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R&D Exports and Imports
New Data and Methodological Issues

Francisco Moris

5.1 Introduction

Innovation—the introduction of new goods, services, or processes in the marketplace—builds on new knowledge as it flows from its originators to its eventual users. This knowledge may or may not result from scientific research and development (R&D), where R&D is defined as "creative work undertaken on a systematic basis to increase the stock of knowledge and [its] . . . use . . ." (OECD 2002,30). In the words of Rosenberg, "a high degree of scientific originality [has] been neither necessary nor sufficient condition for technological dynamism" (Rosenberg, 1982 13–14). Nevertheless, the importance of R&D in economic growth and productivity is well-established at the aggregate level (Griliches 2000, and references therein).

At the same time, the intangible nature of knowledge and its public good characteristics have long presented measurement challenges.[1] Thus, for example, the impact of knowledge is largely captured residually in total fac-

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1. For studies on continuing data needs on the creation, diffusion, and impact of knowledge in the context of theoretical, measurement, and policy-making challenges see Corrado, Hulten, and Sichel (2005), Gault and Earl (2006), Griliches (2000), and Hulten (2007). For ongoing work on innovation-related metrics in the United States see NSF (2007) and Moris, Jankowski, and Perrolle (2008) and references therein.

tor productivity measures, even when some intangibles are capitalized or otherwise considered endogenously. Further, the strategic value and high specificity of knowledge creation implies the prevalence of internal production, minimizing opportunity for arms-length transactions. More recently, however, open or collaborative innovation, outsourcing, and global supply chains (Arora, Fosfuri, and Gambardella 2001; Chesbrough, Vanhaverbeke, and West 2006; Howells 2006; OECD 2006b) imply increased flows of knowledge and technology.

The statistics introduced in this chapter represent a new measure of market-based R&D flows compared with uncompensated knowledge flows studied by the spillovers literature (e.g., Branstetter 2004; Coe and Helpman 1995; Jaffe and Trajtenberg 1998; Xu and Wang 1999). However, given the invisibility of ideas, market-based transactions are bound to capture only a small part of the flows suggested by the economics of intangibles. Further, even in the context of market transactions, cross-border exchanges within MNCs may suffer from coverage or measurement issues such as transfer prices (reported payments that diverge from market prices for similar goods or services), as discussed elsewhere (Grubert and Mutti, chapter 3 in this volume; Hines 1996).

Nevertheless, the new R&D services statistics presented here complement other fee-based knowledge flows such as international royalties and license fees (see Robbins, chapter 4 in this volume), by covering transactions earlier in the innovation process. Secondly, R&D services trade data reflect transactions for knowledge that may not be formally captured by IP protection. Thirdly, R&D services trade bring new insights on the international distribution of R&D, which may inform further studies on the role of trade and FDI in growth. For example, even though R&D services exports represent less than 5 percent of U.S. R&D industrial performance in the early 2000s, the ratio is at least four times larger for foreign-owned companies in the U.S. (as presented in table 5.3). Lastly, to the extent that these data are ultimately embedded in the Bureau of Economic Analysis/National Science Foundation (BEA/NSF) R&D Satellite Account (Jorgenson and Landefeld 2005; Robbins and Moylan 2007; Yorgason 2007), they enhance the international components of the account.[2]

In short, this chapter has two major objectives. It introduces data on affiliated international trade in R&D-related services from Bureau of Economic Analysis (BEA) surveys on international transactions.[3] The affili-

2. Satellite accounts are supplementary estimates of GDP and other National Income and Product Accounts (NIPA), allowing for greater detail or alternative measurement concepts. The R&D satellite account considers R&D as an economic investment, consistent with ongoing revision of the 1993 System of National Accounts (SNA) manual. For information on the SNA update see http://unstats.un.org/unsd/sna1993/snarev1.asp.

3. Data refer to international transactions in private services involving all kind of companies, not just companies classified in services industries. In particular, the R&D services trade data presented in this chapter refer to exports and imports by all companies regardless of industry classification, not just to activities of companies or establishments classified in NAICS 5417.

ated trade data, available since 2001, allows estimating total U.S. trade in these private services. The second objective is methodological. In particular, the R&D services trade data are compared with well-known statistics on industrial R&D from NSF by assessing their underlying accounting concepts. The analysis leads to an integrated characterization of R&D performance (production), funding, and transactions consistent with both trade and R&D statistics terminology. The proposed framework allows identifying data gaps and methodological differences across different sources, and illustrates the potential for data integration.

The next two sections of this chapter discuss issues of globalization statistics and R&D accounting as defined in several international statistical manuals (section 5.2) and presents U.S. data on R&D-related trade and trade-expenditure ratios (section 5.3). Section 5.4 develops an integrated characterization of R&D expenditures and transactions, and applies it to existing data. Section 5.5 concludes. An appendix covers data notes.

5.2 R&D Transactions and R&D Expenditures

Research and development services exports imply R&D performance, whereas R&D imports highlights the need to track external sources of knowledge regardless of whether the buyer is an R&D performer. These activities are tracked by different official surveys subject to several international statistical manuals. Across Organization for Economic Cooperation and Development (OECD) member countries, R&D expenditures are collected on a performance and funding basis by national statistical offices based on definitions and prescriptions of the OECD's *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development* (hereafter Frascati or FM).[4] On the other hand, the OECD's OSLO Manual (OECD 2005b) provides guidance on technological innovation statistics, including external sources of knowledge (see especially paragraphs 265–277).[5] However, R&D exports and imports are not explicitly defined in these manuals, nor in the *Technology Balance of Payments*

4. For example, in the United States national R&D expenditures are measured as the aggregate of R&D performed in industry, colleges and universities, Federal agencies, and other organizations based on NSF surveys targeted to these sectors (NSF 2003). These surveys use common definitions but have their own statistical methodologies appropriate for their respective populations. Respondent burden issues, respondent recordkeeping procedures, and institutional context vary considerably across these sectors, resulting in several unmeasured activities or units. For example, to reduce cost and respondent burden, estimates from the NSF/Census U.S. Survey of Industrial R&D currently exclude companies with less than five employees. Social science R&D is also excluded from this survey. I use industrial R&D data from both the NSF/Census Survey of Industrial R&D and from BEA FDI surveys. See data notes in appendix. For a compilation of official definitions of R&D across U.S. agencies see NSF (2006a).

5. The OSLO Manual serves as the basis for the EU Community Innovation Surveys (CIS). For a recent study on productivity growth, spillovers, and external sources of knowledge using CIS and economic data see Crespi et al. (2007).

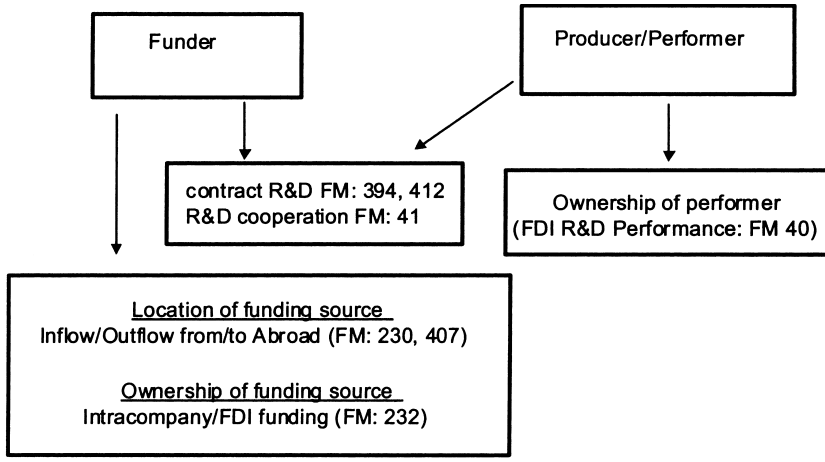


Fig. 5.1 R&D globalization in the Frascati Manual: Ownership and location of funding or performance

Manual (OECD 1990), the *Systems of National Accounts* (CEC et al. 1993 [SNA manual], paragraphs 8.27–8.33), or the *Handbook on Economic Globalisation Indicators* (OECD 2005a).

5.2.1 Globalization and R&D Accounting in the Frascati Manual

The Frascati manual (2002) is devoted to measuring R&D inputs (FM 14). The basic measure is "intramural expenditures," that is, all expenditures for R&D performed within a statistical unit or sector of the economy (FM 34). The manual recognizes that "R&D is an activity for which there are significant transfers of resources among units, organisations, and sectors, especially between government and other performers. . . . [thus] it is important . . . to know who finances R&D and who performs it" (FM 35). Further, Frascati takes "the globalization process into account by suggesting more detailed breakdowns of sources of funds for R&D and extramural R&D for transactions with units abroad" (FM 40), including R&D by multinational corporations (MNCs) through foreign direct investment (FDI), or FDI R&D.[6] See figure 5.1.

The focus by FM on R&D performed and used internally follows the history of R&D activities in industrial economies, along with the received wisdom of the economics of R&D. That is, R&D, and more generally, knowledge and information, exhibit public goods characteristics (e.g., nonrivalry and appropriability issues). These characteristics limit open market transactions and often the full exploitation of technological inno-

6. Within a national territory, this includes R&D by parent companies of MNCs and by affiliates of foreign MNCs.

vation (Teece 1986). However, even though the vast majority of R&D is still performed at home by developed-country MNCs, R&D is increasingly performed globally and collaboratively, driven by market, costs, and technological factors. Increased and more dispersed FDI in R&D-intensive industries (NSB 2008; OECD 2006b; UNCTAD 2005) and emerging global R&D management strategies (Le Bas and Sierra 2002; Niosi 1999; von Zedtwitz and Gassmann 2002) imply the need to complement information on international R&D production and funding with international transactions statistics.

5.2.2 International Transactions and R&D Exports/Imports

Both the *Manual on Statistics of International Trade in Services* (*MSITS*) (UN et al. 2002) and the IMF's *Balance of Payments Manual* (*BPM5*) (IMF 1993) define international trade as transactions between residents and nonresidents of an economy (UN et al. 2002, Box 1).[7] "A transaction itself is defined as an economic flow that reflects the creation, transformation, exchange, transfer or extinction of economic value and involves changes in ownership of goods and/or financial assets, the provision of services or the provision of labour or capital" (UN et al. 2002, 2.31). For its part, residency requires both having a center of interest (i.e., participation in economic activities) and residing in the country for one year or more. This "concept of residence . . . is identical to that used in BPM5 and the 1993 SNA [and] . . . it is not based on nationality or legal criteria . . ." (UN et al. 2002, 3.3).[8] (Note that considerations on ownership of the transaction parties or financing of the exchanged product [good or service] are outside the scope of these definitions.)

The MSITS also recognizes four modes of international delivery of services (UN et al. 2002, 2.14–2.21). Two of them are particularly relevant for business technical services such as R&D. The first mode refers to transactions between residents and nonresidents—international trade in the conventional sense as defined previously. The other mode of interest is the provision of services through foreign affiliates (Mode 3). Notably, the manual indicates that *only* Mode 1 transactions (between residents and nonresidents) should be labeled exports and imports. Separately, the manual recognizes that statistics based on Mode 1 definitions may be disaggregated in terms of transactions between related parties and transactions between unrelated parties (in this chapter, affiliated and unaffiliated trade, respectively) (UN et al. 2002, 3.36).

For a full account of cross-border flows, transfers are also of interest. The SNA defines transfers as "transaction[s] in which one institutional

7. Both manuals are also under revision; however, definitions used in this paragraph are unlikely to be affected.

8. See "The rest of the world account (external transactions account)," in the 1993 SNA, especially paragraphs 14.7 to 14.14.

unit provides a good, service or asset to another unit without receiving from the latter any good, service or asset in return as counterpart." Transfers may arise, for example, across geographically dispersed units of the same company or between public and private organizations. They can be classified as in cash or in kind transfers and as current or capital transfers (where the latter reflects or is linked to change in asset ownership) (CEC et al. 1993 [SNA manual], paragraphs 8.27–8.33). Thus, transfers are one-way or unrequited flows[9] and should be valued as if they were sold or purchased. Note, however, that for the purposes of R&D exports and imports as defined in this chapter, only in-kind transfers of R&D (properly valued) are of interest. Transfers of cash (grants) or other resources targeted for the performance of R&D do not result in cross-border flow of R&D regardless of the context.[10]

This discussion suggests that *R&D exports and imports* should be defined in terms of cross-border exchanges or transactions between residents and nonresidents. The next section introduces available data on international transactions in R&D services. The subsequent section develops a taxonomy that incorporates production, funding, and use/exchange concepts allowing a systematic characterization of exports and imports of R&D. The proposed framework may be useful to identify data gaps and illustrates the potential for integration across different data sources.

5.3 U.S. Trade in Research, Development, and Testing Services

Data on international transactions in R&D services are becoming available in several advanced economies, including the United States.[11] In addition to their potential as new flow indicators for further research and for national accounting development discussed in the introduction, these data may be also useful in studies on services offshoring (Graham 2007; van Welsum 2004).[12] Further, international trade in research, development, and testing (RDT) services is contributing to the U.S. trade surplus in business services overall, based on BEA data (NSF 2006b). Research, development, and testing services are defined as commercial and noncommercial research, product development services, and testing services. In general,

9. Also called transactions without a quid pro quo in the SNA (3.19–3.20).

10. Obviously, transfers in the forms of grants (public or private) are important when the objective is to measure R&D financing/funding flows between countries or within MNCs.

11. According to the IMF Committee on Balance of Payments Statistics, the proportion of IMF countries reporting international transactions in research and development services more than doubled between 1997 and 2003 (IMF 2004). See also OECD (2007).

12. Offshoring refers to the sourcing of production inputs through companies located outside of the home country. Offshoring may be done internally through controlled subsidiaries or affiliates, which involves foreign direct investment (FDI) (leading to affiliated trade within MNCs), or through external providers (leading to unaffiliated trade with independent entities). The latter is part of outsourcing activities that in general involve either domestic or overseas external suppliers.

however, data on R&D services trade include development activities or testing beyond the R&D boundary established by the Frascati Manual.[13] Research, development, and testing services are a category within business, professional, and technical services (BPT). Examples of other categories within BPT are computer and information services and management and consulting services. Business, professional, and technical, in turn, is a major category of private services. Other categories within private services include financial services, travel services, telecommunications, and royalties and licensing fees.

Trade in RDT services can be disaggregated into affiliated (intracompany) and unaffiliated (cross-company) trade. There have been trade surpluses in RDT services since 2001, when these data started to be collected separately from BPT for affiliated companies. Further, U.S. trade surpluses in RDT services have been driven more by U.S. affiliates of foreign MNCs and their relatively large exports of services than by parent companies of U.S. MNCs. This finding is consistent with the growing share these affiliates have in U.S. industrial R&D. In contrast, the unaffiliated trade surplus in RDT services has been down since 2001, due to the faster growth in imports than in exports of these services.

5.3.1 Trade Flows in Private, Business, and RDT Services

The United States has had annual trade surpluses in overall private services of at least $60 billion since the early 1990s, including a surplus of $79.9 billion in 2005.[14] Business, professional, and technical, together with royalties and license fees, accounted for most of the trade surplus within private services in 2005 ($33.1 billion and $32.9 billion, respectively).

In 2005, total exports (affiliated and unaffiliated) of RDT services reached a record $10.1 billion, compared with record imports of $6.7 billion, resulting in a trade surplus of $3.4 billion (table 5.1). This trade surplus is little changed from $3.7 billion in 2004 but smaller than trade surpluses around $5 billion in both 2002 and 2003. As discussed more fully following, this shift reflects gradual increases in trade deficits in unaffiliated trade for these R&D-related services.

5.3.2 Comparison of Affiliated and Unaffiliated Trade in RDT Services

For private services overall, the unaffiliated portion of exports and imports has been larger than the affiliated portion since at least 1992. The reverse has been true for BPT services and its subcomponent, RDT ser-

13. We will return to this point later. At the same time, this disadvantage turns into a plus for studies that focus on innovation activities. In either scenario, however, separating out R&D and non-R&D testing services is still desirable.

14. See Koncz and Flatness (2007) for updated data from BEA. For studies on the measurement of transactions and investment in overall services see Hoekman and Stern (1991) and Baldwin and Kamura (1998).

Table 5.1 **U.S. trade in research, development, and testing services: 2001–2005 (millions of U.S. current dollars)**

	Exports			Imports			Trade balance		
	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated
2001	6,746	5,700	1,046	2,425	1,700	725	4,321	4,000	321
2002	8,142	7,000	1,142	3,028	2,000	1,028	5,114	5,000	114
2003	9,376	8,200	1,176	4,410	3,100	1,310	4,966	5,100	–134
2004	8,760	7,500	1,260	4,993	3,100	1,893	3,767	4,400	–633
2005	10,095	8,800	1,295	6,717	4,400	2,317	3,378	4,400	–1,022

Source: Bureau of Economic Analysis, U.S. International Services. Available at http://www.bea.gov/international/intlserv.htm. Data accessed December 2006.

vices—affiliated exports and imports have been larger than unaffiliated exports and imports—since data have been available (1997 and 2001, respectively). Further, affiliated trade has recorded trade surpluses between $4 billion and $5 billion since 2001. However, unaffiliated trade moved from relatively small surpluses (< $500 million) in the 1990s (NSF 2006b), to small deficits in the early 2000s, reaching a deficit of just over a billion dollars in 2005.

The prominence of affiliated trade in business services, particularly R&D-related services, reflects advantages of internally managing, exploiting, and protecting complex or strategic transactions involving proprietary technical information (Caves 1996; McEvily, Eisenhardt, and Prescott 2004). For the United States, the large size of affiliated relative to unaffiliated trade in RDT services is consistent with strong U.S. FDI activity, which increases the number of potential affiliated trading partners. It is also consistent with expanded R&D by MNCs (NSB 2008).

5.3.3 Affiliated RDT Trade within U.S. and Foreign MNCs

Table 5.2 shows U.S. affiliated trade in RDT services in terms of the identity of the U.S.-located trading partner (parent company of U.S. MNC or U.S. affiliate of a foreign MNC) and the foreign trading partner (foreign affiliate of a U.S. parent or foreign parent of a U.S. affiliate), thus making possible an examination of intra-MNC trade.

From 2001 to 2005, annual exports of RDT services from U.S. parents to their foreign affiliates fluctuated narrowly around $2 billion, compared with around $1 billion in annual imports from their foreign affiliates, resulting in trade surpluses within U.S. MNCs of between one and two billion over this period (table 5.2). Over the same period, RDT services exports by affiliates of foreign MNCs in the United States to their foreign parents (and other foreign members of the company) were larger and increasing, reaching $6.8 billion in 2005. Annual imports under $3.2 billion over this period generated trade surpluses of up to $4.1 billion.

Table 5.2 **U.S. affiliated trade in research, development, and testing services: 2001–2005 (billions of U.S. current dollars)**

	U.S. affiliated trade			Within U.S. MNCs			Within foreign MNCs		
	Exports	Imports	Trade balance	Exports from U.S. parents to foreign affiliates	Imports from foreign affiliates to U.S. parents	Trade balance	Exports from U.S. affiliates to foreign parents[a]	Imports from foreign parents to U.S. affiliates[a]	Trade balance
2001	5.7	1.7	4.0	2.2	0.6	1.6	3.5	1.1	2.4
2002	7.0	2.0	5.0	1.9	0.8	1.1	5.1	1.3	3.8
2003	8.2	3.1	5.1	2.0	1.0	1.0	6.2	2.1	4.1
2004	7.5	3.1	4.4	1.8	1.2	0.6	5.6	1.9	3.7
2005	8.8	4.4	4.4	2.0	1.4	0.6	6.8	3.1	3.7

Source: Bureau of Economic Analysis, U.S. International Services.

[a]Data include transactions with other foreign members of the MNC.

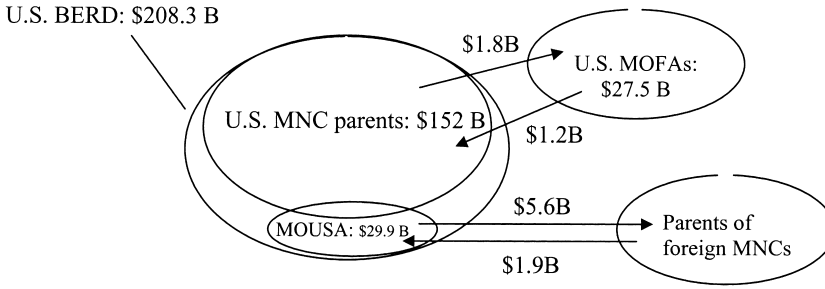


Fig. 5.2 U.S. affiliated RDT services trade flows (*data along arrows*) and industrial R&D expenditures (*U.S. BERD and data inside circles*): 2004

Notes: B = Billions of current U.S. dollars; BERD = Business Enterprise Expenditures on R&D; MOFAs = majority-owned affiliates of U.S. parent companies; MNCs = multinational corporations; MOUSA = majority-owned U.S. affiliates of foreign MNCs. Some companies are both parents of U.S. MNCs and also owned by foreign parent companies. Direction of arrows indicates flow of R&D services.

Sources: NSF Survey of Industry R&D (SIRD); BEA international investment surveys; BEA international transaction surveys.

The preceding analysis suggests that U.S. trade surplus in RDT services is driven by the relatively large exports by U.S. affiliates of foreign MNCs. This is consistent with their growing share in U.S. R&D (NSB 2008), although they still perform under 15 percent of U.S. industrial R&D, according to NSF and BEA data. Further, a substantial share of R&D-related activities is apparently aimed at services for their foreign parents (and other foreign members of the company). In particular, RDT services exports of $5.6 billion from U.S. affiliates of foreign MNCs to their foreign parents in 2004 was the equivalent of 19 percent of their $29.9 billion in R&D expenditures (fig. 5.2 and table 5.3).

For their part, parents of U.S. MNCs performed about three-fourths of U.S. industrial R&D. However, parents' $1.8 billion in RDT services exports to their overseas affiliates was the equivalent of only 1.2 percent of their R&D expenditures (table 5.3).

Note that R&D trade-expenditure ratios combine market-based data with cost-based expenditures that do not include operating surplus.[15] Further, the ratios presented in table 5.3 should be treated with caution. For one, the ratios are overstated since RDT trade includes *non-R&D* testing services. In addition, the ratios for affiliates are further overstated since affiliate's trade data are for all affiliates, not for majority-owned affiliates as the corresponding R&D figures. Nevertheless, they provide one indication

15. In practice, data from these different sources may be closer to each other: some R&D surveys include items on contract R&D while intra-MNC exchanges may not fully reflect arm's-length market values due to transfer pricing issues, as noted earlier.

Table 5.3 **R&D trade/expenditure ratios for selected sectors of U.S. industrial R&D: 2001–2005 (billions of U.S. current dollars, except as noted)**

	R&D performance	RDT exports	(%)	R&D performance	RDT exports	(%)
	All companies located in U.S.	All companies located in U.S.		MOFAs	From foreign affiliates of US MNCs to their US parents[a]	
2001	202.0	6.7	3.3	19.7	0.6	3.0
2002	193.9	8.1	4.2	21.1	0.8	3.8
2003	200.7	9.4	4.7	22.8	1.0	4.4
2004	208.3	8.8	4.2	27.5	1.2	4.4
2005	226.2	10.1	4.5	n.a.	1.4	n.a.
	U.S.-MNC parents	From U.S. parents to their foreign affiliates		MOUSAs	From U.S. affiliates of foreign MNCs to their foreign parents[b]	
2001	143.0	2.2	1.5	26.5	3.5	13.2
2002	137.0	1.9	1.4	27.5	5.1	18.5
2003	139.9	2.0	1.4	29.8	6.2	20.8
2004	152.4	1.8	1.2	29.9	5.6	18.7
2005	n.a.	2.0	n.a.	n.a.	6.8	n.a.

Sources: Based on data from NSF Survey of Industry R&D and BEA surveys on international investment and international services.

Notes: n.a. = not available; MOFAs = majority-owned foreign affiliates; MOUSAs = majority-owned U.S. affiliates; RDT = research, development, and testing services.

[a]This is equal to imports of U.S. MNC-parents.

[b]Data include transactions with other foreign members of the MNC.

of the global distribution of R&D-related services within U.S. MNCs and for MNCs with operations in the U.S.

5.4 R&D Accounting in an Integrated Expenditures-Transactions Framework

The following proposed framework is based on a little-noticed insight in the Frascati Manual on the separate identities of performer, funder, and user of R&D. According to Frascati, for a given R&D project, the performer, funder, and user fulfill different economic functions, possibly performed by three different organizations:

> "The [Frascati] Manual distinguishes between performers and funders of R&D. The SNA distinguishes between the producers and users of

Table 5.4 An integrated expenditures-transactions framework for business R&D

R&D profiles		R&D functions		
		FM Funder	SNA, FM producer/ performer	SNA user
1	Performer of company-funded own account R&D	yes	yes	yes
2	Custom R&D contractor (sale of externally-funded R&D)	no	yes	no
3	Speculative R&D producer	yes	yes	no
3a	Sale of speculative R&D (captive or open market sale)			
3b	Donation of speculative R&D			
4	Purchaser of custom R&D (funder of contract R&D)	yes	no	yes
5	Recipient of speculative R&D (not R&D funder)	no	no	yes
5a	Purchase of speculative R&D			
5b	Reception of donated speculative R&D			
6	Grants recipient (externally funded own account R&D)	no	yes	yes
7	Grants source	yes	no	no
8	Outside R&D statistics	no	no	no

> R&D services (expenditure account). The unit which 'performs' the R&D also 'produces' it. The 'funder' unit is usually, but not always, the SNA 'user.'" (*OECD* 2002, annex 3, paragraph 28).

By acknowledging the SNA user, Frascati effectively recognizes three distinct approaches for the collection and analysis of R&D data.[16] R&D performance reflects technological capabilities of companies, whereas R&D funding reflects financial capabilities or policy priorities. Data based on R&D performers avoid potential double counting of the same activity when funds flow across several sectors. Lastly, R&D users subsequently produce new or improved products or processes, realizing profits through commercialization (*OSLO Manual,* OECD 2005b).[17]

R&D performance underlines the statistical aggregates of gross domestic expenditures on R&D (GERD) and business enterprise expenditures on R&D (BERD), whereas funding is used to compile gross national expenditures on R&D (NGERD). (See appendix, Terms in Official R&D Statistics.)

Table 5.4 summarizes all possible combinations of these R&D functions

16. As noted earlier, acquisition, diffusion, and use of R&D also figure prominently in the OSLO Manual (101, 265–76, 351) (OECD 2005b).

17. For its part, the 1993 SNA states that "goods and services are used when institutional units make use of them in a process of production or for the direct satisfaction of human needs or wants" (SNA 9.35). In practice, for services "the distinction between acquisition and use may not be relevant" (SNA 9.37). Indeed, the definition of services implies that for many services production, delivery, and use may be indistinguishable (SNA 6.8). The SNA terminology is also used to define market and nonmarket R&D and own account R&D.

(and corresponding accounting perspectives), resulting in eight nonoverlapping R&D profiles (rows). This template could be populated with quantitative indicators at a given aggregation level (e.g., country, region, industry, company).

These R&D profiles can also be depicted as an n-Venn diagram where n = 3 intersecting sets or curves correspond to dollar amounts associated with performance, funding, and user activities (fig. 5.3). With 3 curves there are exactly $2^n = 8$ regions that partitions the space of expenditures, one for each R&D profile in table 5.4. The eighth region corresponds to the area surrounding the three circles. The regions formed by the intersections are nonempty. Following is a list of R&D profiles and examples of organizations (numbers indicate rows in table 5.4 and sectors in the Venn diagram of figure 5.3):

[1] Own account, company-funded, R&D: high-tech manufacturers
[2] Custom R&D services supplier: defense contractors
[3] Provider of speculative R&D: companies (or units within companies) specialized in R&D services
[4] Purchaser of custom R&D: defense ministries
[5] Recipient of speculative R&D: financial services companies
[6] Grants recipient: government grantees
[7] Grants supplier: government agencies
[8] Non-R&D-players (the vast majority of economic agents)

The proposed taxonomy identifies different types of R&D producers and users, juxtaposed with different financing schemes. Own account R&D (R&D produced and consumed internally) can either be self-funded (profile 1) or funded externally (e.g., grants) (profile 6). Custom R&D is performed on behalf of an outside buyer under contract. Speculative

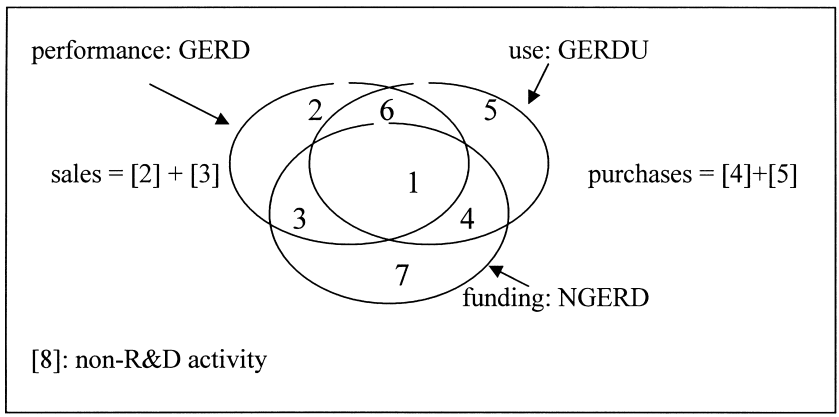


Fig. 5.3 The relationship among R&D functions underlying official R&D accounting

R&D[18] [3] refers to self-funded production not intended for internal use and with no advanced, secured buyer.[19] This is exemplified by commercial R&D service providers (of course, the latter also perform custom R&D). The immediate result of speculative R&D would be an increase in inventories, whereas its eventual disposition is either a sale or transfer. Research and development transfers, as defined earlier, are not generally collected in R&D or services transaction surveys. Thus, most of the remainder of this chapter abstracts from transfers [3b, 5b] and refer to [3] and [5] as a whole as part of sales and purchases, respectively.[20]

R&D transactions comprise profiles [2] through [5], where R&D sales (domestic sales + exports) = [2] + [3] and R&D purchases (domestic purchases + imports) = [5] + [4].

5.4.1 Discussion

R&D in a closed economy: In a closed economy, each "pie" in figure 5.3 is a different representation of the same total R&D in a given period:

- Performance: Gross domestic expenditure on R&D (GERD): total R&D performed in country: [1] + [6] + [2] + [3]
- Funding: Gross national expenditure on R&D (NGERD): total R&D funded by country: [1] + [3] + [4] + [7]
- Use: "Gross domestic expenditures on R&D used": [1] + [6] + [4] + [5]

where GERD = NGERD = "Gross domestic expenditures on R&D used."[21]

The last accounting equality is applicable to a closed economy, assuming no inventories or unused R&D. Further, in this closed economy: [2] = [4]; [3] = [5]; and [6] = [7], assuming R&D grants are used only for own account R&D. This is consistent with intra-country equilibrium, which requires: domestic R&D sales ([2] + [3]) = domestic R&D purchases ([5] + [4]).

R&D transactions in a two-country system: Figure 5.4 shows international R&D exchanges involving R&D services and transfer funds by adding a second country with a similar 3-Venn diagram whose sectors are indicated by (′). Abstracting from intra-country transactions, international trade implies:

18. The label for this profile is due to Charlie Aspden, OECD.

19. The 1993 SNA recognizes speculative production of assets (see, e.g., paragraph 10.75). Mohr and Murphy (2002: 5) consider speculative IP production in the context of product classification systems.

20. The legal form of the underlying IP (e.g., patent rights assignments) is outside the scope of table 5.4. Also note that the framework is static and it is focused on current-period R&D production and exchange. Thus, licensing and sales of R&D-based patents are not considered in the present work.

21. The last term is a new aggregate discussed later.

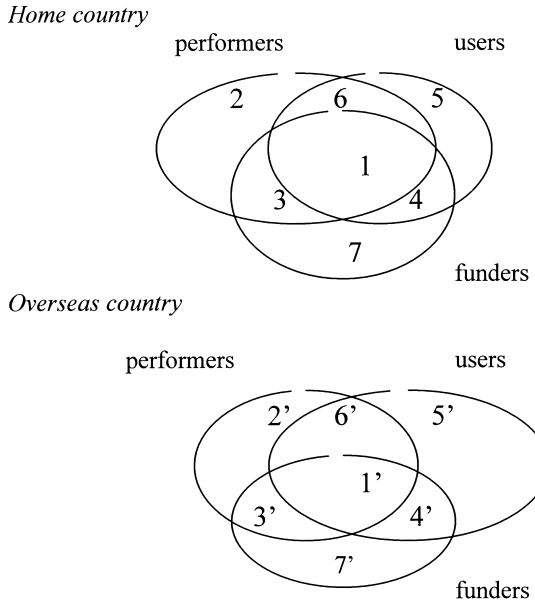


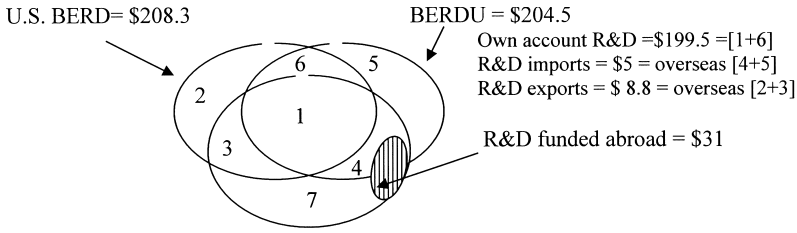
Fig. 5.4 R&D flows in an open economy

Notes: R&D exchanges in a two-country system: As drawn, the home country has larger R&D producer and funding sectors, whereas the overseas country has a larger R&D user sector. Also, the sector that simultaneously produces, funds, and uses its own R&D is larger in the home country: [1] > [1′].

$5 + 4 = 2' + 3'$ (R&D imports in the base country = R&D exports of overseas country) and $2 + 3 = 5' + 4'$ (R&D exports in the base country = R&D imports of overseas country).

Sectors 7 and 7′ in figure 5.4 are R&D grant sources (e.g., nonprofits, public organizations, parent companies). These sectors may direct funds either to domestic or overseas grant recipients (sectors 6 and 6′).

Research and development exports and imports can then be defined as transactions of R&D services between residents and nonresidents. This definition corresponds with Mode 1 of delivery of services (UN et al. 2002, 2.16), namely, "cross border supply [which] takes place when the consumer remains in [the] home territory while the service crosses national borders." In terms of table 5.4, R&D exports are the cross-border components of [2] and [3]. For both [2] and [3], R&D is being performed but not used by the performer. The difference between them is the financing scheme. In [2] the R&D was funded by a customer, whereas in [3] it was funded internally. In turn, the latter can either be sold [3a] or transferred in kind [3b]. Similarly, R&D imports are the cross-border components of [4] and [5], both showing a user of R&D that source it from an external provider. In the case of



BERD: Business enterprise expenditures on R&D;

BERDU: Business enterprise expenditures on R&D use

Fig. 5.5 A profile of U.S. industrial R&D expenditures and flows (billions of current U.S. dollars): 2004

Notes: BERD: Business enterprise expenditures on R&D; BERDU: Business enterprise expenditures on R&D use. Figure does not reflect necessarily the relative size of associated data.
Sources: NSF Survey of Industry R&D (SIRD) and BEA international transactions surveys.

[4], the user paid for the R&D in advance whereas in [5] it acquired existing R&D for a fee [5a] or as a recipient of an in-kind transfer [5b]. Excluded from R&D trade are self-funded own account R&D [1] and R&D grants (cash transfers) [6,7]. Cross-border grants are outside the scope of R&D exports and imports (since they do not involve flow of R&D), although they are obviously important when the objective is to measure financing/funding flows between countries or within MNCs.

In addition to GERD and NGERD defined earlier, the taxonomy suggests a new aggregate: "gross domestic expenditures on R&D use" (GERDU), depicted by the user pie previously, defined more formally as:

$$\text{GERDU} \equiv \text{GERD} - \text{R\&D exports} + \text{R\&D imports.}^{22}$$

The corresponding term for the business sector would be "business enterprise expenditures on R&D use" (BERDU): BERDU ≡ BERD – industrial R&D exports + industrial R&D imports.

The definition for GERDU corresponds to "apparent consumption" in the trade literature. Of course, by combining data from different sources, GERDU has similar shortcomings as the trade-expenditures ratios introduced earlier.

An illustration with 2004 U.S. data: (see fig. 5.5).

22. By using the fact that GERD is also equal to own account R&D plus R&D exports (Frascati Manual OECD 1993: Annex 11, paragraph 58) we also have: GERDU = own account R&D + R&D imports.

- BERD (= aggregate of [1] + [6] + [2] + [3]) = $208.3 billion (NSF SIRD)
- R&D exports (= overseas portion of [2] + [3]) = $8.8 billion (BEA)
- R&D imports (= overseas portion of [4] + [5]) = $5.0 billion (BEA)
- BERDU ≡ BERD – industrial R&D exports + industrial R&D imports = ([1] + [6] + [2] + [3]) – ([2] + [3]) + ([4] + [5]) = $208.3 – $8.8 + $5.0 = $204.5 billion = aggregate of ([1] + [6] + [4] + [5])
- Business own account R&D (= [1] + [6]) = BERD – industrial R&D exports (= BERDU – industrial R&D imports) = $208.3 – $8.8 = $199.5 billion
- Industrial R&D funding from abroad: Not available.
- Industrial R&D funded abroad = $31 billion (NSF SIRD)[23]

5.5 Conclusion

The importance of R&D in economic growth and productivity is well-established at the aggregate level. However, the intangible nature of knowledge and its public good characteristics have long presented problems for the measurements of its outputs, impacts, and associated transactions. In this regard, trade in RDT services constitute a welcome addition to the menu of indicators on knowledge flows, even if market-based transactions are bound to capture only part of the flows of interest. One advantage of services trade data presented in this chapter is that they cover both affiliated (MNCs) and unaffiliated trade, as well as transactions by companies that do not perform R&D (especially important for R&D imports). Even though the size of the trade flows examined here are modest relative to U.S. industrial R&D performance, the data already reveal new insights on the international distribution of FDI R&D. In turn, this may inform further studies on the role of trade and FDI in innovation, productivity, and growth. These exchanges may also be sizable for specific industries,[24] smaller developed economies, and emerging markets.

Further, the new statistics complement other fee-based knowledge flows by covering transactions earlier in the innovation process (compared, for example, with patent fees). The data also capture flows that may not be formally protected by IP (exploited, for example, in the patent citations approach). In addition, by focusing on R&D services across all companies the transaction surveys capture exports beyond stand-alone

23. As collected by NSF, and in the language of this chapter, industrial R&D funded abroad by (R&D-performing) for-profit U.S. residents is the aggregate of overseas purchases of custom and open market R&D, plus cross-border grants. Recipients of the funds include overseas affiliates and independent contractors. Thus, R&D funded abroad straddles the regions corresponding to "custom R&D" imports [4] and grants source [7]. This statistic is not available for U.S. non-R&D performers that may fund or buy R&D abroad.

24. Data limitations on U.S. RDT trade at the industry level precluded further analysis.

R&D labs or captive establishments classified in North American Industry Classification System (NAICS) 5417.[25] However, statistics on R&D services trade may include non-R&D testing services and do not provide additional R&D details (e.g., research vs. development, technology area, product vs. process focus). Some of this information may be obtained without increasing respondent burden, however, by linking data from the relevant surveys.

Lastly, the methodological approach followed in this chapter illustrates potential benefits and challenges of leveraging different official accounting perspectives and existing survey instruments to measure the varied dimensions of global R&D sourcing, deployment, and exploitation. In particular, table 5.4 allows a systematic account of R&D production (own account, speculative, and custom), exports and imports, apparent consumption, and cross-border transfers and grants flows. The application of the proposed framework to existing statistics points out the need not only for continued data development and integration but also to further enhancements in official statistical guidance by more systematically recognizing trade-based measures in Frascati-related manuals, as well as Frascati-based R&D terminology in services statistics, balance of payments, and other SNA-related manuals.

Appendix A

Data Sources

R&D Expenditures

Data for U.S. industrial R&D (BERD) were obtained from the NSF Survey of Industrial R&D (SIRD), a nationally representative sample of all for-profit companies in the fifty U.S. states and the District of Columbia, regardless of ownership status. Estimates are subject to sampling and nonsampling errors. See http://www.nsf.gov/sbe/srs/sird/start.htm for a description of the survey and its methodology.

Estimates on affiliates' and U.S. parents' R&D performance are collected by BEA FDI surveys (along with and other operations data): Survey of Foreign Direct Investment in the United States (FDIUS) and Survey of U.S. Direct Investment Abroad (USDIA). For more information see http://www.bea.gov/bea/surveys/diasurv.htm (USDIA) and http://www.bea.gov/bea/surveys/fdiusurv.htm (FDIUS).

25. For export revenues by NAICS 5417 establishments based on Census Bureau data see "Technology Linkages" section in NSB (2008).

International Transactions

Statistics on affiliated services trade were collected by BEA's quarterly balance of payments surveys on affiliates: Transaction of U.S. Affiliates, Except U.S. Banking Affiliates, with Foreign Parent (survey form BE-605) covers affiliates of foreign MNCs in the U.S.; Direct Transactions of U.S. Reporter with Foreign Affiliate (survey form BE-577) covers U.S. MNCs. In these affiliates' surveys, RDT services are defined as "[c]ommercial and noncommercial research, product development services, and testing services." Affiliated trade data in RDT services, a component of business, professional, and technical services (BPT), have been available since 2001. Business, professional, and technical affiliated trade data have been available since 1997. Previously, these components were included in the overall trade figures but were not separately available.

Data on unaffiliated trade in RDT services were collected by BEA's surveys on transactions with unaffiliated foreign persons, along with other business, professional, and technical services (Benchmark Survey of Selected Services Transactions With Unaffiliated Foreign Persons [survey form BE-20], conducted every five years, and the Quarterly Survey of Transactions Between U.S. and Unaffiliated Foreign Persons in Selected Services and in Intangible Assets [survey form BE-25] for nonbenchmark years). Surveys for unaffiliated transactions define RDT services as "[c]ommercial and noncommercial research, product development services, and testing services. Includes fees for the conduct of experiments or performance of research and development activities aboard spacecrafts. Excludes medical and dental laboratory services." For more information see http://www.bea.gov/bea/surveys/iussurv.htm.

Starting with 2006 benchmark data, new survey forms BE-120 (benchmark) and BE-125 (quarterly) will collect services transactions for both affiliated and unaffiliated trade.[26] For full historical tables on international transactions in private services see http://www.bea.gov/bea/di/1001serv/intlserv.htm.

Services sold to, or purchased from, unaffiliated foreign persons are reported regardless of whether the services were performed in the United States or abroad. Transactions for RDT services are reported on an accrual basis, gross of U.S. or foreign taxes.[27] Purchases of services are included without regard to whether they are charged as an expense on the income statement, capitalized, or charged to inventories. Data is on consolidated enterprise basis for all U.S. reporters. The fully consolidated U.S. domestic

26. The BE-120 replaces BE-20 and adds affiliated services transactions formerly covered by BE-605 and BE-577. Similarly, BE-125 replaces BE-25 and adds affiliated transactions.

27. Accounting data on an accrual basis refer to revenues and expenses recognized in the period in which they are earned (products are delivered or services provided). Cash may or may not be received or paid during this period.

enterprise excludes foreign branches and other foreign affiliates. The classification of services is based on the IMF's Balance of Payments Manual (BPM5), the United Nations' Manual on Statistics of International Trade in Services (MSITS) (which in turn draws guidance from the SNA), and the International Surveys Industry classifications developed by BEA.

Appendix B

Terms in Official R&D Statistics

FM-Based Terms

Business Enterprise Expenditures on R&D (BERD): Portion of GERD performed by the business or industrial sector. This is the same as industrial R&D in this chapter.

Gross domestic expenditure on R&D (GERD): Total intramural expenditures on R&D performed on the national territory during a given period (FM 423). Includes R&D performed within a country and funded from abroad but excludes payments for R&D performed abroad (FM 424).

Gross national expenditure on R&D (NGERD): Total expenditures on R&D financed by a country's institutions during a given period. It includes R&D performed abroad but financed by national institutions or residents; it excludes R&D performed within a country but funded from abroad (NGERD ≡ GERD – funding from abroad + funding funded abroad) (FM 426).

R&D funder: Organization that is source of funding for R&D. R&D funding is the basis for NGERD (defined previously).

R&D performer: Organization that engages in R&D. This is the same as R&D producer in SNA terms. The R&D performance is the basis for GERD and BERD (defined previously).

FDI R&D: R&D performed by multinational corporations (MNCs). Within a national territory, this includes R&D by MNC-parent companies and by affiliates of foreign MNCs.

SNA-Based Terms

Market R&D: R&D produced for sale at an economically significant price (Robbins 2005).

Nonmarket R&D: R&D distributed for free or at noneconomically significant prices (Robbins 2005).

Own account R&D: R&D both performed and used internally, regardless of funding source (also in OECD Frascati Manual 1993: Annex 11, paragraph 58). Own account R&D in the business sector of advanced

economies is funded mostly internally.

R&D producer: Same as R&D performer.

R&D user: Organization that exploits results or knowledge from R&D. The R&D used could be produced internally or acquired from an external provider.

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