured in the QCEW for NAICS 5417 is also captured in the BERD survey (likely just in a different industry). This adjustment is important for comparability of the R&D production data to other BEA industry data.

The first step is to adjust the QCEW employment and wages to align with the employment and compensation that is in scope for the BERD survey. A national wage-to-compensation ratio based on BEA compensation data is applied to the national and state-level NAICS 5417 QCEW wages to account for supplements that are included in compensation but excluded from wages. The second adjustment is motivated by the fact that QCEW data for NAICS 5417 include for-profit (5417P), nonprofit (5417N), and auxiliary (5417A) establishments, while BERD data exclude nonprofit activity. Hence, an estimate of employment and compensation for 5417N establishments anchored in the 2021 NPRA survey is subtracted from the NAICS 5417 QCEW data, conceptually leaving only for-profit and auxiliary establishments within NAICS 5417. A third adjustment is made to remove the FFRDC activity embedded in the QCEW NAICS 5417 for for-profit establishments because these are not in scope for the BERD survey. This adjustment is based on expense data for privately administered FFRDCs from the FFRDC R&D survey. These adjustments effectively set the levels of R&D employment and compensation for NAICS 5417. Note there are additional adjustments made to the BERD data to align it with national accounting concepts; these adjustments were discussed earlier in this section.

The second step is to compute the difference between the adjusted NAICS 5417 QCEW employment and compensation from the respective BERD-based measures for this industry. These are the amounts of R&D employment and R&D compensation that need to be moved from the primary industries (manufacturing and other non-5417 services industries) to NAICS 5417.

¹⁷ The EC data and SAS data are based on receipts and do not cover own-account R&D expenditures. The EC data, however, are augmented with expenses of NAICS 5417 auxiliary establishments. Because the primary role of the auxiliary establishments is to support activities of other establishments within the company, these establishments have no sales, thus expenses rather than receipts are collected for these establishments.



Lastly, for the national statistics, the remaining employment and compensation—calculated residually from the BERD-based measures less the QCEW-based measures for NAICS 5417—are then allocated to detailed industries and R&D commodities using R&D gross output proportions from BEA's SUTs. For the state statistics, the state allocators are adjusted from an enterprise basis to an establishment basis. Adjustment factors are computed by expressing the difference between the adjusted NAICS 5417 QCEW employment and compensation from the respective BERD-based measures as a share of total BERD-based R&D employment and compensation *less* the BERD-based employment and compensation in NAICS 5417. Hence, these adjustment factors vary by state and year but not by non-5417 industry within a state. Applying these factors to the BERD-based R&D employment and compensation for each non-5417 industry ensures amounts are taken out proportionally from each industry and moved to NAICS 5417.

To illustrate the company-to-establishment adjustment consider a numerical example (table 3). Suppose total R&D employment based on the BERD survey for a given economy (national or state) is 1,000. In addition, the BERD-based NAICS 5417 R&D employment for the same economy is 200, whereas the NAICS 5417 QCEW-based employment is 600 (after removing the nonprofit and the FFRDC employment). The difference between the QCEW-based employment measure and the BERD-based measure is 400 (or 600 minus 200). This is the employment that needs to be moved from other industries to NAICS 5417. The adjustment factor is 0.50 computed as 400/(1000 minus 200).

Suppose there are two additional industries in this economy besides NAICS 5417 with BERD-based employment of 500 and 300, respectively. Applying the adjustment factor to the employment of the two industries reduces their employment by 50 percent to 250 and 150, respectively. In turn, employment in NAICS 5417 increases by 400 to 600 so total R&D employment in the economy remains 1,000.

	BERD-based R&D employment (company basis)	QCEW- based employ- ment	Difference	Adjustment factor	BERD-based R&D employment (establishment basis)
Industry 1	500				500 × 0.50 = 250
Industry 2	300				350 × 0.50 = 150
NAICS 5417	200	600	600 – 200 = 400	400 / (1,000–200) = 0.50	200 + 400 = 600
Total	1,000				1,000

Table 3. A Numerical Illustration of the Company-to-Establishment Adjustment

BERD Business Enterprise Research and Development Survey

NAICS North American Industry Classification System

QCEW Quarterly Census of Employment and Wages

R&D Research and development

U.S. Bureau of Economic Analysis



Ongoing research focused on linking establishment data from the Census Bureau's Business Register to the enterprise data from the BERD survey aims to provide state and national company-to-establishment adjustments that vary by industry, to refine the reallocation of the company R&D activity to the establishments that are more likely to perform R&D. These include corporate offices, R&D labs, and manufacturing plants. The refinement of the company-to-establishment adjustment of the company R&D performance to the correct state and industry.

5.2 Higher education sector

The higher education survey data cover both public and private higher-education institutions.

At the national level, R&D employment for this sector is estimated based on headcounts and full-time equivalent (FTE) employment from the HERD survey as well as HERD compensation (salaries, wages, and fringe benefits) data. The R&D employment headcounts in the HERD survey are available up to 2019. These estimates are extrapolated forward to 2020 and 2021 using HERD compensation data. The employment headcounts including the extrapolated 2020 and 2021 values are then converted to an FTE basis using the average FTE-to-headcount ratios in the 2020 and 2021 period, for which FTE employment data are available. The conversion of the headcount series to an FTE basis reflects an adjustment to remove students from the HERD employment headcounts.

Value added for this sector is estimated by adding an estimate of CFC to the compensation estimate. CFC is estimated using a depreciation-to-compensation ratio from the 2021 NPRA survey.

At the state level, the higher education sector estimates are also based on the HERD survey. The HERD survey provides detailed data on R&D expenditures, compensation (salaries, wages, and fringe benefits), and employment by higher education institution. These data are used to prepare allocators to distribute detailed national estimates of R&D value added, compensation, and employment for this sector to states. For value added, the noncompensation component of value added (CFC) is estimated separately based on HERD R&D expenditures and added to the compensation estimates.

In the HERD survey, data are reported separately for private universities and public universities. Two adjustments are made to the data. The first adjustment is to remove passthrough expenditures for R&D that is funded by the federal government. A second adjustment is made to convert the R&D data from a fiscal year basis to a calendar year basis.

The source of funding is important for the R&D that is performed by the academic sector. Unlike the business sector, where R&D funding largely comes from businesses in the same industry and the federal government, the R&D performed by universities and colleges is funded by various sectors. Funding sources include the federal government, businesses, nonprofit institutions, state and local government, and higher education institutions' own institutional funds. The underlying national values provide a detailed breakdown of the higher education institutions' R&D by funding source. To generate the state



estimates, detailed data from HERD by funding source are used to allocate these national values to states.

Own-account R&D expenditures for private universities are estimated using data on institutional funds. For public universities, own-account R&D expenditures are computed as the sum of the institutional funds and state and local government funds.

For both public and private universities, the national values for for-sale R&D that is funded by the business sector are further broken down into several industries. To better align the state allocators with the national values, state-level information from the BERD survey is used to break out the business funding by industry.

Once all the components related to R&D produced by higher education institutions are estimated at the state level, the estimates are then aggregated into two separate groups following BEA conventions: (1) R&D produced by private universities and colleges (assigned to the nonprofit sector) and (2) R&D produced by public universities and colleges (assigned to state and local government).

5.3 Nonprofit sector (excluding higher education)

The source data for the nonprofit sector cover nonacademic nonprofit institutions.

In addition to the private academic R&D described in section 5.2, the experimental BEA statistics for the nonprofit sector consist of estimates for hospitals, R&D facilities, and other nonprofits. Other nonprofit estimates are distributed to a few industries using a naïve distribution (50 percent to museums and 50 percent to grantmaking, civic, professional, and similar organizations).

At the national level, nonprofit R&D employment is based on the employment headcounts from the 2021 NPRA survey. These estimates are extrapolated back to 2017 using data from the SUTs on R&D output in nonprofits and further adjusted to account for incidental employment (using the same adjustment factor used to adjust the BERD employment).

The R&D compensation for the nonprofit sector is based on salaries, wages, and fringe benefits data from the 2021 NPRA survey. These estimates are adjusted for incidental employment and extrapolated back to 2017 using both the employment change (to account for quantity change) and the change in the Consumer Price Index (CPI) (to account for a price change).

Value added for this sector is estimated by adding an estimate of CFC to compensation. CFC is estimated using a depreciation-to-compensation ratio from the 2021 NPRA survey.

At the state level, the estimates for the nonprofit sector are based on data from the NPRA survey. R&D compensation is estimated using a national compensation-to-expenditures ratio for the nonprofit NAICS



5417, which is applied to the state R&D expenditures. R&D employment is estimated using a national average compensation rate for the nonprofit NAICS 5417, which is applied to the state compensation estimates to generate employment. R&D value added is estimated by using state R&D expenditures data to generate state estimates of CFC, which are then added to the compensation estimates.

5.4 Federally funded research and development centers

The FFRDC survey data are a census of all FFRDCs and are reported by the sector of the administrator of the FFRDC.

Based on the survey data, estimates are generated separately for FFRDCs administered by universities, private businesses (attributed to NAICS 5417P), and nonprofits (attributed to NAICS 5417N). These are then added to their respective sectors to generate publication-level statistics.

All FFRDC estimates are largely based on expense data collected by the FFRDCs R&D survey. At the national level, R&D employment is derived using FFRDC costs and employment-to-costs ratios from other R&D surveys: BERD for those FFRDCs administered by for profit R&D institutions, HERD for FFRDCs administered by higher education institutions, and NPRA for FFRDCs administered by nonacademic nonprofit institutions. R&D compensation is derived similarly using compensation-to-costs ratios from the respective R&D surveys.

Value added is computed by adding CFC to compensation for FFRDCs administered by higher education institutions and nonacademic nonprofits. For FFRDCs administered by businesses, value added is computed by adding GOS to compensation. CFC estimates are derived using depreciation-to-cost ratios from each respective R&D survey. GOS for business-administered FFRDCs is estimated using ratios derived from BEA's SUTs data.

At the state level, separate estimates are also generated for the FFRDCs administered by businesses, nonprofits, and higher education institutions. Like the national statistics, state R&D employment and compensation are derived using FFRDC employment- and compensation-to-costs ratios from the respective R&D surveys: BERD for those FFRDCs administered by for profit R&D institutions, HERD for FFRDCs administered by higher education institutions, and NPRA for FFRDCs administered by nonacademic nonprofit institutions. Value added is computed by generating state estimates of the noncompensation components using FFRDC R&D expenditures data, which are then added to the state compensation estimates.

5.5 Government sector

For federal R&D, the experimental statistics use data on federal intramural R&D (paid for and performed by the federal government) and intramural personnel costs. BEA breaks down federal R&D activity into defense and nondefense in the experimental statistics. The source data for state and local government



cover public institutions excluding public universities and colleges. The experimental BEA statistics for state and local government also include public universities and colleges as described in section 5.2.

At the national level, federal R&D employment is derived from personnel costs for federal intramural activity from the Survey of Federal Funds for Research and Development using employment-to-compensation ratios from the 2021 NPRA survey since the federal funds survey does not have employment information. The employment totals are then allocated to defense and nondefense R&D activities using gross output ratios from BEA's SUTs data. Federal R&D compensation reflects the personnel costs for federal intramural activity from the federal funds survey. These are allocated to federal defense and nondefense activities, as is done for employment.

For state and local government, R&D employment is derived from 2021 data for state intramural employment headcounts from the Survey of State Government Research and Development. The 2021 estimates are extrapolated back to 2017 using state intramural expenses adjusted for inflation using the CPI. R&D compensation is derived from state intramural expenses and a compensation-to-cost ratio derived from the 2021 NPRA survey.

For the federal government, value added is estimated by adding CFC to the compensation estimate. CFC is estimated using both the average depreciation-to-compensation ratio from the BERD survey and the average depreciation-to-compensation ratio for other nonprofits from the NPRA survey. The BERD-derived ratio is applied to federal defense compensation, and the other nonprofits ratio is applied to federal defense compensation, and the other nonprofits ratio is applied to federal defense compensation. For state and local government, value added is estimated by adding CFC to the compensation estimate. CFC is estimated using depreciation-to-compensation ratios for nonprofit hospitals from the NPRA survey.

At the state level, estimates for the government sector are based on R&D obligations data by federal agency and state from the Survey of Federal Funds Survey and R&D expenditures data from the Survey of State Government R&D. The Survey of State Government Research and Development provides data on the R&D performed by public institutions excluding public universities (primarily hospitals). Only the information on intramural R&D from the state survey is used. An adjustment is made to convert the data from a fiscal year basis to a calendar year basis.

R&D compensation estimates for the government sector are generated using a national compensationto-expenditures ratio for the nonprofit NAICS 5417 (federal government) and nonprofit hospitals (state and local government) from the NPRA survey, which are applied to the R&D obligations and expenditures data by state from the respective surveys.

R&D employment is estimated using a national average compensation rate for the nonprofit NAICS 5417 (federal government) and nonprofit hospitals (state and local government), which are applied to the corresponding state compensation estimates to generate employment.



R&D value added is estimated using federal obligations data and state and local government R&D expenditures data to generate state estimates of CFC, which are then added to the respective compensation estimates.