Linking Frascati-based R&D Spending to the System of National Accounts

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Abstract:

This paper provides a framework for translating research and development expenditure data organized based on the *Frascati Manual* to a measure of gross output consistent with *The System of National Accounts 1993*. This translation sets up the output measures and sectoral framework for the capitalization of R&D expenditures in a Satellite Account.

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1. Introduction

A first step in capitalizing Research and Development (R&D) expenditures is to relate these expenditures as closely as possible to current national accounting conventions. The internationally accepted guidelines for these accounting conventions are found in the *System of National Accounts 1993* (hereafter *SNA*). Internationally comparable data on R&D activity are collected and organized by the Organization for Economic Cooperation and Development (OECD) based on a classification system described in the *Frascati Manual* (hereafter *FM*) (OECD (2002)). R&D activity can be more clearly quantified in economic terms by linking the two systems.

The primary objective of this paper is to provide that link or bridge. This is accomplished by classifying *FM*-classified expenditures based on their economic purpose, separating current expenditures from capital formation, and sorting expenditures into the sectors used in the *SNA*. Additionally, exports and imports of R&D are presented to obtain the component of R&D expenditures that are used domestically. The resulting accounts provide the working definitions and output measures for the creation of satellite accounts for R&D that will produced by BEA in 2006 and 2007.

The translation of R&D activity into an investment good in a satellite account is a separate and related task not covered in this paper. Several additional conceptual questions must be addressed for capitalization, including identifying the ownership of capitalized R&D and estimating appropriate rates of return and consumption of fixed capital for capitalized R&D. Further, in order to develop constant cost estimates of R&D capital stock, R&D deflators must be identified. A preliminary R&D satellite account for

the U.S. economy will be published by the BEA in the fall of 2006. Since BEA anticipates capitalizing R&D in its core accounts in the future, this satellite account will conform to the national accounting standards used in BEA's National Income and Product Accounts (NIPAs). With few exceptions, the NIPAs are consistent with the SNA; substantive differences that are relevant to the linking of R&D expenditures are noted in the text and footnotes to this paper.[1]

In addition to its role as a building block for the upcoming satellite account, the paper provides a useful alternative view of the economic impact of R&D activity. The construction of the link focuses attention on definitional questions about the range of activities that should be included as R&D, the nature of R&D transactions in the economy, and the economic characterization of R&D as both a market and non-market good. Finally, the paper argues that closer adherence to the *SNA* framework in the measurement of R&D activity will improve measures of the increasingly important international flows in R&D services.

This paper is organized in four sections. Section 1 summarizes the differences between *FM* and the *SNA* in terms of their purposes, their definitions of R&D, and their sectoring. Section 2 describes the sectoring framework used for this *FM* to *SNA* Link. Section 3 describes the translation of expenditures to gross output in general terms. Section 4 concludes. Frequently used acronyms are listed at the end of the paper before the list of references. A companion paper describes these adjustments with U.S. data for 2001 (Robbins (2006)).

[1] For a recent discussion of the NIPAs and the SNA, see Mead, Moses, and Moulton (2004).

1.1. Summary of Differences between the Systems

1.1.1. Two Systems with Different Analytical Purposes

R&D expenditures are key inputs to the process of creating new technological knowledge. They are one of many related indicators of the effort devoted to basic science and innovative activities that are used by those who evaluate science policy. The FM provides guidelines on annual measurement of R&D expenditures and R&D personnel so that these efforts can be compared internationally. The *FM*'s recommendations are the basis for the OECD presentation of internationally comparable R&D expenditures for thirty countries in the publication, *Main Science and Technology Indicators* (OECD (2004)). This publication presents R&D expenditures organized by the sector of the performing institution and the sector of funding institution.

The *SNA*, in contrast, provides a basis for internationally comparable measurement of *economic* activity within a national accounting framework. The *SNA* shows economic activity organized by sector through an integrated system of statements on stocks and flows. These include production, income, saving, investment, financial flows, and balance sheets. Although the *SNA* recognizes that R&D activities provide future benefits and R&D is not completely used up in the production process, the *SNA* does not explicitly treat these activities this way. R&D is treated as current expense rather than as capital expenditure within the *SNA*. The capitalization of R&D expenditures is currently being considered for the next revision of the *SNA*.

This paper proposes a translation of R&D expenditures from a Frascati basis to an *SNA* measure of gross output of R&D activity by adding up the costs of production. In effect, R&D output is measured by the sum of its inputs. Related efforts by Dutch and

Israeli statistical agencies have led the way in translating Frascati-based expenditures to the *SNA*. This paper and the accompanying U.S. tables are informed by the work of Mandler and Peleg (2003, 2004) in translating Frascati-based expenditures into *SNA*-based measures of output of R&D as well as the industry-level accounting of gross fixed capital formation of knowledge capital by de Haan and van Rooijen–Horsten (2003, 2004).

1.1.2. Different Definitions of R&D in the two systems

The simultaneously private and public good qualities of R&D complicate its economic classification. R&D has the nonrival quality of a public good, where the use of R&D by its creator or purchaser does not prevent R&D from providing further benefits to others.[2] On the other hand, it has the quality of a private good that when created or purchased, patenting and trade secrets can render R&D exclusive in its use, at least in the short term.

The *SNA* identifies three general types of output: 1) market, 2) output produced for own final use, and 3) other non-market output (CEC et al., (1993) par. 6.45).[3] In the

[2] A public good has the qualities of non-rivalness and non-exclusiveness in consumption. Paul Romer's (1990) model of endogenous technological change describes the spillover from innovative activity as a non-exclusive public good that the innovating firm cannot completely capture.

[3] There are three types of output in the SNA:
Market production: output that is sold at prices that are economically significant or otherwise disposed of on the market or intended for sale or disposal on the market. Market production has five components: a) The total value of goods and services sold (at economically significant prices); b) The total value of goods or services bartered; c) The total value of goods or services used for payments in kind, including compensation in kind; d) The total value of goods or services supplied by one establishment to another belonging to the same market enterprise to be used as intermediate inputs; and e) The total value of changes in inventories of finished goods and work-in-progress intended for one or other of the above uses (CEC et al., (1993) par. 6.45).
Output produced for own final use: output that is retained by the owners of the enterprises where they are produced for own final use. Own gross fixed capital formation can be produced by any kind of enterprise (CEC et al., (1993) par. 6.45). Own gross fixed capital formation includes the total value of the fixed assets

current version of the *SNA*, R&D can be a market good or a non-market good.[4] It is performed by governments, non-profits, and universities as a collective consumption public good, and as such the *SNA* would consider it a non-market good. It is performed by R&D labs that sell their output to private firms at market prices and thus the *SNA* would consider it a market good. R&D is also performed for internal use by private corporations and as such is currently an expense; in a framework that capitalizes R&D this type R&D would be considered output for own final use.

When treated as capital in an R&D satellite account framework, the *SNA* classification of three general types of output recognizes the different ways that R&D is used in production. Because one of the goals of this paper is to provide a framework for the capitalization of R&D, three types of R&D output, market R&D, non-market R&D, and own-account R&D are used in this paper to assign R&D to sectors. Thus the R&D that is currently considered as an expense for market producers in the *SNA* is treated here as output for own final use.

As described on a Frascati basis, Research and Experimental Development ($R\&D_{FM}$) is "…creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications (OECD (2002) par. 63)." This definition makes it clear that in addition to R&D in the natural sciences, it also covers R&D in the

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produced by an establishment that are retained with the same enterprise for use in future production (CEC et al., (1993) par. 6.48).
Other non-market output: Goods and Individual and collective services produced by non-profit institutions serving households (NPISHs) or government that are supplied free, or at prices that are not economically significant, to other institutional units or the community as a whole. The reasons why this may be done include market failure caused by the non-exclusive aspect of collective goods, or for reasons of social or economic policy , for example education or health services (CEC et al., (1993) par. 6.49).

[4] If R&D were to be considered a capital asset, then R&D would take the three forms of output listed above.

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 (OECD (2002) par. 84)." Within this framework, Frascati-based R&D has three subdivisions, basic research, applied research, and experimental development.

The *SNA*, by contrast, describes rather than defines Research and Development ($R\&D_{SNA}$): "Research and development are undertaken with the objective of improving efficiency or productivity or deriving other future benefits so that they are inherently investment –rather than consumption – type activities (CEC et al., (1993) par. 6.163)." The *SNA* distinguishes R&D from other related activities that also derive future benefits, such as staff training, marketing, and environmental protection (CEC et al., (1993) par. 6.163). Its purpose 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 (CEC et al., (1993) par. 6.142)."

The purpose of R&D for non-market producers is not clearly specified in the *SNA*, but it does give some guidelines on how to value it for both market and non-market producers: "(It) should, in principle, be valued on the basis of the estimated base prices that would be paid if the research were subcontracted commercially, but is likely to have to be valued on the basis of the total production costs, in practice. Research and development undertaken by government units, universities, non-profit research institutes,

etc. is non-market production and is valued on the basis of the total costs incurred (CEC et al., (1993) par. 6.142)."

The Frascati framework provides information about the funding of R&D and the performance of R&D. While performer data are appropriate for identifying the producer of R&D and for developing estimates of gross output by sector, the combination of performance and funding data are insufficient to determine either the nature of the transaction between the funder and the performer or the final owner of the R&D. This determination of ownership is a crucial component of a satellite account that capitalizes R&D. The *FM* does recommend that two categories of government funding be identified for R&D performed in the business sector and in the academic sector. These categories are "those that are specifically for the procurement of R&D; *i.e.* the results of the R&D belong to the recipient of the output or product of the R&D, which is not necessarily the funder of the R&D" and "those that are provided to the performers of R&D in the form of grants or other financial incentives, with the results of the R&D becoming the property of the R&D performers (OECD (2002) par. 396 through 398)." To identify ownership of R&D, a clear distinction is needed between contracts for the purchase of R&D and grants for its performance.

1.1.3. **Differences in Sectors in the two Systems**

Frascati treatment presents R&D expenditures two ways, by institutional sectors of performance and institutional sources of funds. Institutions that conduct R&D are classified into sectors based on their primary activity. There are four sectors of performance: Business Enterprise, Higher Education, Government, and Private Non-

profit Institutions, and five sectoral sources of funding. The additional source of funds is from Abroad. For the most part, the Frascati sectors have a direct relationship to *SNA*-based institutional sectors; a clear difference is that no separate Higher Education sector exists for the *SNA* (OECD (2002) par. 157).

SNA sectors are comprised of institutional units, which are economic entities that can own assets, incur liabilities, and engage in economic activities and transactions (CEC et al., (1993) par. 4.2). The major institutional units recognized by *SNA* include households, corporations, non-profit institutions, and government units.[5] The *SNA* recommends the division of these units into major five major sectors: non-financial corporations; financial corporations; government; non-profit institutions serving households (NPISHs); and households. These sectors can be further subdivided to distinguish different types of corporations as well as levels of government. Transactions between resident units and non-resident units form an additional account, the rest of the world (CEC et al., (1993) par. 1.13).

The *SNA* identifies two kinds of producers, market producers and non-market producers. Corporations and Households are market producers while General Government and NPISHs are non-market producers. Market production involves goods for sale at an economically significant price, and market producers sell most or all of their output on the market. Market producers may also produce output for own account. In contrast, the output of non-market producers is distributed for free or at non-significant prices or may be produced for own account. Because of R&D's characteristics as a quasi-public good, R&D activity can be either market output or non-market output.

[5] An important SNA-identified institutional unit not discussed here is the quasi-corporation. These are units that are grouped with corporations because their economic activities are similar, although they may be owned by different economic entities than corporations.

This duality complicates the *SNA* sectoring task for R&D because the process of sectoring for non-profits and government often begins with determining whether the output is market or non-market. As the *SNA* definition indicates, for R&D it can be either. For the purposes of this paper, this link will be built around an interpretation of the *SNA* that is based on the language cited in Section 1.1.2 about R&D that identifies non-market output based on the sector of the institution that produces it.[6]

2. The Sectoring Framework

The table (Table A) that follows illustrates the Frascati to SNA linking of the sectors. The first column indicates the Frascati sector, the second column indicates the *SNA* sector, and the third column indicates the title of the associated table in the application of the link to U.S. data (Robbins (2006)). Moving left to right across line 1 of the table, the Frascati-based business enterprise sector is linked to non-financial corporations and financial corporations in the *SNA*.[7] Line 2 of the table shows that expenditures for R&D performed by the government sector are linked to *SNA*-based output of general government. Conceptually this linkage should include federal, state, and local government institutions as well as the non-profits that are financed and controlled by the government. Public higher education is part of the *SNA*-based government sector and is

[6] Experienced national accountants could reasonably choose alternate sectoring schemes for R&D. The alternative would be to identify market output based on the ratio of price to cost as a way to decide whether the price is economically significant. An economically significant price is one that has a significant influence on the amount producers are willing to supply and the amount purchasers wish to buy, and is a key criterion for identifying market output (CEC et al., (1993) par. 6.45). Since the Frascati data provides limited information on price and most R&D output is valued at cost, the best assumption one could make based on Frascati expenditure data is that price is equal to cost. This alternative assumption would classify all R&D as a market good, an unsatisfactory conclusion given the high level of government funding of R&D performed by universities and non-profits.

[7] Conceptually, the business enterprise sector in *FM* includes R&D produced by households that is sold on the market (OECD (2002) par. 197).

discussed below. Line 3 is the private non-profit and household sector; this sector is expanded in the *SNA* treatment compared with the Frascati sector because private non-profit colleges and universities are moved here from the Frascati-based higher education sector. Following the Frascati convention, this Frascati-to SNA Link sectors R&D produced by households based on whether or not it is sold on the market, either with the relevant corporate sector or with Non-profit Institutions Serving Households. Line 4 is the Frascati-based higher education sector. Since this is not a sector in the SNA, these expenditures are divided between general government and the non-profit institutions serving households (NPISH) sector. The final line of Table A is Abroad, and is linked to a Rest of the World sector.

Table A: Linking Frascati Sectors to SNA Sectors

	OECD Frascati Manual	SNA	BEA's Frascati-SNA Link
1.	Business Enterprise Sector	Non-financial corporations	Non-financial corporations
		Financial Corporations	Financial Corporations
2.	Government Sector	General Government	Federal Government
			Federally Funded R&D Centers
			State and Local Government
3.	Private Non-Profit Sector	Non-profit Institutions Serving Households	Non-profit Institutions Serving Households
		Households	
4.	Higher Education Sector	General Government	Public Colleges and Universities
		Non-profit Institutions Serving Households	Private Colleges and Universities
5.	Abroad	Rest Of World	Rest of World

2.1. **Business Enterprise to Non-financial and Financial Corporations**

The Frascati-based business sector is composed of "firms, organizations and institutions whose primary activity is the market production of goods or services (other

than higher education) for sale to the general public at an economically significant price." Its counterparts in the *SNA* are the financial and non-financial corporate sectors. For both Frascati and the *SNA* these sectors includes corporations that are owned by government units but provide goods or services that are 1) mainly sold by private enterprises, 2) sold at economically significant prices, and 3) the purchase of these goods is voluntary (OECD (2002) par. 165). Two kinds of non-profits are also in the Frascati-based business sector, these are the non-profits that sell their output at prices that cover most costs (economically significant prices), and non-profits that serve the business sector. Frascati sectoring would include the market activities of households and unincorporated businesses in the business sector. The SNA would sector the market activity of households in the Household sector.

The *SNA* identifies the quasi-corporation as an unincorporated enterprise that functions like a corporation and is sectored with corporations even though it may be owned by a government, non-profit, or household entity (CEC et al., (1993) par. 4.49). While an enterprise like this that conducts market R&D should be included with the corporate sector, the R&D performed by government, households, and non-profits is not included in the sectoring framework described here for practical reasons rather than theoretical ones. Identifying institutions that should be reclassified to the corporate business sector would require unit-based data identifying the amount of government, academic, and non-profit output, including R&D, that was produced as market output. This would require information about the transactions between the R&D funder and performer that is currently unavailable.

Within the *SNA*, the corporate sector is subdivided into a non-financial corporations sector and a financial corporations sector. Non-financial corporations are those engaged in producing market goods and non-financial services (CEC et al., (1993) par. 4.68). Financial corporations are those principally engaged in financial intermediation or closely related auxiliary financial services. On an International Standard Industrial Classification (ISIC) basis these industries are in divisions 65, 66, and 67.

2.2. Government to General Government Sector

The Frascati-based government sector is defined as "All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and economic and social policy of the community." Additionally, non-profit institutions controlled and mainly financed by government, but not administered by higher education are included in the *FM* government sector (OECD (2002) par. 184).

As described earlier, when the government produces goods that are normally sold by private enterprises and sells them at an economically significant prices, these goods are considered by the *SNA* to be market goods and should, with some qualifications, be sectored as output of the corporate sectors. This *SNA* language has led some national accountants to consider the output of U.S. public universities to be market output and to question whether both public and private universities should be properly assigned to the

corporate sector in the *SNA*.[8] A logical extension would be to consider R&D performed by universities to be market output as well. This decomposition could be made in different ways, based on differences in the way that universities are funded and operated in each country. The sectoring used in this paper is consistent the *SNA* language that identifies R&D as a non-market good based on its producer: "Research and development undertaken by government units, universities, non-profit research institutes, etc. is non-market production and is valued on the basis of the total costs incurred (CEC et al., (1993) par. 6.142)." This sectoring scheme has the additional quality that it can be applied to the data available for the U.S. As noted in the previous section, much more detailed source data would be needed to accurately separate out the market R&D output of public colleges and universities.

Federally Funded Research and Development Centers (FFRDCs) are owned or otherwise controlled and financed by the U.S. federal government and administered under contracts between the U.S. government and institutions in industry, academia, and the non-profit sector.[9] The sectoring proposal in these link tables moves all FFRDCs regardless of who administers them to the general government sector.[10] This assignment is consistent with *SNA* guidelines on control and finance. Control is understood to be the ability to determine the general policy and program of the institution by having the right

[8] For an analysis of this alternate treatment for U.S. colleges and universities, see Parker, Robert and Arnold Katz (1995); The Effects of Alternative Rules for Determining the Sectoral Classification of Colleges in the 1993 SNA: A Case Study for the United States.

[9] FFRDCs are institutions whose primary activity includes basic research, applied research, development, or management of R&D. They are separate organizational units from their parent institution and they perform their activities under direct monitorship from the federal government and receive major support from the federal government. They have a long-term relationship with the sponsoring agency of the federal government and most or all of the facilities are owned or funded for in the contract with the federal government (Burke (1999)).

[10] The NIPAs and NSF currently assign R&D performed by FFRDCs with the sector of the institution that administers each FFRDC.

to appoint the officers managing the NPI ((CEC et al., 1994 par. 4.62). In situations where the determination on finance is separate from control, the SNA lacks clear guidelines but the Frascati Manual suggests that where finance and control differ, the source of finance takes precedence over control in determining sectoring (OECD 2002 Figure 3.1). For FFRDCs, the federal government is the overwhelming source of financing.

This sectoring of FFRDCs with general government is also supported by data from a mini-survey about R&D expenditures collected by NSF as part of this project to link U.S. R&D expenditures to the *SNA*. In early 2005 NSF asked FFRDCs how much of the R&D performed in their labs in 2003 was more similar to that performed in Federally-administered labs and how much was more similar to R&D performed in labs not administered by agencies of the Federal government. Of the $12.1 billion in expenditures at the surveyed labs, 87% was reported by the FFRDCs to be more similar to that performed in Federally-administered labs, 10% was reported as more similar to that performed in other labs, and 3% was reported as either a mix of the two or non-response.[11] These results support the sectoring of this R&D with the general government sector.

This sectoring also conforms to the interpretation of the *SNA* that characterizes the R&D produced by government, education, and non-profits as a non-market good because it has more of the qualities of a public good than does the R&D produced by corporations and sold as a market good. Assuming that the government is funding the FFRDCs because the R&D conducted there has enough of this public goods quality to justify its

[11] As described in email dated April 2, 2005 from John Jankowski of the NSF, and documented in a supporting spreadsheet, "Responses from FFRDCs/Sponsoring Agencies."

cost, then the R&D can be characterized as a non-market good. In this case, the reasoning outlined above for sectoring the FFRDCs administered by private universities and non-profits is appropriate. The implicit assumption is that industry-administered FFRDCs receive the vast majority of their funding from the government and produce a non-market good.

In the tables developed for the translation of U.S. R&D expenditures into an *SNA* framework (Robbins (2006)), the general government sector is composed of R&D performed: 1) by the federal government by its agencies and labs; 2) R&D performed by state and local governments; 3) R&D performed by public universities and colleges; 4) R&D performed by all FFRDCs.

2.3. The Private Non-profit Sector

The Frascati-based private non-profit sector is composed of non-market, private non-profit institutions and private households. It includes R&D activity conducted by membership and philanthropic associations as well as the non-market R&D activity of households (OECD (2002) par. 194-197). Both *FM* and the *SNA* exclude from the non-profit sector the activity of non-profit organizations that mainly serve business. The *SNA*-based private non-profit sector also includes private colleges and universities that Frascati has assigned to the Higher Education sector.

The *SNA* identifies households as producers of goods and services in unincorporated market enterprises (CEC et al., (1993) par. 4.49-4.50). Household production is understood to be a very small component of R&D and NSF surveys that count R&D do not allow this small component to be separately identified. In *FM* it is

recommended that household production of R&D be divided between the business sector and the non-profit/households sector based on whether or not it is sold in the market. While no separate household sector is provided in this set of tables, R&D purchased by the Federal Government from individuals has been sectored with industry/corporations.

2.4. "Abroad" to Rest of the World

The *FM* does not provide a classification for foreign performers of R&D. Instead, the Frascati-based expenditure data treat "Abroad" as a source of funds for R&D, and the FM suggests a framework that could be used to classify international flows of funds for R&D. This framework could subdivide "Abroad" into the following sectors: Business Enterprise, Other National Governments, Private non-profit, Higher Education, and International Organizations, and could further subdivide financial flows for R&D between multinational parent companies and their affiliates. A suggested geographic breakdown for the flow of funds for R&D between regions of the world would separately identify continents, OECD countries, non-OECD countries and major economic communities (OECD (2002) par. 231-232).

An *SNA*-based production framework calls for a complete accounting of international transactions in R&D services. For the purpose of capitalizing R&D expenditures in a satellite account, domestic R&D production would include R&D services that were exported and exclude imports. The domestic R&D stock would include R&D services that were imported but would exclude R&D services that were exported. Although the R&D survey data collected for the U.S. and many other countries do not provide the transactions necessary to fully measure this sector, improving these

data would be one of the most useful aspects of the *SNA*-based treatment of R&D activity. For a fuller discussion of this issue, see Moris (2005).

3. Translating Frascati Expenditures into Gross Output

In addition to assigning institutions to *SNA*-based sectors, several adjustments must be made to the Frascati-based expenditures to yield measures of gross output of R&D by sector. As described in Section 1, the *SNA* recommends estimating gross output for government and non-profits with total cost, and for own account R&D on the basis of the estimated basic prices that would be paid if the research were subcontracted commercially.[12] In practice, the SNA recognizes the sum of costs as the available second best measure, and NIPA-based measures of own account R&D are constructed this way. These cost components should include the cost of any purchased R&D from either within or outside the sector as an intermediate input. Gross output also includes a charge for the amount of capital used up in production, but excludes capital expenditures, including those for software and equipment. It includes other taxes less subsidies on production, but not income taxes.

3.1. Starting with Frascati-based Expenditures by Performer

The basic measure of R&D performance in the Frascati framework is intramural expenditure by sector.[13] These intramural expenditures are all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period,

[12] While R&D services that are sold should be valued at basic prices, Frascati data do not report prices. The basic price is the amount receivable by the producer from the purchaser minus any tax payable plus any subsidy receivable as a consequence of production or sale (CEC et al., (1993) par. 6.205).
[13] The *FM* also provides for R&D expenditures by funder, but these data do not reflect measures of sector output.

whatever the source of funds. The FM calls for separate expenditure data for current costs, with subcategories for labor costs of R&D personnel and for other current costs. Other current costs include materials, supplies, and non-capital purchases as well as costs associated with consultants who work on site and indirect labor costs. The FM identifies three types of capital expenditures: 1) land and buildings; 2) instruments and equipment; and 3) computer software (OECD (2002) par. 376).

3.2. Ending with Gross Output consistent with the *SNA*

National accounting provides three distinct ways to measure economic output. From the production side, GDP is equal to total gross output minus total intermediate consumption, plus other taxes less subsidies on products not included in the value of output. From the demand side, GDP is equal to final consumption expenditures plus gross capital formation plus net exports. From the income side, GDP is equal to the compensation of employees plus taxes less subsidies on production and imports, plus mixed income (gross) plus gross operating surplus (CEC et al., (1993) par. 2.222).

The goal of the attached worksheets is to translate the Frascati R&D expenditures into gross output of R&D by building up the full costs of production. In translating the Frascati expenditures, this general expression shows the relationship of the components of the production account (CEC et al., (1993) par. 2.108): (Gross) Output = Intermediate Consumption + Consumption of Fixed Capital + Net Value Added. In current dollars, net value added is the sum of compensation of employees, other taxes on production and imports less subsidies, plus net operating surplus. Thus, if Frascati-based expenditures

can be translated into these components or some combination of them, Frascati-based expenditures can be translated to SNA-based output for each sector.

The Frascati framework calls for separate reporting of current expenses from capital expenses. In practice, compensation costs of employees and some taxes on production are embedded with most intermediate inputs in the Frascati-based expenditure data for the U.S. Subtracting compensation, which is in the expenditure data, from net value added leaves other taxes on production less subsidies and net operating surplus. Other taxes on production are those taxes that an enterprise incurs as a result of production, and specifically excludes taxes on profits or other income that are payable only when the firm is profitable (CEC et al., (1993) par. 7.70). These two items, other taxes on production less subsidies and net operating surplus, together with consumption of fixed capital are needed to transform the Frascati expenditures into the basic components of gross output. Capital expenses themselves are organized together in this Frascati-to-*SNA* link to develop an estimate of additions to capital formation.

Section 3.3 describes the steps involved in developing an *SNA*-based estimate of output from the Frascati expenditures. These steps are summarized in Table B.[14] The gross output estimate is followed by a section for gross additions to fixed capital formation and inventory investment and an additional section for exports and imports. While the translation of R&D expenditures themselves into stocks of useful intangible assets is the task of capitalizing R&D and is not addressed in this document, removing the additions to gross fixed investment is a necessary first step to prevent double-counting of R&D in a satellite account that capitalizes R&D. The value of domestic

[14] The application of these adjustments to actual source data as compiled by the NSF for the U.S. submission to the OECD is described in the companion paper and worksheets (Robbins (2006).

R&D that would ultimately be capitalized is gross output minus intermediate R&D inputs. This value would be further adjusted by adding imports of R&D and subtracting exports of R&D.

3.3. **Summary of the Frascati-to *SNA* Adjustments**

To produce a gross output measure for each sector, Table B starts with intramural expenditures on R&D, as defined in *FM,* for each sector. These include all expenditures for R&D within the sector of the economy from all sources of funds (OECD (2002) par. 358). The sections that follow compare *FM* expenditures with *SNA* measures, and recommend adjustments where an estimate can be made and the size of the adjustment is considered to be significant.

3.3.1. **The scope of R&D**

The first adjustment considered in Table B is for the scope of R&D between the two systems. While this paper concludes that the Frascati-based description appropriately defines the scope of R&D, the absence of a precise *SNA* definition of R&D allows for it to be interpreted either more narrowly than Frascati-based R&D or more broadly. A narrower interpretation would exclude activities that do not lead to improved products or production processes, removing some basic R&D expenditures (Mandler and Peleg (2003b)). One area where the *SNA*-based expenditure concept is clearly narrower than the corresponding Frascati measure involves research conducted by students at the PhD level. Frascati-based R&D expenditures should include scholarships and stipends for research conducted by the PhD students (OECD (2002) par. 68, 324) while R&D on an SNA basis would only include this activity when the expenditure took the form of employee compensation.

Table B. Frascati to *SNA* Adjustments

		Explanation of Adjustment
I. Output		
Frascati-Based Intramural Expenditures on R&D for each sector This includes current costs (labor, materials, supplies, and equipment) and capital expenditures.		
Plus expenditures for R&D as defined by SNA but excluded from Frascati-defined R&D	+/-	The scope of R&D in the SNA is not precisely defined and can be interpreted differently from that of the FM. The SNA could be interpreted to include spending that leads to new or improved products or processes without explicit novelty. It can also be interpreted to exclude basic research that is not directed toward product or process improvement.
Plus R&D purchased as an intermediate input to production of R&D in the sector	+	SNA-based gross output includes intermediate consumption, including the cost of any purchased R&D. Frascati-based output is reported either by performer or by funder and excludes intermediate consumption to avoid double-counting.
Plus any drawing down of inventories or supplies	+	SNA-based gross output reflects the value of inputs used in the production process, while the Frascati-based measure includes all expenditures for R&D. This is likely a small amount, no adjustment is recommended.
		Remove any additions to gross capital
Subtract capital expenditures for structures, equipment, and software	-	Frascati-based reporting calls for separate accounting for capital expenditures; these are land and buildings, equipment and purchased software. All of these expenditures should be removed from an SNA-based measure of gross output.
Subtract additions to inventories or supplies	-	Expenditures for materials and supplies not used for R&D production in the current period are not part of the value of output.
		Adjustments to move from expenditures to full value of output
Plus consumption of fixed capital on structures, equipment, and software owned by R&D producers and used to perform R&D performed in the US.	+	The SNA includes consumption of fixed capital as part of the cost of production; Frascati-based expenditures do not include depreciation or CFC measures.
Plus other taxes on production less subsidies	+	Some taxes on labor are included in Frascati-based expenditures, others may be missing.
Plus Net Operating Surplus	+	The cost of capital includes both the consumption of fixed assets plus the opportunity cost of holding fixed assets. For market producers the latter component could be proxied with net operating surplus or markup. No net operating surplus is included for the output for non-market producers.
Gross Output		

Table B. Frascati to *SNA* Adjustments (Continued)

II. Exports and Imports of R&D Output		
Exports	+	Exports are sales, barter, gifts or grants of R&D services from resident to non-resident units.
Imports	-	Imports are sales, barter, gifts or grants of R&D services from non-resident units to resident units.
Net Exports		
III. Gross Capital Formation		
		Fixed Investment
Investment in structures	+	This measure should exclude land.
Investment in Equipment	+	This should be equipment with a useful life of a year or more.
Investment in Software	+	This should be software with a useful life of a year or more.
Net disposals of capital goods	-	This should be sales or purchases of used assets.
Fixed Investment Subtotal		
Investment in inventories	+	This refers to inventories of materials used for R&D.
Gross Capital Formation		

SNA language on activity improving efficiency or productivity (CEC et al., (1993) par. 6.163) does not limit the scope of R&D to purely novel, uncertainty resolving, or potentially patentable activities. This distinction is noted in a recent paper by Baldwin, Beckstead, and Gellatly (2004) of Statistics Canada, addressing Canada's expenditures on knowledge capital in general. They suggest that the Frascati definition of R&D may underestimate the appropriate *SNA*-based measure of R&D. The broader interpretation of R&D would disproportionately impact R&D undertaken within the service industries. For these industries efficiency improvements are frequently developed in the supply chain, system operation, and expert systems (Jankowski (2002) and (Brown et al (2004) page 57). Keeping these alternate interpretations in mind, the scope of

Frascati-based expenditures is assumed to be a reasonable match for the intent of the SNA, and no adjustment is recommended.

3.3.2. R&D acquired as an Intermediate Input

The next line in Table B makes a key adjustment both for measures of gross output of R&D and for a future capitalized value of R&D is for purchased R&D. A full estimate of gross output includes the cost of all intermediate inputs, including R&D purchased from others that is used in the production of R&D. Since Frascati-based expenditures report R&D by performer, double-counting of purchased R&D is avoided but intermediate purchases of R&D are not fully captured. On an *SNA* basis intermediate inputs are identified by establishment (CEC et al., (1993) par. 2.137) and all intermediate inputs should be included in estimates of gross output. Thus a separate entry is provided in the translation table for the acquisition of R&D used as an intermediate input, whether this acquisition is from within the sector or outside the sector.[15] Since this acquisition represents a purchase of R&D, it should be recorded at market price. This treatment results in counting R&D as output for the unit that sold it as well as for the unit that purchased it as an intermediate input in the production of the purchaser's R&D. When capitalizing R&D in a satellite account, intermediate inputs would be subtracted out in a final measure of the value added from R&D activity.

For market producers of R&D, the economic concept of intermediate R&D inputs is clear and can be identified as the purchase of R&D services. For nonmarket producers,

[15] Since a final accounting of R&D output should be presented net of acquisitions, Mandler and Peleg suggest this special treatment of acquisitions may prove useful for the final purpose of capitalizing R&D and allocating this capitalized asset to the sector or industry that owns it (Mandler and Peleg 2003(a)). Two effects are then captured by this treatment of intermediate inputs—the R&D services end up in the sector that purchased them and, in this case, they are valued at purchasers prices.

the transaction that should be identified is the acquisition of R&D services that are used in the further production of R&D by the nonmarket producer. This identification is hampered by role of government and non-profit institutions in funding the performance of R&D by other institutions under a variety of contractual arrangements. The economic transactions that occur when the federal government funds R&D performed by others should ideally be identified so that grants, subsidies and transfers can be separated from intermediate purchases and the owner of the R&D can be identified. As noted earlier, *FM* provides for this information to be collected when government funds are used specifically for the procurement of R&D from the business and academic sectors.

3.3.3. Materials and Supplies

The next adjustment discussed in Table B is considered to be generally of small magnitude. Inventoried materials and supplies are not separately accounted for in the Frascati framework since Frascati counts purchases instead of consumption of intermediate goods. An *SNA*-based measure would count materials and supplies consumed as intermediate consumption. Any materials and supplies carried over from one year to the next would be inventory investment. This treatment is applied in the link tables. Inventory investment is treated as a category of capital investment separate from gross fixed investment while the drawing down of inventory is treated as a cost of current production.

3.3.4. Separate Additions to Fixed Capital from Gross Output

The next section of Table B adjusts for R&D expenditures that would be considered additions to capital investment instead of gross output. An *SNA*-based measure separates current expenses from capital formation because the latter produces a

flow of services that is not completely consumed in the current period. In the *SNA*, a produced capital asset is one that is used repeatedly, or continuously, in processes of production for more than one year (CEC et al., (1993) par. 10.7). Since these additions to capital are properly measured as changes to gross fixed investment, any existing capital expenditures embedded in the Frascati-based expenditure data must be removed to prevent double-counting.

In addition to structures and equipment (but not land), the *SNA* recognizes software that is expected to be used in production for more than one year as a produced fixed asset (CEC, 1994, par. 10.92). This includes the cost of prepackaged software, custom software, and own account software as well as the cost of development of large databases that are expected to be used in production for more than one year (CEC, 1994, par. 10.93). The FM provides for a classification of capital costs that are subdivided into: land and buildings; instruments and equipment; and computer software ((OECD (2002) par. 376).

R&D expenditures that are used to create own-account software are not included in the capital costs described above (OECD (2002) par. 383) and should be properly be counted as Frascati-based expenditures when they depend on a technical or scientific advance, and resolve a scientific or technical uncertainty. The framework proposed here includes in the measure of R&D gross output the cost of developing software for sale. When BEA capitalizes R&D in its satellite accounts, R&D expenditures for software development should be removed from gross fixed capital formation of software to

prevent double-counting since both the software created and the R&D would be capital assets.[16]

3.3.5. Adjustments to move from expenditures to full value of output

The final set of adjustments to Output in Table B adjusts *FM* expenditures to an *SNA*-based measure of gross final output. This cost estimation method should represent the full costs of production, which from the production side equals intermediate inputs plus gross value added. The costs within gross value added that are not accounted for in Frascati-expenditures are some non-labor taxes and subsidies on production, consumption of fixed capital and net operating surplus. Since the Frascati framework provides for capital expenditures in total expenditures, it does not include a measure of the consumption of existing fixed capital as part of current expenses. In the *SNA*, this consumption of fixed capital (CFC) is the decline in the value of the fixed assets value owned by an enterprise, as a result of their physical deterioration and normal rates of obsolescence and accidental damage. The value of a fixed asset is determined by the benefits that can be expected to flow from the asset for the remainder of its service life. This value is estimated in current period prices as a discounted value that would accrue to the owner of the fixed asset if it were to be rented out at current prices for the remainder of its service life (CEC, (1994) par. 10.118).

R&D produced by market producers should be valued at basic prices, but in practice these prices are rarely available outside of the NAICS industry 5417, R&D

[16] The SNA currently recognizes two distinct products embodied in the creation of a software original, the software original itself and the copies that can be made from the original. The value of the software original, which may be protected by copyright, is determined by the receipts or sales of the copies of the original and must cover the production costs of both the original and the copies (CEC, 1994, 6.143). R&D expenditures are currently an intermediate input in the production of this software.

Services. While own account R&D should also be valued at estimated basic prices, the *SNA* suggests that production costs may need to be used instead when reliable market prices are not available. This "second best procedure" is to value output of the goods or services produced for own account as the sum of their costs in production, specifically intermediate consumption plus compensation of employees plus consumption of fixed capital plus other taxes less subsidies on production (CEC et al., (1993) par. 6.86).[17] This procedure is used by the NIPAs.[18]

3.3.6. **Imports and Exports and Gross Additions to Capital Formation**

While *FM* provides a framework for international flows of R&D, in practice the Frascati-based expenditure data do not generally provide the information necessary to create complete estimates of imports and exports. Similarly, *FM* provides a classification framework for capital expenditures, but in practice the data for a complete accounting are unavailable. These two sections of the table are provided to describe a possible layout for this information.

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[17] In practice, estimated basic prices can differ from those constructed using this "second best procedure" of summing the costs of production. This difference involves the taxes less subsidies on production. Since the basic price is "the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any tax payable, and plus any subsidy receivable, on that unit as a consequence of its production or sale (CEC et al., (1993) par. 6.205)," it reflects the social or full cost of production. Using instead the SNA's second best procedure to value own account output, the calculation calls for the addition of other taxes and subtraction of subsidies on production. This latter calculation produces an estimate of the private cost of production rather than the social cost. The approach to this problem taken by Mandler and Peleg (2003b) is to consider these subsidies as components of R&D funding rather than performance.

[18] In other SNA text, the general valuation rules of the SNA call for market and own-account goods and services to include a mark-up that reflects the net operating surplus or mixed income attributable to the producer (CEC et al., (1993) par. 3.73). Net operating surplus implicitly includes interest charges and rents or other property incomes payable on financial assets, land or other tangible non-produced assets required to carry on production (CEC et al., (1993) par. 7.82). Since the second best procedure described above includes no estimate for net operating surplus, its exclusion underestimates full cost. In practice, this surplus is measured as a residual and it is noted in the tables without an associated estimate for market producers. The lack of an independent measure of this net operating surplus is one of the reasons why it is excluded from NIPA estimates.

While this Frascati-to-*SNA* Link presents a method for estimating gross output of R&D for a country, future work in capitalizing R&D will require clear accounting of R&D exports and imports. Conceptually, imports would add to domestic R&D capital stock, and exports would subtract from that stock. Exports and imports are transactions in R&D services between the domestic sectors of the economy and the rest of the world. The SNA-based rest of the world sector consists of non-resident institutional units that enter into transactions with resident units. The rest of the world sector includes institutional units within the domestic country's boundaries when they are entities like foreign embassies, consulates or military bases or international organizations (CEC et al., (1993) par. 4.163). Exports are considered to be sales, barter, gifts or grants of goods and services from resident to non-resident units (CEC et al., (1993) par. 14.88).

The Frascati framework includes the Abroad sector as source of R&D funding and as destination of R&D resources and is consistent with the SNA concept of non-resident status. Abroad consists of 1) institutions and individuals located outside of the political boundaries of a country[19] and 2) international organizations other than business enterprises, including those international organizations that exist within a country's borders (OECD (2002) par. 229).

Frascati-based data conceptually includes R&D exports and imports. The transactions to and from abroad are included in the extramural expenditures reported by R&D performers and funders, but are not generally separately identified in the Frascati-based data in practice. Improving the collection of data on international transactions with

[19] The testing and operation of vehicles, ships, aircraft and space satellites, as well as the testing grounds of a domestic institution is not considered as "Abroad" (OECD 2002 par. 229).

the rest of the world for each sector of the economy will enhance the accuracy the overall R&D measures.

An important economic input to the production of R&D is the capital used in its creation. Accounting for the full cost of production involves creating a framework for measuring the stocks of capital that provide a flow of services to produce R&D. The final section of Table B presents the changes in gross investment for the sector. These changes are composed of investments in structures, equipment, software, and changes in inventories minus the sale of any used assets. A further potential for double-counting capital involves the disposals or resale of capital assets. Within the *SNA* framework, gross fixed capital investment is reduced by these sales and disposals. A full measure of value would also reflect changes in the value of assets due to holding losses and revaluation, an adjustment that is not included in the link tables.

The Frascati-based measures include expenditures for land along with capital expenditures. For the *SNA*, land is considered to be a tangible non-produced asset, and only improvements to land would be included in gross fixed capital formation (CEC et al., (1993) par. 10.51). However, the *SNA* recognizes the difficulty in separately valuing existing land and structures, and in this case suggests that a transaction involving an existing structure be classified based on the asset with the higher value—either the land or the structure. In the case where this determination cannot be made, the *SNA* suggests that the transaction be classified as the purchase of a structure (CEC et al., (1993) par. 10.125).

Summary and Further Discussion

This paper has proposed a sectoring framework to translate Frascati-based measures of R&D expenditures into gross output of R&D on an *SNA* basis. The sectoring framework adjusts for the differences between the sectors of the FM and those of the *SNA* and is consistent with the level of detail currently available from U.S. source data collected at the firm level. For the application of this framework to the R&D data collected for the U.S. economy by the National Science Foundation, see Robbins (2006). This document provides the framework for measuring R&D output in current dollars for BEA's 2006 and 2007 R&D Satellite Accounts. As described earlier, where NIPA practice differs from an SNA interpretation, NIPA practice will be followed.

The paper provides a conceptual basis to distinguish market R&D from nonmarket R&D given limited information about the R&D transactions characterized in the source data. This limitation with respect to the transaction occurring between funder and performer is one of the most important differences between the Frascati framework and the economic accounting framework of the SNA. The Frascati provision for identifying the purpose of government funds provided to academia and industry incompletely addresses this gap. While the Frascati framework carefully avoids double-counting of R&D, it leaves a data gap for identifying R&D used as an intermediate input to the production of R&D. An *SNA*-based set of R&D accounts needs to identify the economic transactions between funder and performer. For example, when the federal government funds R&D performed by others, grants, subsidies and transfers should be separated from intermediate purchases.

Because most R&D is own account or non-market production, the translation of R&D expenditures to gross output is done by building up the cost components of the full value of production. The Frascati framework provides many of the components of cost needed for this translation, but not all. The largest missing component is consumption of fixed capital, which can be estimated if good data exist on capital investment each year. An important feature of the Frascati framework is that it identifies the major components of gross fixed investment, structures, equipment, and software, as well as compensation costs. The latter is necessary when R&D is capitalized in a satellite account to develop final estimates of value added by subtracting intermediate inputs from gross output.

The use of the cost method to estimate the value of R&D assumes that the measure of R&D output is equal to the sum of the inputs. While providing a means to estimate the value of an intangible commodity, this method imposes certain limitations. With no separate measure of output, output price deflators cannot be constructed for any R&D other than that which is sold on the market. The use of inputs to measure outputs also implies that no productivity improvement in the production of R&D can be identified.

Frequently Used Acronyms

FM: Frascati Manual
FFRDCs: Federally Funded Research and Development Centers
CFC: Consumption of Fixed Capital
OECD: Organization for Economic Co-operation and Development
NAICS: North American Industry Classification System
NPISH: Non Profit Institutions Serving Households
R&D: Research and Development
SNA: System of National Accounts

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