International Trade in Research and Development Services and the Activity of MNC Subsidiaries

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Dedication

To Mami, whose love for learning and math got me started in a lifelong quest for knowledge.

Abstract of Dissertation

International Trade in Research and Development Services and the Activity of MNC Subsidiaries

International technology diffusion reflects global R&D production and collaboration that increasingly accompany other forms of international activity such as trade and foreign direct investment. This thesis studies country-level market flows of disembodied technology or intangibles trade. The main conceptual premise is that operations of MNC subsidiaries have a substantial effect on these market-based flows, consistent with public goods aspects of industrial knowledge and with theories on MNC R&D strategies. Extensive previous country-level work relating FDI and technology flows focuses largely on knowledge spillovers (benefits from involuntary, uncompensated knowledge flows). Further, this study considers simultaneously two types of MNC subsidiaries (foreign owned subsidiaries and overseas subsidiaries of domestic MNCs) to acknowledge the likely role of two-way FDI (measured by MNC activities) in intangibles trade. In turn, the influence of these subsidiary groupings on intangibles trade reflects varied motives of the underlying R&D investments. The predicted effects of MNC operations on intangibles trade result in hypotheses that are tested with published aggregate statistics from the U.S. balance of payments on total U.S. exports and imports in R&D services as the dependent variables.

Theoretically, the thesis introduces the concept of reverse knowledge transfer from international business research to the study of bilateral intangibles trade. More generally, the thesis contributes to the literature by integrating macro and micro perspectives useful to understand the direction and nature of disembodied technology flows. In particular, the conceptual approach is consistent with macro trade models (two-way trade and two-way FDI from new trade theory), international business research, knowledge-based and transaction costs theories of MNCs (internalization of knowledge production and transfer), and innovation theory (knowledge seeking/exploiting). Consistent with these theoretical considerations, the empirical implementation considers panel countries as both exporters/importers of intangibles and host/home countries of R&D-performing MNC

subsidiaries. In turn, estimated equations use panel econometrics to relate observed heterogeneity in the geographic structure of bilateral trade with the geographic distribution of MNC operations for the two types or groupings of MNC subsidiaries.

The main conceptual premise of this study was supported by the empirical findings. In the aggregate, U.S. MNCs and foreign MNCs with U.S.-located subsidiaries appear to engage in knowledge seeking R&D investments that influence transactions captured in balance of payment statistics. At the same time, the hypotheses regarding the effect of value added operations were not sustained statistically, failing to support knowledge exploiting as conceptualized here.

International transactions in intangibles in the form of services trade have yet to be integrated in the mainstream S&T policy literature. The analysis of aggregate R&D services trade pursued in this study may complement research on industrial knowledge flows based on other S&T indicators (or levels of aggregation) thus potentially allowing monitoring and analysis of international technology diffusion earlier in the innovation cycle (e.g., before or apart from patenting), and suggests the potential of non-spillover flows as targets of international S&T policy tools, perhaps in conjunction with trade and investment policy frameworks. The study also discusses the need for enhanced and integrated domestic and international statistics on R&D and related intangibles to support future research and the design or modification of policy tools to monitor and facilitate cross-border flows of industrial knowledge.

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List of Acronyms

BOP	Balance of Payments
BPM6	Balance of Payments Manual, 6th Edition
BERD	Business expenditures on R&D
CSAs	Country-specific advantages
FDI	Foreign Direct Investment
FDIUS	Foreign Direct Investment in the U.S.
FE	Fixed effects panel estimation
FSAs	Firm-specific advantages
GDP	Gross Domestic Product
HBA	Home-base augmenting
HBE	Home-base exploiting
HQs	Headquarters
IB	International Business
IPP	Intellectual Property Products
MNCs	Multinational companies/multinational enterprises
MOFAs	Majority-owned foreign affiliates of U.S. MNCs
MOUSAs	Majority-owned affiliates of foreign MNCs located in the U.S.
MSITS	Manual on Statistics of International Trade in Services
OECD	Organization for Economic Cooperation and Development
OLI	Ownership, location, internalization
RDT	Research, development, and testing services
RE	Random effects panel estimation
RKT	Reverse knowledge transfer
R&D	Research and Development
RDFDIUS	Stocks of R&D performed by MOUSAs
RDMOFA	Stocks of R&D performed by MOFAs
SNA	System of National Accounts
SSAs	Subsidiary-specific advantages
S&E	Science and engineering
S&T	Science and technology
TBP	Technology Balance of Payments
TKT	Traditional knowledge transfer
USDIA	U.S. Direct Investment Abroad
USPTO	U.S. Patents and Trademarks Office
UNCTAD	United Nations Conference on Trade and Development
VA	Value added
VAFDIUS	Valued Added by MOUSAs
VAMOFA	Valued Added by MOFAs
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Glossary of Terms[1]

Affiliate: A company or business enterprise located in one country but owned or controlled (in terms of 10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Affiliated trade: cross-border transactions within MNCs.

Balance of Payments (BOP): a statement that summarizes economic transactions between residents and nonresidents during a specific time period (BMP6 2.2(b)).

Business Enterprise Expenditures on R&D (BERD): component of national R&D that is performed by the business sector.

Disembodied technology: technical knowhow (e.g., blueprints for new products and technical services including R&D services), patents, licenses, trademarks, and software (OECD/Eurostat 2005: 79). More recent terms for essentially the same concept include intangibles and intellectual property products (IPP).

FDI in R&D: R&D performed by subsidiaries of multinational companies (MNCs).

Foreign direct investment (FDI): Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

Foreign-owned affiliate: Company located in one country but owned by a foreign parent.

Gross domestic product (GDP): The market value of goods and services produced within a country.

Home-base augmenting (HBA) FDI: This is an example of knowledge seeking FDI intended to benefit parent companies or home countries.

Home-base exploiting (HBE) FDI: FDI motivated by the deployment and adaptation of existing competencies and technologies developed in home countries.

Innovation: introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or in the open marketplace (OECD/Eurostat 2005).

Intellectual Property Products (IPP): R&D, software, and entertainment, literary, and artistic originals.

[1] Sources: NSB (2012) [2012 S&EI, Chapter 4], BEA (2013), IMF (2009) [BPM6], Kuemmerle (1999), OECD (1990, 2002), OECD/Eurostat (2005), UN et al. (2011) [MSITS], UN et al. (2009) [SNA].

International transactions/international trade/cross-border transactions: transactions between residents and non-residents of an economy involving change in economic ownership of goods or services (MSITS).

Majority-owned affiliate (same as subsidiary): Company owned or controlled, by more than 50% of the voting securities (or equivalent), by its parent company.

Multinational company (MNC): A parent company and its foreign affiliates.

Research and development (R&D): creative work undertaken on a systematic basis to increase the stock of knowledge and its use to devise new applications (OECD 2002).

R&D intensity: A measure of R&D relative to production, financial, or other characteristic (e.g., R&D-to-GDP ratio, R&D value-added ratio).

R&D performer: unit that conducts R&D. This is the same as 'R&D producer' in SNA terms.

Research, development, and testing services (RDT): commercial and noncommercial research, product development services, and testing services.

Reverse knowledge transfer (RKT): transaction involving disembodied technology flows from MNC subsidiaries (or host countries) to their parents (or home countries). In this thesis, RKT is associated with home-base augmenting strategies. Flows originating in subsidiaries may also support innovation elsewhere in the MNC, resulting in subsidiary to subsidiary flows not covered in this study.

Technology Balance of Payments (TBP): sales or licenses of patented/unpatented inventions; transfers of designs and trademarks; provision of technical services (computer, engineering, and R&D services); and industrial R&D (OECD 1990).

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place or for some other purpose.

Traditional knowledge transfer (TKT): transaction involving disembodied technology flow from MNC parents (or home countries) to their subsidiaries (or host countries), typically intended for exploitation of existing knowledge.

Transaction: voluntary economic flow between two parties. Include exchanges and transfers (unrequited provision of funds [cash grants], goods, or services) (SNA 3.7, 3.51, 3.58).

Value added. Gross output less intermediate inputs (gross output refers to sales or receipts, and other operating income, plus commodity taxes and changes in inventories).

Chapter 1: Introduction

Foreign sources of knowledge and technology account for a large proportion of productivity growth in many countries (Eaton & Kortum, 1996; Keller, 2004), illustrating the impact of the increasing globalization of research and development (R&D) and innovation. Given the intangible nature of knowledge as discussed further below, "a huge proportion of knowledge is not traded in the framework of monetary transactions" (Foray, 2004, p. 12). Knowledge is thus considered to be exchanged largely by means of informal mechanisms or transferred in the form of spillovers (benefits from involuntary, uncompensated flows). (See also Griliches, 1979, 1992; Keller, 2004, 2009). Indeed, the international technology diffusion literature has studied cross-country knowledge flows in the form of knowledge spillovers involving the business sector and tied to several channels including trade (final goods, intermediate goods, or capital goods trade), foreign direct investment (FDI) financial flows or MNC activity, foreign patenting and patent citations, mobility of scientists and engineers, and international business travel (Blomström & Kokko, 1998; Branstetter, 2006; Bosworth, 1980; Bosworth, 1984; Cincera & Van Pottelsberghe de la Potterie, 2001; Coe & Helpman, 1995; Eaton & Kortum, 1996; Eaton & Kortum, 1999; Freeman & Soete, 1997; Hovhannisyan, 2012; Jaffe & Trajtenberg, 2000; Keller, 2010; Liu 2008; Stoneman & Battisti, 2010).

At the same time, intended or strategic transfers in the form of contractual and other market-based international transactions of disembodied technology have increased along complex modes of inter-firm and intra-firm collaboration to develop and exploit technological knowledge. This thesis studies one form of country-level market flows of disembodied technology or intangibles trade. At the firm or industry level, Arora and colleagues (Arora et al., 2002) have modeled "markets for technology" focused on technology licensing among independent parties. However, international market transactions in disembodied technology at the country level remain little-studied (Mendi, 2001; Mendi, 2007; Organisation for Economic Co-operation and Development (OECD), 2009; Spulber, 2008; World Intellectual Property Organization (WIPO), 2011), compared with the literature on embodied technology flows and spillovers highlighted above. Embodied technology refers to physical products or assets. Disembodied technology refers to technical knowhow (e.g., blueprints for new products and technical services including R&D services), patents, licenses, trademarks, and software (OECD/Eurostat 2005, p. 79). More recent terms used to refer to disembodied technology include intangible assets or simply intangibles, and 'intellectual property products' (IPP). (See List of Acronyms and Glossary of Terms.)

Developments behind all forms of cross-border technology flows include fragmented production processes and global value chains (Sturgeon, 2002; UNECE/OECD 2014), innovation networks (Arora, Fosfuri, & Gambardella, 2002; Malerba & Vonortas, 2009), open business models (Chesbrough, Vanhaverbeke, & West, 2006), and FDI R&D operations (Dunning, 1992; Moncada-Paternò-Castello & Vivarelli, 2011; National Science Board (NSB), 2012; Organisation for Economic Co-operation and Development (OECD), 2008b; United Nations Conference on Trade and Development (UNCTAD), 2005). The rest of this chapter discusses objectives and research questions, analytical strategy and unit of analysis, and relevance for theory and policy.

Objectives and Research Questions

The main conceptual premise is that operations of MNC subsidiaries have a substantial effect on market-based flows of disembodied technology, consistent with several theories on MNCs and R&D strategies. The main objective is to understand the relationship between international trade in R&D services and the activities of MNC subsidiaries, in particular, R&D performed by subsidiaries of MNCs, called “FDI in R&D” in this study. In particular, the study addresses the following questions:

1-What is the role of FDI in R&D in cross-border flows of disembodied technology in the form of R&D services?

2-To what extent do subsidiaries of foreign MNCs located in a reference country and overseas subsidiaries of MNCs based in the reference country have different impacts on the country’s exports and imports of R&D services?

These questions are explored with a conceptual framework (developed in chapter 2) drawing on trade, FDI, and innovation theories leading to hypotheses to be tested with statistics on exports and imports of R&D and testing (RDT) services as dependent variables (often called “R&D services” in this study) and MNC operations as explanatory variables, controlling for partner country technological capacity and other national level variables (called country endowments in traditional trade theory and country-specific advantages (CSAs) in international business (IB) theory). Empirically, this study examines to what extent country-specific FDI in R&D influences the pattern of bilateral cross-border disembodied technology flows in the form of trade in R&D services. The methodology employed is panel econometrics (chapter 3) using public aggregate statistics on trade and FDI where panels are trading partner and investing/host countries, with the U.S. as reference country. The hypotheses are listed below and fully developed in chapter 3. (See Figure 3-6 for the hypothesized model.)

Hypothesis 1. U.S. RDT exports are positively related to U.S. R&D performed by subsidiaries of foreign-owned MNCs (RDFDIUS).

Hypothesis 2a. U.S. RDT imports are positively related to U.S. value added by subsidiaries of foreign-owned MNCs (VAFDIUS).

Hypothesis 2b. The size effect in U.S. RDT imports of U.S. value added by subsidiaries of foreign-owned MNCs is larger (in absolute value) than size effect of their U.S. R&D performance.

Hypothesis 3a. U.S. RDT exports are positively related to value added by majority-owned foreign affiliates of U.S. MNCs (VAMOFA).

Hypothesis 3b. The size effect in U.S. RDT exports of value added by majority-owned foreign affiliates of U.S. MNCs is larger (in absolute value) than size effect of their R&D performance.

Hypothesis 4. U.S. RDT imports are positively related to R&D performed by majority-owned foreign affiliates of U.S. MNCs (RDMOFA).

Analytical Strategy and Unit of Analysis

The empirical component of this study analyzes annual total U.S. exports and imports of R&D services for 2006 to 2011 from U.S. balance of payment (BOP) statistics in a country panel setting reflecting bilateral transactions. The main explanatory variables are subsidiary level aggregates of MNCs R&D and value added operations by investing or host country, thus differentiating between foreign MNCs with U.S. operations and foreign affiliates of U.S. MNCs. Thus the dependent variables (RDT exports and RDT imports) are national level aggregates explained by a combination of subsidiary level aggregates and national level controls, as further discussed in chapter 3.

Relevance for Theory and Policy

Theoretically, the thesis introduces the concept of 'reverse knowledge transfer' from international business research to study bilateral intangibles trade.[2] As an example of reverse knowledge transfer, a U.S.-owned affiliate located in Canada may perform research in materials engineering as input for further R&D by the MNC parent and perhaps by units elsewhere. In international trade statistics, reported fees received by the affiliate from the U.S. MNC parent for R&D outcomes are measured as U.S. R&D services imports (see Box 1 in chapter 2 for other examples). More generally, the study contributes to the literature by integrating macro and micro perspectives useful to

[2] In this thesis, reverse knowledge transfer (RKT) is associated with home-base augmenting strategies, as discussed in chapter 2 (see also Glossary and chapter 3). Flows originating in subsidiaries may also support innovation elsewhere in the multinational company, resulting in subsidiary to subsidiary flows not covered in this study.

understand the direction and nature of disembodied technology flows. Further, the present study suggests that designing or modifying policy tools to support international exchange of industrial-relevant knowledge calls for 1) approaches that jointly consider trade, MNC, and cross-border innovation strategies as developed in this thesis, and 2) enhanced and integrated domestic and international statistics on R&D and other intangibles as discussed in the concluding chapter.

More specifically, the relevance of this study can be described with following four observations. First, affiliated transactions – transactions within MNCs – account for most country-level flows in intangibles as measured in balance of payments (BOP) statistics (as described in chapter 3). The present study develops a framework to explicitly account for MNC subsidiaries and strategies in FDI R&D to understand aggregate flows of disembodied technology by combining trade and MNC/international business theory. Extensive previous work relating FDI and technology flows at the country level largely focus on spillovers (involuntary, uncompensated flows or on embodied technology flows (Chung, 2001; Keller & Yeaple, 2012; Saggi, 2002; Xu & Wang, 2000).[3]

Indeed, intra-MNC (or affiliated) trade in final and intermediate goods (embodied technology) account for a large proportion of global merchandise trade (Lanz & Miroudot, 2011; Zeile, 1997). Trade in disembodied technology is not different in this regard, as reflected in large share of affiliated transactions in R&D and testing services

[3] More generally, for findings from the FDI spillovers literature, such as regressions of domestic productivity to FDI variables (financial flows or operations), FDI spillover channels (e.g., patent citations, labor mobility, and business linkages with the domestic sector), and the relationship of FDI and trade in consumer, capital, or intermediate goods (embodied technology) see Blomstrom & Kokko (1998); Branstetter (2006); Gorg & Strobl (2001); Keller (2004); Liu (2008); and OECD (2008a).

discussed later in this study. However, the role of the activities of subsidiaries of MNCs in intangibles trade (observed market flows of intangibles or disembodied technology) have not been studied even though MNCs are widely recognized as major actors in cross-border R&D and innovation (Zander & Solvell, 2000). Further, this study quantifies for the first time the simultaneous role of foreign-owned MNC subsidiaries and domestically-owned subsidiaries abroad for intangibles trade to/from a given reference country.

Second, transactions in R&D services in a given technical project occur earlier than other forms of knowledge or technology transfer such as new patents. Focusing on cross-border R&D services complements existing work on (market-based) patent licenses and (uncompensated) patent citations, especially for technology areas where patenting is not the main form of IP protection or transfer.

Third, international technology flows in all forms, including market-based disembodied technology transactions (sometimes studied under the labels of intangibles or intellectual property products trade), matter for social welfare, economic growth and development, and long-term technological capabilities (Archibugi & Michie, 1997; Archibugi & Iammarino, 1999; Rama, 2008; Saggi, 2002). Indeed, the importance of knowledge flows within innovation systems have been recognized for many years within policy circles (e.g., OECD 1999). However, international transactions in intangibles such as technical services and R&D services have yet to be fully integrated with mainstream science and technology (S&T) policy literature on innovation systems and R&D globalization.

Further, it can be argued that policies to promote S&T capabilities and economic growth need to go beyond R&D production (or knowledge creation) into diffusion/use of knowledge. The design or modification of policies aimed at domestic and international flows of industrial knowledge need a better understanding of what drives intended flows, not only R&D spillovers studied extensively elsewhere.

Lastly, FDI and technology-related MNC operations and cross-border transactions in goods and services affect the balance of payments (and other international accounts components) (Dunning & Lundan, 2008, p. 469; IMF, 2009 [BPM6] chapter 6 and appendix 4; UN et al., 2009 [2008 SNA] chapters 16 and 26; Yorgason, 2007). Further, given globalized innovation activities, domestic R&D output may be exported for further research and/or commercialization elsewhere, while R&D imports add to the domestic supply or stock of knowledge. Thus, trade in R&D and other intangibles also affect economic accounts such as national, state, and industry-level GDP (BEA, 2013). For example, exports and imports of R&D services statistics are used to adjust domestic R&D stocks when incorporating R&D as investment in GDP (capitalizing R&D) in the U.S. and in other OECD countries. Yet few studies have systematically studied these flows. In this study, the terms disembodied technology, industrial knowledge, intangibles, and intellectual property products (IPP) are used interchangeably, reflecting the usage across different but related literatures. R&D and testing services (RDT) is one of several forms of disembodied technology. See chapter 3 for description of variables and data sources.

Conclusion

A major conceptual premise of the present study is that subsidiaries of MNC figure prominently in understanding aggregate market-based disembodied technology flows. Though this observation is consistent with theories on MNCs strategies for knowledge creation and transfer at the firm level, intra-MNC perspectives have not been incorporated in studies on observed technology-related flows at the macro level such as those recorded in balance of payments statistics.

Theoretically, this thesis introduces the concept of 'reverse knowledge transfer' from international business research to the study of observed trade in intangibles at the country level. More generally, the study contributes to the literature by integrating macro and micro perspectives useful to understand the direction and nature of disembodied technology flows. Chapter 2 provides a literature review, including summaries in Table 2-1 and Figure 2-1. The hypotheses developed in chapter 3 (see Figure 3-6 and related text) focus on the differential impact of two types of MNC subsidiaries, majority-owned by foreign MNCs but located in the U.S. and majority-owned foreign subsidiaries of U.S. MNCs. FDI in R&D strategies in the aggregate may also vary with observed and unobserved (or omitted) characteristics at the country level (simultaneously trading partners and FDI host/home countries). Unobserved or omitted variables –such as IP protection or cultural traits that facilitate trust in business technological transactions– are taken into account by panel estimation techniques. Chapter 3 also presents variables, data sources, and econometric methodology, and discusses threats to the validity of research findings.

An integrated 'MNC-trade' model for intangibles trade is developed, tested, and discussed in chapter 4. The main conceptual premise of this study was supported by the empirical findings. In the aggregate, R&D stocks of U.S. MNCs subsidiaries and of U.S.-located subsidiaries of foreign MNCs have statistical significant effects on the cross-border flows of disembodied technology examined in this study, with implications for the character of these flows in terms of knowledge seeking FDI strategies. At the same time, the hypotheses regarding the effect of value added operations were not sustained statistically, failing to support knowledge exploiting as conceptualized here. Chapter 5 concludes by revisiting research questions, findings, and limitations; discussing the relevance of results for statistics on globalization and intangibles and for S&T policy analysis; and describing future research, data needs, and possible strategies for statistics development.

Chapter 2: Literature Review

Introduction

This chapter reviews theories relevant to understand the relationship between R&D in FDI and intangibles trade. The chapter contains four sections covering literatures of interest: MNC and FDI theories; international trade theory and technology flows; transactions costs and innovation theory; and technology balance of payment (TBP) studies. A fifth section describes the conceptual framework for the present study, and the last section offers a chapter conclusion.

Theories of MNCs, FDI in R&D, and International Business

For the purposes of the present study, theories of firm-level FDI strategies may be categorized as emphasizing the exploitation of existing assets including technology (asset exploiting) and the augmentation of capabilities to generate new knowledge (strategic asset seeking, here limited to knowledge augmenting strategies). In FDI and MNC theory, technology has long being considered a source for firm-level "ownership advantage" or firm-specific advantages (FSAs) that compensates for so called 'liability of foreigness' of MNCs – the higher costs and risks from operating abroad relative to domestic firms in the same industry (Dunning, 1981; Dunning & Rugman, 1985).[4] Thus in early FDI/MNC theory, the existence of MNCs can be conceptualized as a way to internally transfer abroad firm-specific advantages such as managerial expertise or technological knowhow to exploit host country specific advantages (CSAs). Note that in

[4] At the same time, globalization via MNCs was largely globalization of production, not R&D, for much of the 20th century, consistent with Vernon's (1966) model (Patel & Pavitt, 1991).

these early FDI theories –as in contemporaneous theories of technical change, growth and trade –technology was effectively an exogenous advantage whose development was outside the model, though attributed to the home country base of the MNC.

In subsequent literature going back at least to Dunning's strategic asset seeking FDI (Dunning, 1992), host countries are not only the location of external advantages to be combined with existing firm technology or capabilities as in early theories but also the source of new firm-specific advantages and enhanced innovation performance. In particular, subsidiaries are seen as able to create technological and business knowledge for local and global use, and serve as internal vehicles to monitor, absorb, recombine, and transfer local external knowledge. In this scenario companies locate not primarily based on low production costs or large markets to exploit existing technology transferred from home countries but rather to complement or strengthen technological capabilities, resulting in subsidiaries recognized as 'centers of excellence' with capabilities that benefit the whole MNC (Frost et al., 2002), as studied under the related concepts of subsidiary initiative (Birkinshaw 1998, 2000), subsidiary-specific advantages (SSAs), and 'location-bound' firm-specific advantages (Rugman & Verbeke, 2001; Rugman et al., 2011).

Research on subsidiaries as sources of knowledge for the whole MNCs (parents and sister subsidiaries) is consistent with the conceptualization of MNCs as networks, including double networks/double diamonds perspectives (Ietto-Gillies, 2012; Rugman &

Verbeke, 1993; Zanfei, 2000).[5] For the purposes of the present study, the conceptualization of MNCs as networks imply complex forms of intangibles inflows/outflows including one-way and two-way vertical and horizontal/lateral disembodied technology flows. This contrast with an earlier hierarchical view of MNCs where parents designed corporate strategy and performed fundamental R&D, and subsidiaries functioned primarily as recipients/adaptors of parent technology (Birkinshaw, 2000; Michailova & Mustaffa, 2012) implying mostly one-way parent-to-subsidiary flows often called traditional knowledge transfers (TKT).

A parallel stream of research is found in the literatures on internationalization of R&D and international business. This research documents the evolution of R&D performance by MNC subsidiaries from an early focus on demand factors and adaptive R&D (Ronstadt, 1978; Terpstra, 1977) to supply factors such as the ' access to science' motive (von Zedtwitz & Gassman, 2002) driving overseas MNC R&D with the goal of learning via fundamental research and related innovation activities (Brockhoff, 1998; Dunning & Lundan, 2008; Granstrand, 1993; Hakanson, 1981; Hakanson & Nobel, 1993; Ietto-Gillies, 2012; Niosi & Godin, 1999; Pearce, 1989; Pearce, 1999; Reddy, 2000). This literature include, particularly important for our purposes, research on FDI in R&D by European and Japanese companies in the U.S. and U.S. MNCs overseas (Athukorala & Kohpaiboon, 2010; Dunning & Narula, 1995; Florida & Martin, 1994; Serapio & Dalton, 1999).

[5] The term double networks refers to the interaction of internal MNC networks with external networks or clusters in host countries; 'double diamonds' refers to the interaction of country-level competitive factors of home and host locations by means of MNC subsidiaries (Rugman & Verbeke, 1993).

Kuemmerle's (1999) home-based exploiting (HBE) and home-based augmenting (HBA) terminology was coined to capture FDI that either exploits parent company technology or enhances parents' capabilities, applied to the question of the location of R&D by MNC outside home countries (see also Fors, 1998). HBE refers to the exploitation of competencies and technologies developed in home countries on a global scale by doing adaptive R&D, engineering, and design abroad. The HBE concept is directly related to asset exploiting FDI in early theories of MNCs where home-based ownership advantages led to the formation of MNCs (Dunning, 1981; Hymer, 1976).

Kuemmerle's home base augmenting strategy for FDI can be described as a subset of knowledge seeking strategies (motivated by the development of new capabilities or technologies) that benefit the MNC parent company (Cantwell, 1989; Dunning, 1988; Kogut & Chang, 1991). 'Home base augmenting' strategy, 'access to science' motive, and the 'centers of excellence' literature (see Box 1) are consistent with the view that subsidiaries and host locations are a key source of firm specific advantages (FSAs) by contributing subsidiary specific advantages (SSAs) (Rugman & Verbeke, 2001) .[6] Subsidiaries also enhance connections with external environments via sourcing (e.g., external R&D contracting or unaffiliated transactions), monitoring, and spillovers from local subsidiary activity (as captured in double network/double diamonds perspectives) (Rugman & Verbeke, 2001). This study, however, focuses on the role of internal/affiliated MNCs activities on cross-border knowledge flows.

[6] Note that compared with the more general concepts of knowledge seeking and knowledge exploiting, both HBA and HBE are 'home-centered' or 'parent-centered' in terms of strategy setting and ultimate competitive benefits of FDI, in contrast with subsequent views that emphasize strategic decentralization and subsidiary initiative in firm-level or R&D management studies (Birkinshaw, 2000; Criscuolo, 2004 (page 42 and footnote 65 in page 149); and Fors, 1998).

Firm and project level research on MNCs R&D from international business literature has explicitly noted the potential of "intra-firm knowledge flows across national borders as firms expand the number of R&D sites abroad" (Kuemmerle, 1999, p. 19). In these studies, "how efficiently MNCs share knowledge across HQs and subsidiaries" across globally dispersed R&D operations is deemed to confer MNCs and their home countries a competitive advantage (Kurokawa, Iwata, & Roberts, 2007, p. 4). More importantly for our purposes in examining country-level disembodied technology flows is the acknowledgement by this literature of the possibility of knowledge flows not only from MNC parents to subsidiaries as in traditional 'North to South' or home to host country technology transfer, but also subsidiary to parent flows or 'reverse knowledge transfer' (RKT) originating in host countries (Almeida & Phene, 2004; Buckley & Carter, 2000; Criscuolo, 2004, 2009; Hakanson & Nobel, 2000, 2001; Kurokawa et al., 2007; Michailova & Mustaffa, 2012; Yamin & Otto, 2004). RKT has been particularly studied in management research on 'centers of excellence' (Rabbiosi, 2008).[7] See Box 1 for examples and relationship with the present study. The present study argues that firm-level strategies and MNC activities to develop, acquire, and transfer knowledge affect aggregate cross-border knowledge flows.

[7] Blomström & Kokko (1998) use the term 'reverse technology transfer' when they discuss FDI spillovers for home countries (involuntary, uncompensated flows in the form of productivity or market access benefits to companies or industries other than the MNC parent company or industry) associated with foreign centers of excellence located in advanced host countries. In the present study, reverse knowledge transfer (RKT) refers to voluntary flows or transactions (not spillovers) in order to link RKT as used in international business research and R&D management/strategy to international trade theory.

Box 1: MNC's 'Center of Excellence', FDI in R&D, and Reverse Knowledge Transfer

Knowledge seeking FDI may occur among advanced economies with similar endowments, as emphasized by new trade theory models that incorporate two-way FDI, but this type of investment may also occur in the form of outward FDI from emerging markets such as China (chapter 4 in Yao & Wang, 2014). In either setting, knowledge seeking investments are often associated with intra-MNC 'centers of excellence' by the R&D and strategic management literature referring to "an organizational unit that embodies a set of capabilities that has been explicitly recognized by the [MNC parent] firm as an important source of value creation, with the intention that these capabilities be leveraged by and/or disseminated to other parts of the firm." (Frost et al., 2002, p. 997). The term appears in several subsidiary typologies (Harzing & Noorderhaven, 2006) that distinguish the strategic importance of MNC units, especially as source of knowledge. As Frost et al. note, parent companies typically act as technological centers of excellence for innovative MNCs compared with cases where foreign subsidiaries act as global sources of knowledge for the MNC (Birkinshaw, 1998). In the context of this study, parents acting as centers of excellence would be consistent with traditional knowledge transfer, whereas subsidiary centers of excellence (and more generally, affiliates having subsidiary specific advantages that benefit the whole MNC (Rugman & Verbeke, 2001) are associated with reverse knowledge transfer and home-base augmenting FDI strategies.

Studies on FDI in R&D by European and Japanese companies in the U.S. and U.S. MNCs overseas (e.g., Athukorala & Kohpaiboon, 2010; Dunning & Narula, 1995; Florida & Martin, 1994) are consistent with research on subsidiaries considered R&D 'centers of excellence' in the strategic management literature. Consider the case of an European-based drug manufacturer that establishes its global research center for a type of biotechnology drug in the U.S. area of New England attracted by world-class universities and research workforce expertise in this field. The unit is then charged with performing and coordinating basic biotech research as input for further pharmaceutical R&D by company units elsewhere. To the extent that the U.S.-located subsidiary record and report fees for their R&D services to affiliated units overseas, such transactions are aggregated in cross-border transactions such as those captured in public U.S. balance of payment statistics studied here. Fees charged for R&D services to unaffiliated overseas customers by R&D

performing subsidiaries are also part of total transactions in R&D services. See Arora et al. (2002) for examples in ‘markets for technology’ among unaffiliated parties (e.g. licensing of chemical products and manufacturing processes, and specialized engineering firms offering technical services).

International Trade Theory, MNCs, and Technology Flows

Traditional trade theory developed in general-equilibrium settings did not accommodate MNCs (Markusen & Venables, 1998). In traditional trade theory, comparative advantages in the production of homogenous goods are determined either by exogenous differences in technologies (Ricardo) or in factor endowments (Hecksher-Ohlin). According to the latter approach, countries produce and export the good intensive in the factor abundant in the home country, resulting in trade across industries. Factors (including technology!) are immobile across countries in a macroeconomic setting of exogenous technology, constant returns to scale (CRTS), and perfect competition. This model is inconsistent both with disembodied technology trade and with the presence of MNCs which imply monopoly power and firm-specific advantages.

New trade theories (Krugman, 1991; Markusen, 1995) move away from constant returns to scale and exogenous technology. The approach incorporates economies of scale both internal to the firm (at the plant or at the corporate level as in internal R&D) and external to the firm in the form of, for example, knowledge spillovers at the industry level (learning by doing; benefits from other companies' R&D or from public research). In these models, internal increasing returns to scale (IRTS) for differentiated products yield intra-industry trade among countries even if they have similar endowments.

In Krugman's framework, MNCs are formally introduced using firm-level economies of scale from a joint input such as headquarter services, marketing services, or R&D (chapter 12 in Helpman & Krugman, 1985). Thus technology is now endogenous in an integrated trade/MNC macro model.[8] On the other hand, according to Ietto-Gillies (2012), Krugman's 'joint input' approach to introduce horizontal FDI and MNCs result more precisely in multiplant firms that may still be inter-regional, not necessarily inter-national since country borders (and associated costs and opportunities) are absent from his models.[9] (Internalization theory of MNCs, discussed below, addresses some of these concerns.) Nevertheless, for the purposes of the present study Helpman and Krugman's (1985) key contribution is that their approach accounts for intra-MNC trade in the form of 'trade in invisibles'. In particular, in their two-country model there is one-way FDI (headquarter services [or R&D], a capital intensive good, is produced in only one country that becomes the only parent country in the model), leading to one-way trade in the firm-specific intangible. This result is formally similar to asset exploiting FDI in Dunning, and like the latter, does not account for the possibility of subsidiary R&D that may benefit the parent or subsidiaries located in third countries (so that trade in intangibles is only one-way).

Further, in Krugman macro trade-FDI models that allow two-way FDI (when both countries developed and produce the joint input [R&D]), the resulting trade in intangibles is one-way within each type of MNC (home-based MNC and foreign-based MNC) as long as only MNC parents (and not their subsidiaries) engage in R&D. In this case each parent would be sharing internally their own R&D with their affiliates outside their

[8] Knowledge production is also endogenous in contemporaneous and subsequent theories of the firm from microeconomic and management/strategic perspectives, e.g., knowledge-based, technology-based, and resource-based theories of the firm (Grant, 1996; Granstrand, 1998; Wernerfelt, 1984). However, these theories were effectively developed with a domestic focus and had no formal links with macroeconomic or country level theories of FDI and trade.

[9] Indeed, Helpman and Krugman (1985) ultimately need to appeal to factor price equalization (via production costs minimization) to actually yield production outside the home country – apparently without using their initial joint input argument (see figure 12.2 and related text in Helpman & Krugman, 1985).

borders. In the aggregate, however, one would observe both home exports of R&D services (but only from home-based MNCs) and home imports of R&D services (but only involving foreign-based MNCs). Thus, we would observe two-way aggregate R&D services trade but only traditional knowledge transfer (one-way parent to subsidiary flow).

Therefore, the present study suggests that for aggregate trade in R&D services to reflect reverse knowledge transfer a necessary and sufficient condition is the existence of subsidiaries that perform R&D for the benefit of the whole MNC, even if FDI is only one-way (i.e., only one of the two countries is an MNC parent country). In this scenario, home-based MNCs not only export (to exploit) but also import (to learn). To be sure, even if a foreign subsidiary performs R&D, this may be of adaptive character or for new local products, so the potential to benefit other MNC members is important for identifying reverse knowledge transfer whether the setting is one-way or two-way FDI. As an example of reverse knowledge transfer, a U.S.-owned affiliate located in Canada may perform research in materials engineering as input for further R&D by the MNC parent and also perhaps by units elsewhere (see also Box 1 earlier in this chapter). In international trade statistics, reported fees received by the affiliate from the U.S. MNC parent for R&D outcomes are measured as U.S. R&D services imports.

Transaction costs, Innovation Theory, and Knowledge Flows

Internalization theory of MNCs and market failures in knowledge transfer

Transactions in disembodied technology and other forms of industrial knowledge are likely to suffer from severe market failures associated with the difficulty in appropriating and protecting information and other forms of public goods (Arrow, 1962).[10] Indeed, Coase theory of the firm and subsequent industrial organization approaches [IO] (Williamson & Winter, 1991) posit the existence of firms as the result of minimizing transactions and coordination costs –often proxied by geographic distance – by internalizing some activities within an organization (Davidson & McFetridge, 1984). In turn, the internalization theory of MNCs applies Coase's transaction costs theory to international modes of entry (e.g. exports vs. unaffiliated licensing vs. FDI) and emphasizes the need to internalize knowledge production and exploitation when companies engage in international activities (Buckley & Casson, 1976; Hennart, 1982; Rugman, 1981).[11] Even within MNCs, however, transferring complex technologies and intermediate inputs is still costly and transfer costs can vary across recipient host countries and industries (e.g., Keller & Yeaple, 2008; Markusen, 2002; Teece, 1977). For our purposes, the important insight from the internalization theory is that most trade in

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[10] Public goods are said to be non-excludable: so that others are able to use it without consent or compensation to owners) and non-rivalrous: consumption by some do not preclude consumption by others (Foray, 2004). Either property creates difficulties for appropriating benefits and for open market exchanges.
[11] See Ethier (1986) for an international trade model where internalization is endogenous in a general equilibrium framework that incorporates FDI.

disembodied technology should be within MNCs, with little arms-length or unaffiliated transactions.

On the other hand, according to innovation theory not all forms of industrial technological knowledge or information (or public goods more generally) suffer equally from market failures. Disembodied technology or knowledge may be tacit, as in informal exchanges of ideas, or codified in manuals, licenses, and patents. Codification of knowledge facilitates market transactions (Foray, 2004, p. 74). Tools such as information/communication technologies (ICT) and electronic media increase the codifiability of knowledge, raise the value of codified knowledge, and reduce transaction and communication costs (Andersen & Foss, 2005; Foray, 2004, p. 86). Conversely, tacit knowledge is said to be highly localized, 'sticky', and difficult (costly) to transfer especially across distant locations or outside organizational boundaries, compared to codified knowledge (Foray, 2004, pp. 18, 72-76). Thus the presence of tacit knowledge suggests the importance of physical proximity (so that distance acts as a barrier) even in the context of R&D and intangible flows (Castellani, Jimenez Palmero, & Zanfei, 2011; Feldman & Massard, 2002).

Learning and organizational factors

Organizational and social factors may reduce the negative effect of distance emphasized in early studies of economics of knowledge and in transactions costs theory. In particular, a common organizational culture, as in geographically dispersed units of MNCs (Kogut

& Zander, 1993), offset some of the challenges in transferring tacit knowledge thus increasing the efficiency internal transactions. Thus internalization (internal knowledge creation and transfer) not only protects proprietary technology (avoiding negative externalities suggested by transaction costs and internalization theory of MNCs), but also facilitates internal cross-border transfer and learning to the extent that common administrative and managerial tools and corporate norms within MNCs compensate for the difficulties in co-developing and transferring knowledge across borders.

Geography, external sources of knowledge, and knowledge flows

At the country level, innovation theory suggests that external sources of technology, aided by absorptive capacity often proxied by national level resources such as total R&D or patents, can contribute to economic and productivity growth (Keller, 1996; Mendi, 2007; Hall et al. 2010). At the firm level, innovation networks or clusters of independent firms and public research units facilitate exchanges, learning, and spillovers and create agglomeration economies for all types and size of firms (an example of external IRTS emphasized in new trade studies).

To the extent that industrial relevant technological knowledge is ‘location bound’ or ‘sticky’, MNCs and non-MNCs alike need to reach outside their local units and international borders to access clusters of skills and resources to complement their firm-specific advantages. However, MNCs have advantages in terms of sourcing from external sources across borders since their overseas affiliates are able to establish longer term relationships with local external environments facilitating interaction, monitoring, and transferring external knowledge, as studied by the subsidiary embeddedness literature (e.g., Andersson et al., 2001) from international business research and work on outward FDI spillovers (e.g., Branstetter, 2006) from the literature of international technology diffusion. (See Rugman & Verbeke (1993) and Dunning (1998) for early expositions of these ideas from the perspective of FDI strategies and MNC activities. On outward FDI spillovers see also discussion in Blomstrom & Kokko (1998, pp. 5-7, 24-25) and Keller (2010, pp. 810, 813-816).) In turn, these local relationships can generate 'location-bound' firm-specific advantages cited earlier, resulting in more frequent or valuable knowledge flows within MNCs. In this study capabilities external to MNCs associated with host or parent countries are controlled for using national level S&T variables.

In sum, several geographic factors affect intangibles trade and FDI. S&T country endowments should positively affect both outflows and inflows of knowledge. On the other hand, geographic distance may negatively affect the exchange of intangibles according to the transactions costs, internalization, and innovation literatures, though the effect is subject to mediating factors including the presence of codified knowledge and organizational factors that benefit cross-border learning within MNCs.

Technology Balance of Payments Studies

R&D services examined in this study are part of what the OECD calls "technology balance of payments" (TBP), a term first mentioned in an early publication on international comparisons in R&D (Freeman & Young, 1965). TBP is published by the

OECD as a single aggregate for each member country compiled from four items (OECD 2005): sales or licenses of patented/unpatented inventions; transfers of designs and trademarks; provision of technical services (computer, engineering, and R&D services); and industrial R&D.

Transactions recorded in balance of payment (BOP) surveys as a proxy for disembodied technology flows have been examined by relatively few country level and policy studies (Madeuf, 1984; Mendi, 2007; Organisation for Economic Co-operation and Development (OECD), 2009; World Intellectual Property Organization (WIPO), 2011). On the other hand, royalties and license fees, especially at the firm level, have been studied for decades, both domestically in IO research, and as a strategy of entry into foreign markets alongside FDI and manufacturing exports in international business and economics. (See Davidson & McFetridge (1984; 1985), Davis (1977), and more recently Hovhannisyan (2012), Robbins (2009), and Vishwasrao (2007).) This section briefly describes previous work on TBP (either aggregate or for selected components), which has focused mostly on distance and intellectual property rights (IPR) issues, whereas one study explored the role of financial FDI flows, as discussed next.

Bascavusoglu-moreau and Athreye (2009) used UK balance of payments data for computer services, R&D services, and royalties and licenses fees in a gravity equation. The paper studied the impact of distance as a proxy for transfer costs in separate exports and import equations for each service type as dependent variables. Their econometric specification was an augmented gravity equation with UK and partner country GDP, different distance measures using the CAGE approach (Cultural, Administrative/political, Geographic, and Economic distance) as explanatory variables (same explanatory variables across equations), and technological capacity controls (USPTO patents) estimated using random effects (baseline) and fixed effects (with no distance variables).

In Bascavusoglu-moreau and Athreye (2009), IPR rights were measured as a 'distance' variable relative to UK scores, by itself and in interaction with partner GDP. For R&D services, IPR rights variable had a statistically significant negative sign (except in one random effects equation). A negative sign implied that 'countries with similar IPR regimes are preferred partners with UK technology services' (p. 17). The authors speculated IPR rights matter more for unaffiliated than for affiliated transactions (p. 18) citing earlier research on patent licensing to third parties. Technological capacity was positive and statistically significant for R&D services imports and insignificant in random effects export equations.

Zuniga and Bascavusoglu-moreau (2003) studied total TBP receipts (exports) by French companies from OECD countries (aggregate, not by TBP component) to assess the role of IP protection, controlling for several factors including trading partner R&D intensity at the industry level (business R&D/production), patent output, human capital, merchandise trade relative to GDP, and GDP. They found that patent rights matter for TBP exports to countries with high technological capacity and market size, but not for exports to low-income countries.

Mendi (2001, chapter 2) applied financial measures of foreign direct investment (FDI) to total (not bilateral) TBP imports by OECD countries (aggregate, not by TBP component) as compiled and published by the OECD. One of Mendi's equations regressed a country-level panel of total net TBP exports (ratio of exports to imports) to countries R&D to GDP ratio, inward FDI stock relative to GDP, and inward FDI stock relative to GDP (all in logs) using OLS with country fixed effects. (R&D used in Mendi's model referred to national totals.) A separate model accounted for co-integration in the 14-year panel applied separately to TBP exports and TBP imports. In all equations, the R&D to GDP ratio was a positive and statistically significant factor in TBP flows, confirming one of his main hypotheses. Inward and outward FDI had different signs and statistical significance across several models.

The link between financial FDI flows and technology transfer has been made earlier in the context of diffusion of embodied technology (Hirschey & Caves, 1981; Mansfield & Romeo, 1980) and in the spillovers approach to international technology diffusion (see references on FDI spillovers and related literature in footnote 3). Mendi (2001) macroeconomics research introduced financial flows of FDI in studies of market-based flows of disembodied technology, using a measure of total TBP trade. The present study considers the link of FDI and intangibles trade from the perspective of the operations of MNC subsidiaries and strategies of FDI in R&D. The next section summarizes the conceptual approach.

Conceptual Framework

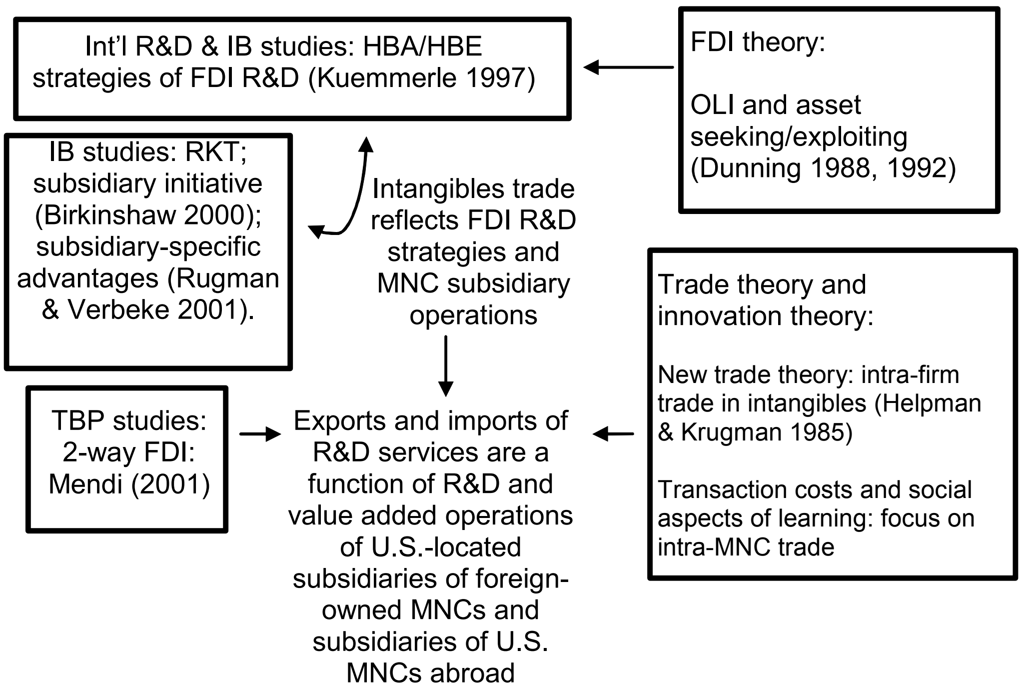
This study combines macro and micro theoretical perspectives from traditional and new trade theory (two-way trade/FDI and intra-firm trade), international business, and R&D strategies to explain country-level trade in intangibles. The literature review suggests that intangibles trade reflects FDI R&D strategies and MNC subsidiary operations (see Figure 2-1 and Table 2-1). In particular, it is argued here that the increased role of subsidiaries within MNC networks as source of knowledge (Birkinshaw, 1998; Frost et al., 2002; Kuemmerle, 1999; Rugman & Verbeke, 2001) imply testable hypotheses on the nature and direction of *aggregate* cross-border flows of disembodied technology. Thus MNC subsidiary operations and country level factors from macro trade and innovation theories should be considered jointly in explaining trade in R&D and other intellectual property products (as further discussed in the methodology chapter 3 and implemented empirically in chapter 4).

The empirical implementation of this framework adapts Kuemmerle's use of host country R&D to identify home-base augmenting FDI and host market size (GDP or value added) to identify home-base exploiting FDI by focusing not on national levels of these variables but on operations of MNC subsidiaries suggested by more recent international business theory on the strategic importance of subsidiaries in innovation (Birkinshaw, 2000; Rugman & Verbeke, 2001).[12] Further, the presence of *two-way FDI in R&D*, where a given country is both home to MNCs and host to foreign MNCs that perform R&D, is

[12] A related use of firm value added to identify adaptive R&D (term used in earlier FDI literature related to Kuemmerle's home-base exploiting) appeared in Fors (1998). Fors (1998, p. 127) uses the share of firm-level value added relative to industry value added to test for adaptive R&D as a motive for locating R&D abroad.

incorporated here by exploring the specific effects of *sub-national aggregates* of MNC subsidiary activity (based on ownership and location), something not explored in prior work on country-level disembodied technology flows. Thus in this study the U.S. and any given partner country are both exporters/importers of intangibles and host/home countries of R&D performing subsidiaries (reflecting two-way trade and two-way FDI in R&D shown in the hypothesized model summarized in figure 3-6). Econometrically, these considerations were implemented by pairing *observed heterogeneity* in the geographic structure of bilateral trade in R&D services with the geographic structure of operations of the two types of MNC subsidiaries. Estimation of the preferred 'MNC-trade model' (see chapter 4) controls for unobservable characteristics by a mixed linear panel model with both random intercepts and random coefficients for the MNC R&D variables.

Figure 2-1 Relationship across theories relevant for intra-MNC intangibles trade



FDI Foreign direct investment; HBA Home-base augmenting; HBE Home-base exploiting; IB International Business; OLI Ownership, location, internalization; RKT Reverse knowledge transfer; TBP Technology Balance of Payments

Table 2-1. Theories Relevant for Knowledge Transfer involving MNCs

Theories of FDI/MNCs and Trade	**Innovation, R&D, and MNC strategies**	***Implications for intra-MNC Transactions in Disembodied Technology***
1960s, 1970s		
Firm-specific advantages (FSA)(Hymer 1960/1976) or ownership advantages (Dunning, 1981) exploited abroad; host country-specific advantages (CSA) or location advantages; FSAs and CSAs are independent Dunning's OLI [O] ownership, [L]location, [I] internalization (1988, 1992, 2008): [O] Home countries as source of FSA or ownership advantages. [L] Location advantages (host countries) focus on exploiting objectives (low production costs; large markets). [I] Protection of firm-specific advantage (later expanded with transaction costs approach: see next cell). Vernon product life cycle model (macro model of FDI, trade, and technology diffusion) (Vernon, 1966): R&D & production at home; exploitation abroad first with exports, then FDI	Centralized R&D; overseas technology exploitation by product adaptation (Ronstadt, 1978; Terpstra, 1977) Asset exploiting FDI (Dunning 1981, 1988)	Traditional knowledge transfer (TKT) TKT is associated in this study with Dunning's asset seeking and Kuemmerle's (1999) home-base exploiting (HBE) Direction: Traditional vertical flow from parent to subsidiary or from 'North' to 'South' countries (macroeconomic models Helpman, 1984; Brainard, 1997) Content and timing of knowledge flows/diffusion: - Transfer of capabilities (knowhow, managerial) - Transfer of mature, embedded technology toward the end of the innovation cycle: intermediate and capital goods, technology blueprints, licenses
1980s		
Internalization/Transaction Costs applied to MNCs: [I] Internalization advantage: internal creation/exploitation of knowledge addresses market failure for intangibles across borders; reduction of TCs and coordination costs (Buckley & Casson, 1976; Hennart, 1982; Rugman, 1981) New trade theory: endogenous technology as source of IRTS and imperfect competition (Helpman, 1984).	Centralized basic research; dispersed adaptive R&D (Reddy, 2000; von Zedtwitz & Gassmann, 2002) Asset seeking FDI (Dunning 1988) – FDI to secure strategic inputs (including but not limited to technology, e.g. mineral deposits; oil reserves).	Centralized internal market for research: focus remains on one-way transactions (traditional knowledge transfer, HBE).

Table 2-1. Theories Relevant for Knowledge Transfer involving MNCs (continued)

Theories of FDI/MNCs and Trade	**Innovation, R&D, and MNC strategies**	***Implications for intra-MNC Transactions in Disembodied Technology***
1990s-present		
New trade theory: endogenous technology in an integrated trade/MNC macro model; intra-firm two-way trade (Helpman & Krugman, 1985: chapter 12). Resource and knowledge-based views of firms/MNCs and strategic management: purposive creation of competences/capabilities that are difficult to imitate (Grant, 1996; Granstrand, 1998; Wernerfelt, 1984). MNCs as networks; Differentiated MNC (Bartlett & Ghoshal, 1989; Gupta & Govindarajan, 2000) Double networks, double diamonds (Rugman & Verbeke, 1993) FSAs and CSAs are mutually endogenous → location-bound FSAs developed abroad for the whole MNC (Rugman & Verbeke, 2001; Rugman et al. 2011) Subsidiary initiative (Birkinshaw, 1998, 2000) Subsidiary-specific advantages (SSAs) (Rugman & Verbeke, 2001).	Two-way FDI in R&D among advanced countries (macroeconomic studies: Helpman & Krugman, 1985; Markusen, 2002; microeconomic studies: Dunning and Narula 1995; Florida & Martin, 1994; Serapio & Dalton, 1999; Von Zedtwitz, 2004) Collaborative, distributed R&D on global scale; 'cross-border innovation' (Zander & Sölvell, 2000): internal and external collaboration, networks Host location as source of competitive advantage; host location diamond interacts with home country diamond by means of MNC subsidiaries and their partners (interaction of internal and external networks) Knowledge seeking and home-base augmenting (HBA) FDI (Fors, 1998; Kuemmerle, 1999) Subsidiaries as source of MNC-wide learning and innovation (Birkinshaw, 2000).	Reverse knowledge transfer (RKT) Direction: Firm level/ international business studies: from subsidiaries to parent companies (reverse vertical flows) or from subsidiary to subsidiary (lateral or horizontal flows) Macro studies – contemplate multilateral flows: not just North to South (UNCTAD, 2005 & 2013; WIPO, 2011) Content and timing of knowledge flows/diffusion: Intra-MNC flows earlier in the innovation process (Zanfei, 2000). Collaborative R&D inside the MNC network at all levels of innovation chain implies knowledge flows in all directions. Implications for macro indicators of intangibles trade: two-way FDI R&D and two-way trade of intangibles reflect a combination of R&D strategies – asset exploiting/traditional knowledge transfer (HBE) and strategic asset augmenting/RKT (HBA) strategies involving both home-based and foreign MNCs.

Conclusion

This chapter reviewed the literature relevant to explain trade in intangibles and developed a conceptual framework to be empirically tested. Studies on reverse knowledge transfer and overseas R&D strategies at the project and company level suggest that FDI in R&D should impact country-level cross-border disembodied knowledge flows. The present research applies this insight to market-based measures of disembodied technology flows captured in balance of payment statistics, as described in the next chapter.

Chapter 3: Methodology

Introduction

This chapter describes variables and data sources, describes econometric specifications, and discusses threats to validity. The first section describes dependent and explanatory variables and data sources. The second section presents a descriptive analysis of major trends in the dependent variables and key explanatory variables. The third section describes the hypotheses to be tested, followed by a section on control variables. Econometric specification is discussed in fifth section, followed by a section on panel estimation. The seventh section discusses in detail potential threats to the validity of research findings, followed by a concluding section.

Main Variables and Data Sources

Table 3-1 at the end of this section defines variables, and presents information on units and data sources. Table 3-2 (provided in Appendix) shows pairwise correlations. The dependent variables of interest are U.S. bilateral exports and imports of R&D and testing services (RDT), called "R&D services" in this study.[13] The main explanatory variables are subsidiary level aggregates of MNCs R&D and production operations (measured as value added) by investing or host country. The main data sources are the U.S. Bureau of Economic Analysis services trade survey covering intangibles and FDI surveys. The

[13] The term 'R&D services' has two different meanings in international statistical manuals. The first refers to the provision or acquisition of customized and non-customized or speculative R&D (Moris, 2009; UN et al. 2011 [2010 MSITS]; OECD 2010). This thesis uses 'R&D services' term in this sense. The second meaning refers to income/payments from the sale or license of R&D assets (UN et al. 2009 [2008 SNA]; IMF, 2009 [BPM6]; UNECE/OECD, 2014). For a detailed discussion see "R&D globalisation" chapter in the upcoming version of the OECD Frascati Manual (OECD, 2015).

former covers bilateral international transactions in services and intellectual property; the latter cover activities or operations of MNC subsidiaries (U.S. affiliates of foreign MNCs and overseas affiliates of U.S. MNCs) from separate FDI surveys. National-level statistics were obtained from OECD, World Bank, and Penn World Tables (PWT 7.1) databases. Bilateral data for total U.S. international transactions in R&D services (affiliated and unaffiliated) are available from 2006 to 2011 for 24 countries that include G7 countries, small high-income countries, and several emerging markets: Argentina, Australia, Belgium-Luxembourg, Canada, Chile, China, France, Germany, Ireland, Israel, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, United Kingdom.[14]

R&D and testing services (RDT) trade is one of several forms of trade in disembodied technology intangibles or intellectual property products in the balance of payments. RDT belongs to the broad category of business, professional, and technical services (BPT) (Table 3-3).[15] BPT includes management and consulting services and computer and information services. In 2011 RDT services accounted for 17% of U.S. BPT exports and 30% of BPT imports.

Another broad category of intangibles trade is royalties and license fees, sale/purchases and licensing for the right to use industrial property (industrial patents) (Table 3-4). This category also includes other forms of intellectual property such as trademarks and

[14] However, as noted in the discussion around table 4-1 in chapter 4, some countries are not included in the final model due to data limitations for some explanatory variables or controls.
[15] 'Testing services' may have both R&D and non-R&D components (e.g., routine quality testing in manufacturing). However, statistics on testing services were not separately available.

ownership/use rights for books, records, and films. (See Robbins (2009) for a detailed analysis of statistics for intellectual property payments.)[16] Within royalties and license fees, fees for industrial products are typically deemed to be closely related to scientific and technological activities. Royalties and license fees for industrial products have been studied by the economics of innovation and technology diffusion discussed earlier, though many countries do not separate out these fees from total royalties and license fees.

RDT services and industrial processes royalties and license fees share two characteristics based on 2011 summary statistics: the U.S. is a net exporter of both forms of disembodied technology, and affiliated transactions represent more than 2/3 of trade in each of them. Though a formal comparison across these two forms of intangibles is outside the scope of the present research, RDT services is likely to be more related to ongoing R&D (especially RDT exports), whereas patent licensing may include transactions in both new and relatively mature technology. R&D transactions are also likely to be concentrated in high-technology (R&D-intensive) industries or companies, whereas patent licensing (especially purchases or imports) is likely to be more broadly distributed across all industrial sectors. However, statistics on intangibles trade are not available by industry classification of respondents. See table 4.5 in Robbins (2009) for a distribution by broad industrial sector for royalties and license fees from unaffiliated companies. The rest of this discussion focuses on trade in RDT services.

[16] For recent U.S. domestic data on license and royalty fees income at the enterprise level see https://www.census.gov/econ/esp/.

It is important to note that while total RDT transactions are available for both U.S. MNCs and U.S.-located subsidiaries of foreign MNCs, bilateral country transactions with the U.S. are available only as the aggregate of affiliated and unaffiliated transactions.[17] Nevertheless, aggregate transactions are bound to reflect the larger of these two major transactions types, affiliated flows. Further, unaffiliated transactions also occur between members of separate MNCs or between an MNC and an independent company. Therefore, MNCs operations are also likely to be a significant driver of the unaffiliated portion of total transactions.

[17] For a description of U.S. goods and services trade by MNCs see BEA (2012).

Table 3-1 Description and sources of variables
All variables, except dummies, are in natural logs.

Variables	Definition	Units	Source
Dependent variables			
U.S. RDT exports	R&D and testing services exports	millcurrUS$	BEA Transactions survey
U.S. RDT imports	R&D and testing services imports	millcurrUS$	BEA Transactions survey
Explanatory variables			
RDFDIUS	stocks of R&D performed by MOUSAs	millcurrUS$	BEA FDIUS survey
VAFDIUS	Valued Added by MOUSAs	millcurrUS$	BEA FDIUS survey
RDMOFA	stocks of R&D performed by MOFAS	millcurrUS$	BEA USDIA survey
VAMOFA	Valued Added by MOFAs	millcurrUS$	BEA USDIA survey
Control variables			
BERD excluding RDMOFA	Business expenditures on R&D minus RDMOFA	millcurrUS$	OECDStat
U.S. BERD excluding RDFDIUS	Business expenditures on R&D minus RDFDIUS	millcurrUS$	OECDStat
USPTO	Fractional count of number of USPTO granted utility patents by issue year & foreign inventor country	Count	USPTO
sepapers	Journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) relative to U.S.	Count	Thomson Reuters, SCI and SSCI
corporate tax distance = (log of corptax (USA/country))	corporate tax ratio (USA/partner country), where corporate tax = combined central/sub-central government corporate income tax	Percent	OECD Tax Database
Distance	Geographic distance (dyadic geodesic distance) relative to U.S.	Km	CEPII
dummy contiguous country	dummy	1,0	CEPII
dummy English language	dummy	1,0	CEPII
GDP	GDP for partner country	mill PPP$	World Bank
USA GDP	USA GDP	mill PPP$	World Bank
trade openness	trade/GDP (%)	Percent	Penn World Tables (PWT 7.1)
R&D/GDP	R&D/GDP	Percent	BEA and World Bank
inward FDI/GDP	inward FDI/GDP	Percent	BEA and World Bank
outward FDI/GDP	outward FDI/GDP	Percent	BEA and World Bank

Table 3-2. Correlation coefficients. Please see last page in Appendix.

Table 3-3 U.S. trade in Business, Professional, and Technical Services, 2011
Millions of current U.S. dollars

	Total BPT services	Management, consulting, and PR	R&D and testing services	Computer and information services	Operational leasing	Other
			Exports			
Total	134,416	32,169	23,364	15,501	7,142	56,240
Unaffiliated	66,280	3,659	2,954	10,000	5,216	44,452
Affiliated	68,136	28,510	20,410	5,501	1,926	11,788
			Imports			
Total	104,773	24,823	22,360	24,538	1,922	31,130
Unaffiliated	30,173	3,453	3,922	4,671	404	17,724
Affiliated	74,600	21,370	18,438	19,867	1,518	13,406
			Trade balance			
Total	29,643	7,346	1,004	-9,037	5,220	25,110
Unaffiliated	36,107	206	-968	5,329	4,812	26,728
Affiliated	-6,464	7,140	1,972	-14,366	408	-1,618
			Shares by affiliation (%)			
	Exports					
Total	100.0	100.0	100.0	100.0	100.0	100.0
Unaffiliated	49.3	11.4	12.6	64.5	73.0	79.0
Affiliated	50.7	88.6	87.4	35.5	27.0	21.0
	Imports					
Total	100.0	100.0	100.0	100.0	100.0	100.0
Unaffiliated	28.8	13.9	17.5	19.0	21.0	56.9
Affiliated	71.2	86.1	82.5	81.0	79.0	43.1
			Shares by services type (%)			
	Exports					
Total	100.0	23.9	17.4	11.5	5.3	41.8
	Imports					
Total	100.0	41.8	30.0	8.1	2.8	17.3

BPT = Business, Professional, and Technical; PR = Public relations
Source: Author's calculations based on BEA's Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Table 3-4 U.S. trade in Royalties and License Fees, 2011
Millions of current U.S. dollars

	Total	Industrial processes	Other
	Exports		
Total	120,836	43,952	76,884
Unaffiliated	43,757	12,076	31,681
Affiliated	77,079	31,876	45,203
	Imports		
Total	36,620	22,633	13,987
Unaffiliated	10,405	7,432	2,973
Affiliated	26,215	15,201	11,014
	Trade balance		
Total	84,216	21,319	62,897
Unaffiliated	33,352	4,644	28,708
Affiliated	50,864	16,675	34,189
	Shares by affiliation (%)		
	Exports		
Total	100	100	100
Unaffiliated	36.2	27.5	41.2
Affiliated	63.8	72.5	58.8
	Imports		
Total	100.0	100.0	100.0
Unaffiliated	28.4	32.8	21.3
Affiliated	71.6	67.2	78.7
	Shares by services type (%)		
	Exports		
Total	100.0	36.4	63.6
	Imports		
Total	100.0	61.8	38.2

Source: Author's calculations based on BEA's Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Descriptive Analysis of U.S. Trade in R&D Services

In 2011, U.S. exports of R&D services were $23.4 billion and imports reached $22.4 billion, for net exports of one billion US$. By comparison, 2011 business R&D performed in the U.S. was in the order of $294 billion. Thus, BOP-based transactions in R&D services (RDT) represent less than 10% of R&D performance (or 'R&D production'). Of course, this order of magnitude comparison is only illustrative since services may be related to prior year R&D, hence empirical specifications below use R&D stocks. Nevertheless, the observation on the relative size of R&D production and R&D services trade is consistent with the fact that services are typically less tradeable compared with manufactured goods. Knowledge-related intangibles have additional market failures (discussed above) that preclude widespread open market activity. At the same time, however, some MNCs groups show a higher share of R&D services transactions activity relative to R&D performance compared to the share computed for all businesses, as discussed next.

More than 85% of annual RDT exports and at least 75% of annual RDT imports reflect affiliated transactions between 2006 and 2011 (Table 3-5). Affiliated transactions were not only larger but exhibited positive net exports, averaging $2.9 billion in net RDT exports over the sample period. Unaffiliated transactions exhibited negative net exports (averaging $900 million annually in current U.S. dollars) over the same period. Within affiliated transactions of R&D services, net exports were driven by U.S. affiliates of foreign MNCs (see Table 3-6 and Figure 3-1). This is notable since total RDT trade within U.S. MNCs is somewhat larger than that of U.S. affiliates of foreign MNCs. In spite of the apparent importance of MNCs in transactions in intangibles, previous studies on TBP or its components have not considered the operations of MNC subsidiaries as explanatory variables.

Between 2006 and 2011, annual exports of R&D services by U.S. affiliates (subsidiaries of foreign MNCs in the U.S.) grew faster than their annual R&D performance in the U.S.

(7% average annual growth rate vs. 4%, respectively) (both measured in nominal terms). Further, U.S. affiliates had a higher rate of RDT exports relative to their R&D performance compared both with the aggregate of all U.S. R&D-performing business and with parent of U.S. MNCs (see Table 3-7 and Moris, 2009). The relatively large RDT exports by subsidiaries of foreign MNCs located in the U.S. is consistent with knowledge seeking FDI strategies and 'reverse knowledge transfer' discussed in previous chapters. U.S.-located companies export on average over $2 billion of these services to companies located in Ireland ($2.5 billion), Switzerland ($2.5 billion) and Japan ($2.1 billion) (Figure 3-2). The UK ($2.4 billion) and Canada ($1.4 billion) are the top RDT importing countries.

It is also useful to briefly consider the country distribution of R&D performed (measured as R&D stocks) by the two groupings of MNC subsidiaries. The United Kingdom and Germany stand out as having annual R&D stock averages of more than $30 billion both as host countries of U.S. MOFAs R&D and also as investor countries in FDI R&D in the U.S., based on separate FDI surveys from the Bureau of Economic Analysis (BEA). Switzerland, France, and Japan are the next largest FDI in R&D investor countries in the U.S., whereas Canada hosts the third largest R&D stocks by U.S. MNC subsidiaries (Figure 3-3).

Figure 3-4 shows the much larger means of annual value added levels over the sample period, with UK and Canada as the largest host of U.S. FDI by this measure. Figure 3-5 shows an R&D intensity measure, R&D performance divided by value added for both types of MNC subsidiaries, showing Israel by far the most R&D intensive host location, followed by Sweden. On the other hand, U.S.-located subsidiaries owned by Switzerland, Israel, and Taiwan MNC parent companies are the most R&D intensive by this measure. The next section draws from the literatures on FDI strategies in R&D, trade, and economics of knowledge to develop hypotheses on the role of MNC operations on observed trade in R&D services.

Table 3-5 U.S. trade in R&D and testing (RDT) services, 2006-2011
Millions of current U.S. dollars

		Affiliated	Unaffiliated	Affiliated share (%)
	Exports			
2006	12,810	11,146	1,664	87
2007	15,625	13,373	2,252	86
2008	17,345	14,498	2,848	84
2009	18,136	15,837	2,298	87
2010	21,385	18,369	3,016	86
2011	23,364	20,410	2,954	87
average	18,111	15,606	2,505	86
	Imports			
2006	9,276	6,953	2,324	75
2007	13,032	9,772	3,260	75
2008	16,322	12,546	3,776	77
2009	16,641	12,971	3,670	78
2010	18,927	15,395	3,532	81
2011	22,360	18,438	3,922	82
average	16,093	12,679	3,414	78
	Net exports			
2006	3,534	4,193	-660	na
2007	2,593	3,601	-1,008	na
2008	1,023	1,952	-928	na
2009	1,495	2,866	-1,372	na
2010	2,458	2,974	-516	na
2011	1,004	1,972	-968	na
average	2,018	2,926	-909	na

na Not applicable

Source: Author's calculations based on BEA’s Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Table 3-6 Affiliated trade in U.S. R&D and testing (RDT) services, 2006-2011

Billions of current U.S. dollars

	Total Affiliated transactions			
	Exports	Imports	Net exports	Total trade
2006	11.1	7.0	4.2	18.1
2007	13.4	9.8	3.6	23.1
2008	14.5	12.5	2.0	27.0
2009	15.8	13.0	2.9	28.8
2010	18.4	15.4	3.0	33.8
2011	20.4	18.4	2.0	38.8

	By U.S. MNC parents from/to their foreign affiliates			
	Exports	Imports	Net exports	Total trade
2006	4.8	5.2	-0.3	10.0
2007	7.6	7.4	0.2	15.1
2008	7.5	9.3	-1.8	16.8
2009	8.8	10.1	-1.3	18.8
2010	10.2	12.3	-2.1	22.5
2011	11.6	15.3	-3.8	26.9

	By U.S. affiliates of foreign MNCs from/to their foreign parent groups			
	Exports	Imports	Net exports	Total trade
2006	6.3	1.8	4.5	8.1
2007	5.7	2.3	3.4	8.1
2008	7.0	3.2	3.8	10.2
2009	7.1	2.9	4.2	10.0
2010	8.2	3.1	5.1	11.3
2011	8.9	3.1	5.7	12.0

Source: Author's calculations based on BEA’s Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Table 3-7 R&D performance and RDT services trade, 2006-2011
Millions of current U.S. dollars

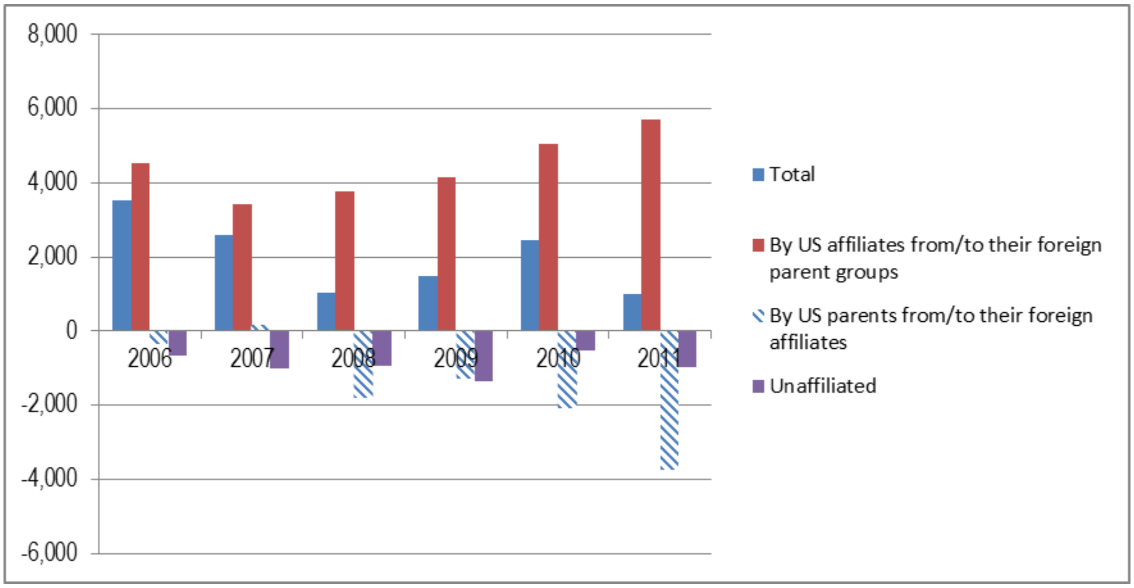
	All U.S.-located companies			U.S. MNCs Parents			Subsidiaries of foreign MNCs*		
	Total RDT Exports	R&D performed	Ratio (%)	RDT Exports	R&D performed	Ratio (%)	RDT Exports	R&D performed	Ratio (%)
2006	12,810	247,669	5.2	4,848	184,428	2.6	6298	34,625	18.2
2007	15,625	269,267	5.8	7,630	203,678	3.7	5743	40,967	14.0
2008	17,345	290,681	6.0	7,501	198,762	3.8	6996	40,727	17.2
2009	18,136	282,393	6.4	8,751	207,297	4.2	7087	40,425	17.5
2010	21,385	278,977	7.7	10,192	212,513	4.8	8177	41,272	19.8
2011	23,364	294,093	7.9	11,557	217,729	5.3	8853	42,119	21.0
Average	18,111	277,180	6.5	8,413	204,068	4.1	7,192	40,023	18.0
AAGR (%)	12.8	3.5	na	19.0	3.4	na	7.0	4.0	na

AAGR average annual growth rate; na Not applicable; RDT Research, development, and testing

* Majority-owned U.S. affiliates of foreign MNCs (MOUSAs)

Sources: Author's calculations based on NSF's Business Research and Development and Innovation Survey and BEA's Survey of U.S. Direct Investment Abroad, Survey of Foreign Direct Investment in the U.S. and Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Figure 3-1 Net exports of U.S. RDT services, by affiliation: 2006-2011 (millions of current US$)



RDT Research, development, and testing
Source: Author's calculations based on BEA's Survey of Transactions in Selected Services and Intellectual Property With Foreign Persons.

Figure 3-2 Mean of U.S. exports and imports of R&D and testing services (RDT): 2006-2011 annual average, by trading partner countries N = 24 countries (millions of current US$)

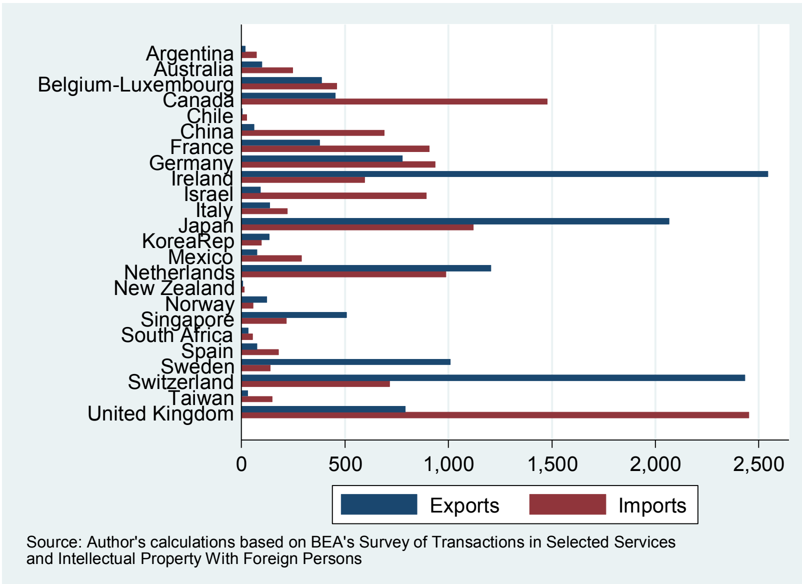


Figure 3-3 Mean of stocks of R&D performed by majority-owned subsidiaries of foreign MNCs in the U.S. (by parent country) and by majority-owned foreign affiliates of U.S. MNCs abroad (by host country): 2006-2011 annual average of stocks (millions of current US$), N=24 countries

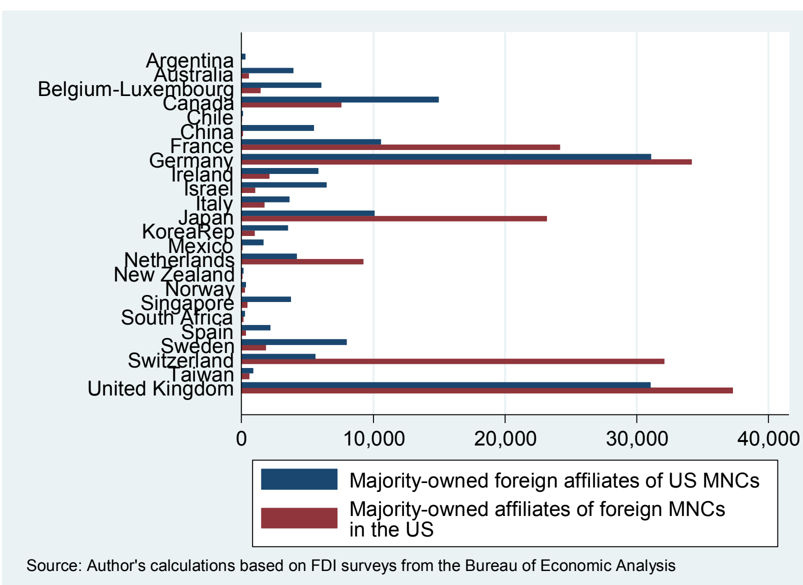


Figure 3-4. Mean of value added by majority-owned subsidiaries of foreign MNCs in the U.S. (by parent country) and by majority-owned foreign affiliates of U.S. MNCs abroad (by host country): 2006-2011 annual average (millions of current US$), N=24 countries

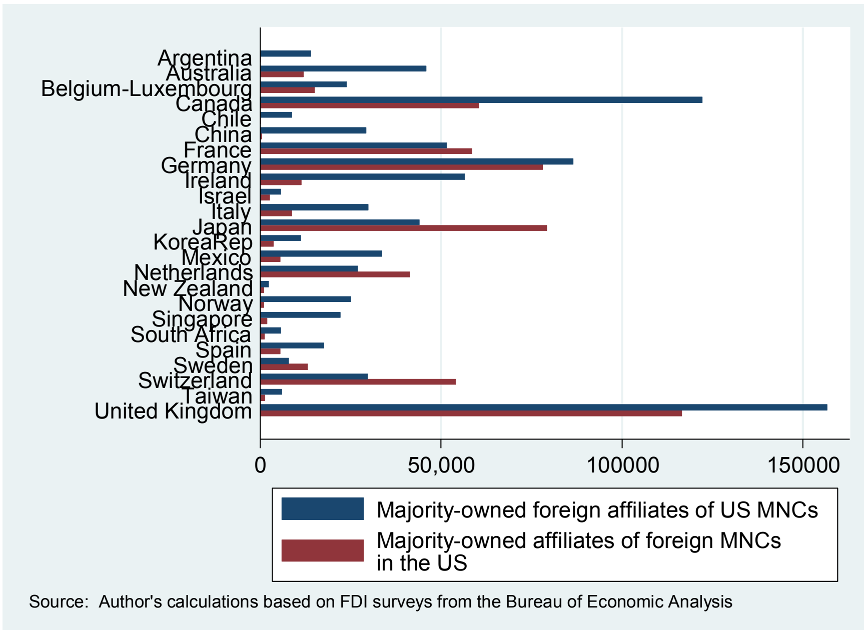
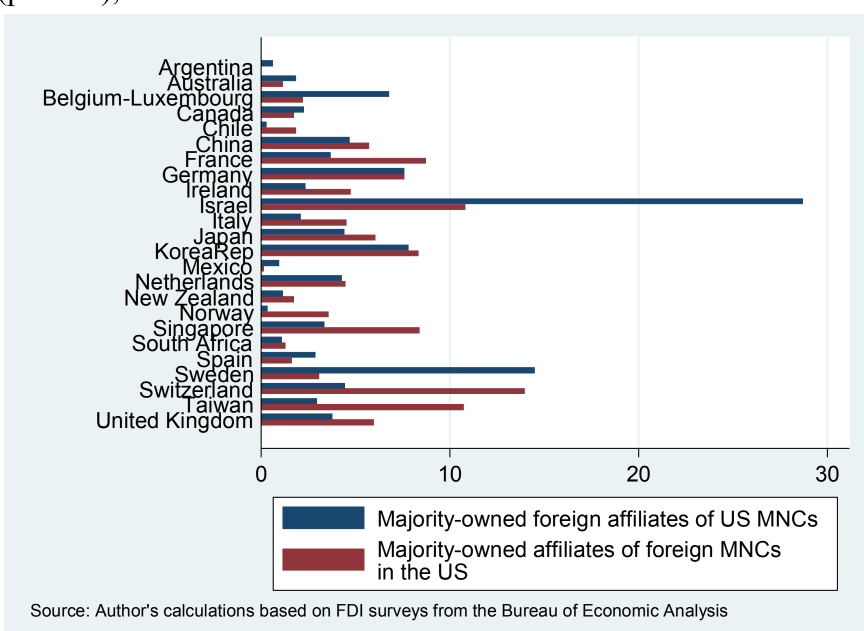


Figure 3-5. Mean of the ratio of R&D performance to value added by majority-owned subsidiaries of foreign MNCs in the U.S. (by parent country) and by majority-owned foreign affiliates of U.S. MNCs abroad (by host country): 2006-2011 annual average (percent), N=24 countries



Hypotheses

This study examines to what extent country-specific FDI in R&D influences the pattern of bilateral cross-border disembodied technology flows. Knowledge exploiting and knowledge seeking strategies are likely to impact these aggregate flows, though not equally across different groupings of MNC subsidiaries (U.S. vs. foreign owned). Thus equations for U.S. RDT services exports and imports need to explicitly control for subsidiary activity of these subsidiary aggregates. Hypotheses 1 and 2a/2b address the influence of U.S. operations of foreign-owned MNCs. Hypotheses 3a/3b and 4 consider the effect of subsidiaries of U.S. MNCs abroad. (Hypotheses 1 and 4 focus on R&D operations; the rest focus on value added or its size effect relative to R&D).

Consider first U.S.-located foreign-owned subsidiaries. The U.S. is of course the largest economy and R&D performer, based on well-known OECD and UN comparative statistics. Thus the U.S. is both a source of global technology and also a large high-income market for innovative products. Studies focused on U.S. R&D operations of Canadian, Japanese, and Swedish owned MNCs have found that a combination of demand factors (e.g. production support) and (technological) supply factors (specialized local R&D or skilled labor), conditional on industrial specialization of subsidiaries, explain inward FDI R&D activities (Granstrand, 1999; Hakanson, 1981; Hakanson & Nobel, 2001; Iwata, Kurokawa, & Fujisue, 2006; Kurokawa et al., 2007; Niosi & Godin, 1999). Further, research on U.S. subsidiaries of foreign MNCs has established that technology sourcing and learning is one of the main objectives of their R&D and innovation activities (Dunning & Narula, 1995; Florida & Martin, 1994; Florida 1997;

Serapio & Dalton, 1999). Thus it is expected that aggregate U.S. RDT services exports are positively related to the stock of U.S. R&D performance by foreign MNC subsidiaries (RDFDIUS).[18] This would imply that exports associated with foreign MNC activity can be characterized as home-based augmenting transactions, representing a form of reverse knowledge transfer (RKT) studied extensively in the international business literature.

Hypothesis 1. U.S. RDT exports are positively related to U.S. R&D performed by subsidiaries of foreign-owned MNCs (RDFDIUS).

For U.S. RDT services imports, the influence of foreign MNCs is likely to reflect home-based exploiting (HBE) motives to the extent that foreign MNCs with U.S. operations are targeting the largest global market with their firm-specific technologies. Thus it is predicted that U.S. RDT services imports are positively related to local (U.S.) production of foreign MNC subsidiaries measured by their value added (VA) (VAFDIUS). The relationship of RDT imports with local R&D performed by foreign MNC subsidiaries, measured as stocks (RDFDIUS), is ambiguous. Even if the motive is knowledge exploitation in the aggregate, imports of R&D services may reflect a complementary (positive) relationship with subsidiary R&D, or be a net substitute for these activities (negative relationship). Thus, the present study does not predict a sign for this variable for RDT imports. However, the study predicts that the size effect of value added in RDT

[18] Hypotheses 1and 4 relating knowledge stocks and the direction of trade at a macro level are consistent with propositions relating knowledge stocks and outflows at the project, subsidiary, or firm level in behavioral, organizational, and strategic management studies of MNCs. See for example Gupta & Govindarajan (2000) and Foss & Pedersen (2002). Apart from differences in level of aggregation, those studies do not typically consider simultaneously foreign-owned subsidiaries vs. home-owned subsidiaries abroad and the possible differences in their R&D strategies.

imports is larger (in absolute value) than the size effect from R&D operations consistent with the expected predominance of HBE motives of imports within this MNC grouping.

Hypothesis 2a. U.S. RDT imports are positively related to U.S. value added by subsidiaries of foreign-owned MNCs (VAFDIUS).

Hypothesis 2b. The size effect in U.S. RDT imports of U.S. value added by subsidiaries of foreign-owned MNCs is larger (in absolute value) than size effect of their U.S. R&D performance.

The rest of the hypotheses focus on the role of overseas subsidiaries of U.S. MNCs in U.S. RDT export and imports. The majority of total U.S. MNCs R&D is still performed in the U.S. (home country) (Table 3-8). Thus it is rather likely that U.S. RDT services exports associated with U.S. MNCs have the character of home-based exploiting (HBE) with a positive relationship to their majority-owned foreign affiliates (MOFAs) value added in host countries (hypothesis 3a).

Table 3-8 Worldwide, U.S., and overseas R&D performance by U.S. MNCs
Millions of current U.S. dollars

				Shares (%)	
	Worldwide R&D by U.S. MNCs	U.S. MNC Parents	MOFAs	U.S. MNC Parents	MOFAs
2004	190,029	164,189	25,840	86.4	13.6
2005	205,251	177,598	27,653	86.5	13.5
2006	214,011	184,428	29,583	86.2	13.8
2007	238,124	203,678	34,446	85.5	14.5
2008	240,461	198,762	41,699	82.7	17.3
2009	246,502	207,297	39,205	84.1	15.9
2010	251,983	212,513	39,470	84.3	15.7

MOFAs majority-owned foreign affiliates
Source: Author's calculations based on BEA's Survey of U.S. Direct Investment Abroad.

On the other hand, U.S. MOFA's R&D (RDMOFA) may be either positively related to U.S. RDT exports to the extent that R&D performed in host countries would complement received R&D services or negatively related if parent R&D (and other U.S.-based knowledge) is overall a substitute to overseas knowledge development. Thus the study does not propose a predicted sign for this variable for RDT services exports. However, the study predicts that the size effect of valued added by MOFAs in RDT services exports is larger (in absolute value) than the size effect of their R&D operations measured as stocks consistent with the expected predominance of HBE strategies in RDT exports for this MNC subsidiary grouping (hypothesis 3b). Lastly, U.S. RDT services imports should be positively related to U.S. MOFA's R&D as it is one technological source for these imports (hypothesis 4). See Table 3-9 for a summary of hypotheses and Figure 3-6 for the hypothesized model.

Hypothesis 3a. U.S. RDT exports are positively related to value added by majority-owned foreign affiliates of U.S. MNCs (VAMOFA).

Hypothesis 3b. The size effect in U.S. RDT exports of value added by majority-owned foreign affiliates of U.S. MNCs is larger (in absolute value) than size effect of their R&D performance.

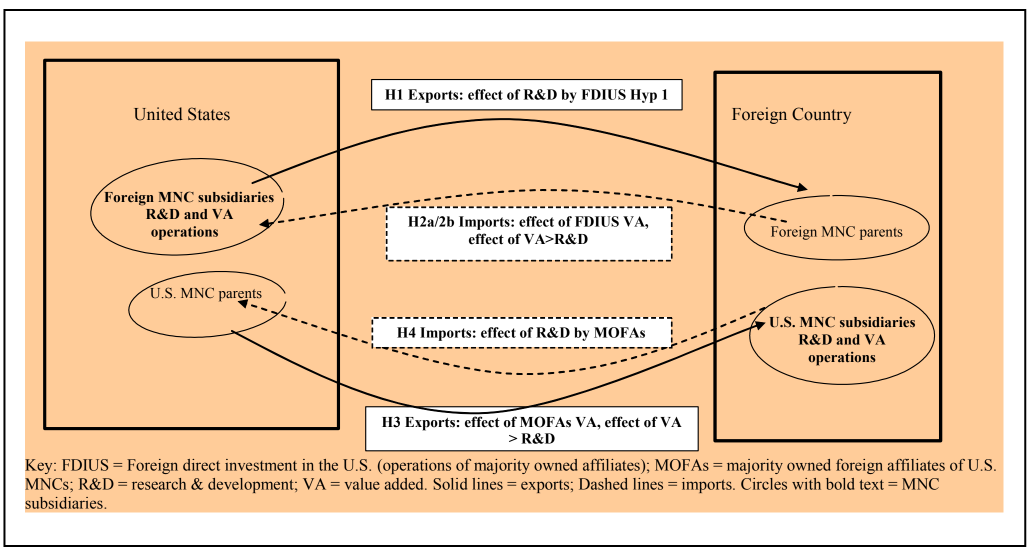
Hypothesis 4. U.S. RDT imports are positively related to R&D performed by majority-owned foreign affiliates of U.S. MNCs (RDMOFA).

Table 3-9 Summary of Hypotheses

	Dependent variables	
Explanatory variables: operations of MNC subsidiaries (R&D, value added)	U.S. RDT services exports	U.S. RDT services imports
Foreign owned subsidiaries located in the U.S. (majority-owned affiliates from FDI in the U.S.)	H1 R&D by foreign owned subsidiaries in the U.S. >0	H2a Value Added by foreign owned subsidiaries in the U.S. >0 H2b Value Added > R&D
Foreign subsidiaries of U.S. MNCs (majority-owned foreign affiliates or MOFAS)	H3a Value Added by foreign subsidiaries of U.S. MNCs >0 H3b Value Added > R&D	H4 R&D by foreign subsidiaries of U.S. MNCs >0

MNCs Multinational companies
RDT Research, development, and testing

Figure 3-6. Hypothesized model:
U.S. exports and imports of R&D services and operations of MNC subsidiaries (foreign-owned subsidiaries in the U.S. and U.S. MNCs abroad)



Control Variables

Control variables include several national-level characteristics of trade/FDI partners. S&T controls based on innovation and other theories discussed earlier include business expenditures for R&D (BERD variable), published scientific and engineering papers (S&E papers variable), and patents registered at the USPTO but owned by foreign countries (USPTO variable). These controls are intended to capture S&T aspects of more general country endowments emphasized by traditional trade theory by focusing on technological capacity. Other controls tied to trade theory include market size (GDP) controls for final demand factors, overall openness to trade (total merchandise/services exports plus imports as percent of GDP), and several measures of 'distance'. The latter include geographic distance, contiguous border dummy, and cultural distance (language dummy and colonial history dummy) as proxies for transactions costs discussed earlier. Given the highly multicollinear nature of many economic and S&T controls, not all controls are used in a given equation. The modeling strategy includes examining blocks of variables from received trade, FDI, and S&T theory as a prelude to the proposed integrated MNC-trade model.

This study uses the difference between U.S. corporate tax rate and foreign corporate tax rates ("corporate tax difference" variable) as a control variable motivated by transfer price issues. To the extent that MNCs engage in income shifting to minimize worldwide tax burden, transfer prices (non-market prices set for internal MNC transactions) are likely to distort reported intra-firm trade including but not limited to intangibles trade

(Eden, 2005; Feldstein et al., 1995; Hines & Jaffe, 2001; OECD, 2011b). For example, U.S. MNCs may "underprice goods sold [exported] to affiliates in low-tax countries and overprice goods sold by affiliates [imported from] low tax countries…" so that "…intra-firm trade flows to low-tax country affiliates should be low relative to intra-firm trade flows to high-tax country affiliates, ceteris paribus" (Clausing, 2001: 175-176). On the other hand, transfer price issues involving foreign subsidiaries in the U.S. remains little studied. Other complexities affecting transfer price behavior but outside the scope of this study include the impact of U.S. vs. foreign tax credits and tax withholding related to royalties and license fees. Another modeling strategy to account for the possible effect of transfer prices is to run estimations with sub-samples excluding transactions with Ireland, which has been widely reported as a preferred location by MNCs to register IP regardless of where it was created or whether is being exploited in the country (Simpson, 2005).

Lastly, financial measures of FDI and the R&D/GDP ratio or R&D intensity (where R&D is total R&D or gross expenditures on R&D (GERD), not only business R&D) are also used in one of the preliminary models to compare with results of Mendi (2001).

Econometric Specification

This section develops a country-level panel econometric model to understand the relationship between bilateral U.S. international transactions in R&D services and FDI in R&D, controlling for partner country characteristics. The empirical specification consists of separate equations for the two dependent variables, U.S. RDT services exports and imports. The explanatory variables are R&D performed by MNC subsidiaries and value added (VA) (RDFDIUS and VAFDIUS variables for foreign MNCs in the U.S. and RDMOFA and VAMOFA variables for U.S. MNC subsidiaries), along with national level control variables for trade/FDI partner countries. Table 3-10 shows summary statistics with information on 'between' and 'within' panel structure. Recall that variable definitions, units, and sources are shown in Table 3-1.

Table 3-10. Summary statistics with information on 'between' and 'within' panel structure. All variables, except dummies, are in natural logs.

Variable		Mean	Std. Dev.	Min	Max	Observations
Dependent variables						
log U.S. RDT exports	overall	5.072396	1.919811	0	8.402455	N = 143
	between		1.899524	0.853994	7.78585	n = 24
	within		0.4291656	3.87996	6.875693	T-bar = 5.958
log U.S. RDT imports	overall	5.540304	1.422483	1.609438	7.973845	N = 144
	between		1.378282	2.448663	7.79576	n = 24
	within		0.4361387	3.7764	6.603199	T = 6
Explanatory variables						
log R&D stock MOFAS	overall	7.669019	1.665065	3.241518	10.59912	N = 144
	between		1.636144	4.242697	10.13156	n = 24
	within		0.4348258	6.667839	8.534353	T = 6
log R&D stock FDIUS	overall	6.775015	2.43509	-0.15388	10.69685	N = 138
	between		2.411716	2.310663	10.31873	n = 23
	within		0.5705828	4.310472	8.809094	T = 6
log Value Added MOFAS	overall	9.954972	1.039484	7.594884	12.03688	N = 144
	between		1.043059	7.895653	11.96659	n = 24
	within		0.1749193	9.364485	10.53296	T = 6
log Value Added FDIUS	overall	8.513237	2.208294	2.772589	11.71797	N = 144
	between		2.218773	3.262418	11.63254	n = 24
	within		0.3545992	7.134293	9.561406	T = 6
Controls						
log busR&D exMOFARD	overall	8.704163	1.566227	4.049974	11.76664	N = 144
	between		1.576771	5.446193	11.57133	n = 24
	within		0.2319256	7.307944	9.441083	T = 6
log USbusR&D exFDIUSRD	overall	12.4816	0.0874838	12.29975	12.57998	N = 144
	between		0.0089489	12.46089	12.48704	n = 24
	within		0.087041	12.31758	12.57802	T = 6
log S&E papers	overall	9.294633	1.065344	7.351992	11.28945	N = 144
	between		1.081668	7.460437	10.99719	n = 24
	within		0.0765545	8.933382	9.586891	T = 6

Table 3-10. Summary statistics with information on 'between' and 'within' panel structure.

Variable		Mean	Std. Dev.	Min	Max	Observations
Controls (continued)						
log USPTO patents	overall	6.707658	1.835349	2.344974	10.71213	N = 144
	between		1.856118	2.904754	10.47797	n = 24
	within		0.2092629	5.913892	7.599919	T = 6
log distance	overall	8.870536	0.66785	6.306995	9.680893	N = 144
	between		0.6798411	6.306995	9.680893	n = 24
	within		0	8.870536	8.870536	T = 6
dummy contiguous country	overall	0.0833333	0.2773501	0	1	N = 144
	between		0.2823299	0	1	n = 24
	within		0	0.0833333	0.0833333	T = 6
dummy English language	overall	0.3333333	0.4730499	0	1	N = 144
	between		0.4815434	0	1	n = 24
	within		0	0.3333333	0.3333333	T = 6
log trade/GDP (openness)	overall	4.357985	0.5389813	3.260401	6.070853	N = 144
	between		0.5467583	3.350151	6.037321	n = 24
	within		0.0448196	4.248116	4.476845	T = 6
log GDP	overall	13.55717	1.129237	11.56444	16.30953	N = 132
	between		1.147445	11.70508	16.01934	n = 22
	within		0.0938037	13.22055	13.84736	T = 6
log USA GDP	overall	16.47166	0.044346	16.38777	16.52078	N = 144
	between		0	16.47166	16.47166	n = 24
	within		0.044346	16.38777	16.52078	T = 6
log corptax(USA/country) [corptaxdistance]	overall	0.3446719	0.2670088	-0.010178	1.145496	N = 114
	between		0.2671248	-0.006351	1.144221	n = 19
	within		0.0556358	0.1696618	0.4745988	T = 6
log R&D/GDP ratio	overall	0.5269907	0.6253435	-1.299135	1.509225	N = 132
	between		0.6329731	-1.009447	1.43617	n = 22
	within		0.0754428	0.237303	0.6960911	T = 6
log inward FDI/GDP	overall	4.270012	1.868557	-0.117572	7.247747	N = 137
	between		1.872148	0.8081496	7.145297	n = 23
	within		0.3080606	3.238055	5.156009	T-bar = 5.957
log outward FDI/GDP	overall	5.294878	1.098752	2.877929	7.358919	N = 138
	between		1.102505	3.186375	7.236235	n = 23
	within		0.1900062	4.54895	5.815078	T = 6

The two MNC subsidiary R&D explanatory variables are measured as stocks, computed by the author with perpetual inventory method using a 0.05 depreciation rate with 2003 starting values.[19] Subsidiary R&D stocks are deemed more appropriate than annual flow measures published by BEA since the source knowledge embedded in RDT trade is cumulative, as suggested by innovation economics (Foray, 2004). Separately, stocks are lagged once given likely endogeneity between current RDT services trade and current R&D stocks.

The dataset is a panel of U.S. exports and imports of R&D services with 24 countries. The theoretical approach in this study linking FDI and trade implies that these countries are both trading partners and FDI investors in R&D. We observe the dependent variables total RDT exports and total RDT imports at the country level, though not separately for affiliated vs. unaffiliated transactions or by MNC type within affiliated transactions. On the other hand, the main explanatory variables – FDI activity in R&D and production (value added) – are available at the country-level for each type of MNC subsidiary, foreign MNCs in U.S., and U.S. MNCs subsidiaries overseas. Thus country-level data are observed for total RDT transactions (the dependent variables) and for each MNC type for the main explanatory variables.

Unobserved heterogeneity (excluded or omitted factors) needs to be addressed. Following Wooldridge (2010, pp. 22, 285), the unobserved effects model for panel data account for

[19] The perpetual inventory formula used to compute K = R&D stock was: $K_t = (1-\delta) K_{t-1} + I_{t-1}$, with $\delta = 0.05$.

unobserved heterogeneity or individual (country) effects by specifying individual-specific intercepts (α_i) in equations explaining y_{it}, where i indexes countries and t time (years):

$$y_{it} = \alpha_i + x_{it}'\beta + \text{controls} + \varepsilon_{it}, \quad i=1,2,\ldots N; t=1, 2, \ldots T \quad (1)$$

In each equation x_{it} is a 1 x K vector of explanatory variables, β is a Kx1 vector of corresponding coefficients, and K = k + 1, k= number of explanatory variables which may differ across alternative models. ε_{it} is the idiosyncratic error assumed to be independently and identically distributed (iid) with zero mean. The dataset has 144 country-year observations from N = 24 countries and T = 6 years (2006 to 2011), thus this is a short panel where N > T.

All variables will be implemented as natural logs to reduce non-normality (skewness and kurtosis) common in economic data. The corresponding coefficients are thus elasticities. Economic variables are millions of U.S. dollars, geographic distance are kilometers, and certain S&T variables are counts, such as patents and scientific and engineering papers.

Time fixed effects are used for two different purposes (Wooldridge, 2009, pp. 448, 466). Notwithstanding my short panel, data may still reflect long-term changes that are outside the model but affecting all countries largely to the same extent. In particular, overall rise in intangibles trade may reflect greater openness in services trade, due to for example, better IT and communications technologies, multi-lateral trade agreements such as those within the WTO, or secular growth in the mobility and dispersion of scientists and engineers. Secondly, to the extent that the study uses variables in natural logs, changes in general price levels over time will be absorbed in overall intercepts. Thus time fixed effects (year dummy variables 'D_t') capture both unobserved time-varying factors and overall changes in prices.

Note that $x_{it}'\beta$ can be split into two sub-vectors (abstracting for an overall constant) labeled '1' for U.S.-located majority-owned affiliates of foreign MNCs and '2' for majority-owned foreign affiliates (MOFAs) of U.S. MNCs, so that we have $x_{it}'\beta \equiv x_{1it}'\beta_1 + x_{2it}'\beta_2$. Thus the basic panel model in this study is the following (overall constant was pulled out of the original β in the previous equation):

$$y_{it} = \beta_0 + \alpha_i + D_t + \beta_1' x_{1it} + \beta_2' x_{2it} + \text{controls} + \varepsilon_{it}$$

$$= \beta_0 + \alpha_i + D_t + [\beta_{11}\ \ \beta_{12}]'\ [\text{R\&D VA}]_{1it} + [\beta_{21}\ \ \beta_{22}]'\ [\text{R\&D VA}]_{2it} + \text{controls} + \varepsilon_{it}$$

$$= \beta_0 + \alpha_i + D_t + \beta_{11}{*}\text{R\&D} + \beta_{12}{*}\text{VA} + \beta_{21}{*}\text{R\&D} + \beta_{22}{*}\text{VA} + \text{controls} + \varepsilon_{it},$$

where y_{it} = RDT exports and separately RDT imports, and i=1,2,…24; t=1, 2, …6. (2)

The expected signs for MNC operations in each export and import equation are covered in the hypotheses and represent the key parameters to be tested.

Panel Estimation

Unobserved effects at the level of panels or clusters (here, trading/investing/host countries) can be thought as omitted country-specific variables (they may also vary over time). These unobserved effects create consistency, endogeneity, and identification problems for OLS estimation (Wooldridge, 2010, pp. 13, 18, 53-54, 57, 66, 168). Identification (obtaining B_{OLS} from observables) and consistency (plim B_{OLS} = true B) require the strict exogeneity condition $E(\varepsilon /x) = 0$, which implies $Cov(\varepsilon, x) = 0$ and also $E(\varepsilon) = 0$ since x contains elements equal to unity (Wooldridge, 2010, pp. 18, 167, 287-288). And given that $Cov(a,b) = E(ab) - EaEb$, we also obtain $E(x' \varepsilon) = 0$ as an alternative expression for exogeneity, zero covariance, or orthogonality condition (Wooldridge, 2010, pp. 18, 56, 126, 165).

The treatment and impact of unobserved characteristics can be illustrated in simple OLS with an omitted or latent variable q (with associated coefficient δ), considered part of the error, yielding a composite error $v = \varepsilon + \delta q$ (Wooldridge, 2010, pp. 65-66). Then if x (an included variable) and q are correlated, Cov(x, v) is not equal to zero and x is now endogenous and not identifiable. In our panel notation, the composite error is $v_{it} = \alpha_i + \varepsilon_{it}$ (Wooldridge, 2010, p. 291). Pooled OLS (with cluster robust errors) are also estimated for comparison purposes. Robust errors are needed for inference under plain OLS since data are likely non iid.

Random effects (RE) and fixed effects (FE) are basic panel models that differ in how they treat unobserved effects, symbolized above by the individual effect α_i. Random effects assume that α_i is uncorrelated with included explanatory variables, $Cov(x_{it}, \alpha_i) = 0$, whereas fixed effects allows for non-zero correlation. Estimation methods based on the fixed effects assumption eliminate α_i, and in the process are unable to estimate the effect of any observed variable that does not change over time, thus eliminating identification and endogeneity implications of unobserved variables. In contrast, random effects models are able to use information implicit in the individual effects α_i. In particular, the

TxT variance-covariance matrix of the composite error simplifies to a matrix with two parameters with diagonal elements ($\sigma_\alpha^2 + \sigma_\varepsilon^2$) and off-diagonal elements σ_α^2. Further, the correlation between composite errors is constant, equal to ($\sigma_\alpha^2 / (\sigma_\alpha^2 + \sigma_\varepsilon^2)$), also known as the intra-class correlation coefficient (ICC), and reported as 'rho' in RE estimation from statistical packages. This measure also gives the relative importance of individual or unobserved effects (Wooldridge, 2010, pp. 291-294).

A drawback of both standard FE and RE is that coefficients are assumed constant across countries (or panels more generally) so only the intercept is allowed to capture unobserved heterogeneity.[20] This is shown in equation (1) by having the β's be fixed across countries (no 'i' suffix).

The mixed linear model allows for random slopes, also called random coefficients, individual specific slopes, or heterogeneous slopes (see Cameron and Trivedi (2010) section 9.5, pp 305-312 and Wooldridge (2010) section 11.7, pp. 374-387), hence mixed linear models are also called random intercept/random coefficient models. The general linear mixed model is shown in equation (3) with $u_i \sim N(0, \sum_u)$ and $\varepsilon_{it} \sim N(0, \sum_\varepsilon)$. $\sum_u$ is the variance-covariance of the random effects.[21] The random intercept is the first element

[20] The random intercepts in the export and import equations capture omitted variables at the level of whole countries as the basic unit of analysis (e.g., unobserved aspects of S&T capacity that can affect bilateral trade in R&D services). But MNC groupings of subsidiaries within countries (inherent in the conceptual approach here linking trade and MNC perspectives) in effect introduce another level of omitted variables or unobserved effects. The latter variability is what is formally captured by the random slopes typically used in full hierarchical data structures. Thus although the dependent variable is bilateral U.S. trade in total R&D services, the panel structure includes sub-country aggregates for the key explanatory variables (operations of MNC subsidiaries by ownership type) whose unobserved characteristics are not recognized by simple random intercepts in standard FE or RE estimation.

[21] Equation (1) corresponds to $z_{it}=1$ and $u_i = \alpha_i$ in equation (3) since only the intercept is random. Further, note that $z_{it}=0$ brings us back to simple OLS.

in z_{it} with z_{1t}=1. (See equations 4 and 5 and related text in chapter 4 for a full implementation of this estimation technique.)

$$y_{it} = x_{it}'\beta + z_{it}'u_i + \text{controls} + \varepsilon_{it}, \quad i=1,2,\ldots N; t=1, 2, \ldots T \qquad (3)$$

Threats to Validity and Reliability of Findings

This section discusses validity and associated limitations on inferences in terms of measurement validity and reliability, external validity, internal validity, and statistical conclusion validity as defined in Newcomer (2013). The discussion below is based on the recognition that "a regression result, no matter how statistically significant, cannot prove causality. All regression analysis does is test whether a significant quantitative relationship exists" (Studenmund, 2006, p. 7). In the language of Shadish et al., econometric approaches control for confounds "through statistical manipulation [rather] than on experimental design" (Shadish, Cook, & Campbell, 2002, p. 500). At best, the research approach in this study addresses two of the three requisites for establishing a causal relationship (Shadish et al., 2002, pp. 9, 205), namely time precedence of the cause and co-movement of cause and effect. But "uncontrolled correlation" (meaning, absence of manipulable causes) makes it difficult to rule out alternative explanations (the third causality component) afforded by methods in experimental research. On the other hand experimental methods are, of course, not always feasible or even appropriate for certain types of research questions and disciplines (Shadish et al., 2002, pp. 276, 495, 499, 503).

Measurement Validity

This study uses business R&D services and MNC R&D performance to measure flows and production of disembodied technology. However, knowledge production and transfer are of course multidimensional, even within the narrower area of industrial disembodied technology, and may be operationalized in multiple ways.

Survey–based measures of R&D performance operationalize industrial technological knowledge using the cost of producing 'scientific R&D' as defined in the Frascati Manual, the OECD manual that prescribes internationally comparable measures. Further, business R&D expenditures reflect an input that may or may not result in usable and/or transferable industrial knowledge. Lastly, other forms of technological knowledge production (and transfer), such as engineering practice and innovative design, are likely missed by survey-based measures that emphasize links to disciplinary research in the natural sciences.

For their part, the novelty of using balance of payment (BOP) statistics for R&D-related services comes at a price, since BOP surveys are not particularly designed to capture 'R&D' or 'technological knowledge' broadly understood. Secondly, survey respondents in companies are more likely to have accounting or international business backgrounds than knowledge about their company's technological activities. Third, R&D-related transactions are admittedly small, and thus less salient in accounting records, compared with licensing transactions and with non-technological transactions (e.g., insurance services, logistics services) that may have a larger impact in short-term profits. At the same time, editing of survey data by statistical agencies is limited by staff and other resource constraints that may lead to a focus on items with large impact in overall aggregates. More generally, archival economic international data (services trade and MNC operations) have limitations relative to my research purposes and underlying conceptual framework. Existing time series or panel data are collected for non-research purposes such as administrative requirements or needs not directly related to S&T policy/economics.

In sum, this study is likely to suffer from mono-operation bias (a single measure for industrial knowledge production and for knowledge flow), underrepresenting the ultimate related constructs of interest. Secondly, the mono-method bias could be avoided by combining qualitative and quantitative methods, but that is beyond the scope of the study. Lastly, the use of existing public economic data may result in inappropriate operationalization since data were not collected to address the specific research questions.

Measurement Reliability

In general, economic surveys, like the ones used in this study, are subject to well-known sample and non-sample errors as described in the survey methodology literature (Groves et al., 2013). The discussion on reliability here focuses on non-sample errors; sample-related errors are covered under statistical conclusion validity below.

Among the most important sources of non-sample errors in establishment or organizational surveys, in contrast to demographic or individual surveys, are the quality of accounting records and the peculiarities of institutional/bureaucratic reporting. Further, MNC accounting is notoriously complex and intertwined with legal and taxation issues, complicated by different regulations or practices that may result in 'accidental misrepresentation' and/or uneven response quality across subsidiaries of the same MNC. On the other hand, 'purposeful misrepresentation', discussed in Shadish et al. in the context of measurement validity and reliability, may also apply here due to strategic reporting of activities to minimize taxes across jurisdictions –the subject of transfer pricing literature cited above.

To the extent that the dependent variables (R&D services trade) and the explanatory variables are obtained from separate surveys or sources, the usual assumption that measurement error in the dependent variable is uncorrelated with all the explanatory variables may not be too troublesome, e.g., different respondents even within the same company; different timing and reference point across surveys. However, the classical errors-in-explanatory variables (CEV) assumption of no correlation between measurement errors in explanatory variables and their unobserved counterparts may produce both biased and inconsistent OLS estimators (Wooldridge, 2009, p. 319). The typical effect is the so-called attenuation bias, where OLS is underestimated, is likely to be present in this study due to measurement error in explanatory variables.

External Validity or Generalizability

Perhaps the biggest threat to external validity in this study is the single reference country. Regardless of the statistical validity of possible findings, they may not apply to transactions from activities originating in developing countries, smaller economies, or markets where MNCs are not as predominant as they are in the U.S. Public bilateral data used in this study are limited to 24 partner/investing countries. Findings may not apply to countries not separately available in the public data on trade in services and FDI R&D.

In addition, the present study focuses on 2006-2011 data. The incidence and geographic spread of disembodied knowledge flows may not apply to earlier historical periods when company R&D was both less collaborative and more concentrated at home, and when knowledge flows were related to a larger extent to mature technology later in the innovation process, as in the original Vernon 1966 PLC model (which helped to generate technology diffusion models focused on embedded technology as in capital or intermediate goods trade or licensing of patents/existing technologies, rather than in transactions at the R&D stage). Further, the study spans the U.S. 2008-2009 financial collapse. On the other hand, trade/FDI partner countries differed widely in the timing and severity of their own macroeconomic effects related to the U.S. crisis, further complicating the design of a formal test for a possible break in the size or significance of key coefficients due to the financial crisis.

The mono-operation bias noted earlier also limits the generalizability of findings, since R&D services flows may interact with other forms of both disembodied and embodied technology diffusion not included in this study.

Internal Validity and Statistical Conclusion Validity

The empirical component of this study does not attempt to show ‘causation’, but rather to quantify the importance of FDI in R&D in intangibles trade. The study uses standard panel methods (Wooldridge, 2010) that account for unobserved effects in the proposed relationships as described elsewhere in this document. The validity of inferences from linear regression models of conditional means (OLS and related methods) can be discussed as they relate to two major goals:

a) unbiasedness and consistency of estimators, and

b) valid statistical tests of the resulting estimators.

The most important OLS assumption and adaptations for panel models to obtain unbiasedness and consistency of estimated coefficients is exogeneity of regressors (zero conditional mean of idiosyncratic error). Threats to validity of findings include omitted variables, inclusion of irrelevant variables, misspecified functional forms, measurement error, and other measurement reliability issues (see above). Empirical econometric practice calls for specification tests, model diagnostics, and robustness checks to be employed in this study.

More subtle and difficult to handle threats to validity include simultaneous causation and selection bias. As noted earlier, simultaneity between MNC subsidiary R&D and R&D services is handled by one-period lags. Longer lags are precluded by the relatively small sample (small T or short panel), and thus the approach here may not fully account for this source of endogeneity. Unobserved group effects are handled by RE and FE, while time-varying unmeasured effects are accounted for by time fixed effects (year dummies), as discussed elsewhere.

Countries not included in the publicly available data used here present a selection issue as noted earlier under external validity. However, the included countries are bound to represent the largest performers of R&D and drivers of most R&D-related transactions. My sample is effectively non-random, subject to publication parameters of official statistics such as economic relevance of published country level data and disclosure limitations to protect confidentiality of respondents.

Valid inferences depend on the assumed structure of the variance-covariance matrix of the idiosyncratic error (including the composite error in RE models). Classical OLS assumes independently and identically distributed (iid) idiosyncratic errors. Several panel data models explored here are designed to account for violations of iid errors assumption, e.g., group heteroskedasticity.

Lastly, similar to FDI, trade, and S&T studies based on macroeconomic or country-level data, findings from this study are subject to aggregation bias (Garrett, 2002). The latter refers to the possibility that coefficients from aggregate data may have a different size, sign, or significance compared with regressions on individual units. The present study should then be considered only a first step in a larger research agenda that includes micro-level data. Nevertheless, recurrent time series statistics used for policy monitoring and policy-inspired research are often available only in aggregate estimates to protect confidentiality of respondents.

Conclusion

This chapter presented the study's dependent and explanatory variables, including major trends and country distribution, along with control variables and data sources. It also presented hypotheses investigating the relationship between total U.S. exports and imports of disembodied technology in the form of R&D services and the operations (R&D performance and value added) of MNC subsidiaries. The coefficients on subsidiary R&D stocks and production activity (value added) are the main parameters of interest in separate equations for U.S. total exports and total imports of RDT services, as summarized in the hypotheses (see Figure 3-6 and Table 3-9).

This chapter also developed an econometric model to test the hypotheses using a country-level panel of trading and investing/host countries based on U.S. balance of payments and FDI/MNC statistics. The panel econometric strategy exploits country heterogeneity in MNC activity by both inward and outward FDI (consistent with theories of MNC R&D strategies) to explain observed transactions in R&D and testing services. Lastly, in light of limitations discussed in this chapter, findings from this study should be taken as results to be modified by future research.

Chapter 4: Results and Discussion

Introduction

This chapter discusses empirical models and results, robustness of findings, and implications for the study's hypotheses. The empirical objective is to understand the relationship between trade in R&D services, measured as R&D and testing (RDT) services from U.S. balance of payments statistics, and the operations of MNC subsidiaries. Five models each for RDT exports and imports equations were estimated.[22] The first four models– (1) quasi-gravity trade, (2) FDI, (3) S&T controls only, (4) MNC operations only– are intended as exploratory models leading to the final 'MNC-trade' model (5). Results are shown in Appendix Tables A1-A3 (RDT exports) and B1-B3 (RDT imports).

The first four models are estimated with three estimation techniques: cluster robust OLS, robust fixed effects (FE), and robust random effects (RE) (using feasible generalized least squares [FGLS]). Model 5 is estimated with five estimation techniques, the latter 3 techniques plus RE using maximum likelihood estimation (MLE) and random intercepts/random coefficients also known as 'mixed linear model' (which also uses MLE), with robust estimation. The preferred final specifications for RDT export and RDT imports equations – MNC-trade model 5 with robust mixed linear estimation – are almost identical in terms of explanatory variables. The final model 5 equations differ by one control variable and also by different estimation assumptions within the mixed linear

[22] Estimates were obtained using Stata/IC 12.1 for Windows. See Cameron and Trivedi (2010) and Hamilton (2009).

setting: which slopes are considered random and whether or not random intercepts and random slopes are independent, based on statistical testing for each equation. All models use variables in natural logs, an overall constant, and time fixed effects. All continuous regressors are lagged once.

Exploratory Models

Model 1 (quasi-gravity trade or trade model for short) and model 2 (FDI) are intended to compare results with limited previous work that focused or included R&D services trade, though previous papers covered different time periods, countries, or focused on total technology balance of payments (TBP). Model 3 explores the role of national-level S&T controls in line with innovation, trade, and international business theories (e.g., role of country endowments in trade, country-specific advantages in MNC location, and absorptive capacity factors suggested by innovation and growth studies discussed in the literature review). Model 4 and 5 include the MNC operations variables introduced in this study as explanatory variables for intangibles trade: by themselves in model 4 and combined with trade, MNC variables, and selected controls in the final model 5.

A trade gravity model similar to model 1 was used by Zuniga and Bascavusoglu-moreau (2003) in one of the few studies that separately considers R&D services trade. As noted in chapter 2, that paper focused on several distance measures and IPR issues using UK-based data. The present study's gravity equation includes seven main regressors: recipient/sending GDPs, U.S. GDP, geographic distance, two additional distance measures (common language dummy for cultural distance and dummy for contiguous countries), an economy openness measure (trade/GDP percent) and difference in corporate tax rates relative to the U.S. (See the first three columns in Appendix Tables A1 [RDT exports] and B1 [RDT imports].) In both exports and import equations, recipient/sending GDP variables are positive and geographic distance is negative (in OLS and RE estimation), as expected in gravity equations, though not all coefficients are statistically significant. The dummy for trading partner countries where English is the official language (used as proxy for cultural distance/affinity) is positive in both OLS and RE estimation, but significant only for RDT exports.

Model 2, 'FDI model', includes three explanatory variables used in Mendi 2001 (though for the time periods of the present study): R&D to GDP ratio, inward FDI/GDP, and outward FDI/GDP (see Mendi's 2001 table 2.9). As noted in chapter 2, Mendi's work was perhaps the first major study to include FDI financial measures in a study on intangibles trade, though his dependent variable was net exports in total TBP (including but not separating out R&D services). The closest estimation technique to this study was his OLS equation with fixed country effects (he also used time series and long panel models (T>N)). In general, cluster robust OLS and robust RE estimation for both model 2 equations in the present study show positive and significant variables (for at least two of the three substantive regressors), whereas FE estimation of model 2 was not able to capture any statistically significant relationship for either RDT exports or imports. (See the last three columns of Appendix Tables A1 (RDT exports) and B1 (RDT imports).)

Thus, estimation results from models 1 and 2 for both equations in this study suggest that the present new U.S. panel dataset for RDT trade behaves in a manner generally consistent with previous related studies, though the data structure, time period, and/or reference country differ from the present study. Model 3 (first three columns of Appendix Tables A2 and B2) shows the effect of four S&T controls by themselves. USPTO patents coefficient is positive as expected, except in two estimations. The largest coefficient in all model 3 estimations (U.S. business R&D excluding R&D by foreign owned subsidiaries in the U.S.) is negative and statistically significant in all but one estimation. However, this is difficult to interpret since by construction this variable does not vary across the country panels. Given the high correlation among the dependent variables (RDT exports and imports), MNC R&D variables, and S&T controls (Table 3-2) final specifications include only some of these S&T controls.

Model 4 (last three columns of Appendix Tables A2 and B2) includes four MNC subsidiary operations variables by themselves: R&D performed (RD) and value added (VA) by majority-owned foreign affiliates (MOFAS) of U.S. MNCs and by majority-owned subsidiaries of foreign MNCs located in the U.S. (labeled 'FDIUS'): RDMOFAS, VAMOFAS, RDFDIUS, VAFDIUS. The coefficients of R&D by MNC subsidiaries (RDMOFAS and RDFDIUS) were positive in OLS and RE models, though only R&D by U.S. MOFAs was statistically significant and positive in both exports and imports equations estimated using RE. MNC value added (VA) variables were positive but not statistically significant in most equations (the only exception was an insignificant negative sign in cluster robust OLS for RDT imports). As in model 2, robust FE panel estimation of model 4 is unable to find any statistically significant relationship. This is not surprising since within country variability is much smaller than cross-country variability for many of the key variables. See Table 3-10.

MNC-trade model and estimation

The MNC-trade model (model 5) combines the four MNC operations variables of the simple MNC model 4 with selected control variables from trade and S&T theory. The current RE and FE specifications of model 5 (see equation 4 below) allow for country-specific effects (intercepts α_i), with all coefficients fixed across countries.

$$y_{it} = \beta_0 + \alpha_i + D_t + \beta_{11} *RDFDIUS + \beta_{12}*VAFDIUS+ \beta_{21}*RDMOFAS+ \beta_{22}*VAMOFAS + controls + \varepsilon_{it}, \quad (4)$$

where y_{it} = RDT exports, RDT imports and i=1,2,…24; t=1, 2, …6

To guard against multicollinearity, and keeping in mind the modest sample size, the initial MNC-trade model 5 has only two trade controls (geographic distance and trade openness) and one S&T control (USPTO patents) based on several exploratory runs. At this point of model development the main goal is to assess suitability of estimation methods. The significance of variables across estimation methods vary for RDT exports of model 5. But for the RDT imports equation no individual regressor was significant in either FE and RE estimation of model 5 even though the equation is overall highly significant and the exploratory models showed significance of some of the variables included (the cluster robust OLS had better fit but as discussed earlier, it does not control for omitted variables as panel methods do). Dropping USPTO control in the model 5 equation for RDT imports increased R^2 and lowered RMSE. Thus, the current equations for model 5 for exports and imports differed by the latter having one less control variable.

One typical question in panel models is whether FE or RE effects estimation is more appropriate. Using RE FGLS to estimate current equations for model 5, a Hausman test comparing FE with RE estimates was unable to reject the null of that RE yields consistent estimates (or a null that difference in coefficients are not systematic). At the same time, as Cameron and Trivedi note (2006, p. 267) a "serious shortcoming of the standard Hausman test" is the lack of a robust version of the test. (Indeed, to implement the Hausman test it was required to estimate RE assuming iid errors). On the other hand, the statistical result of this test is consistent with the fact that within variation in the dataset is much smaller than between or cross-country variation as noted earlier. In those situations, RE is generally considered more efficient since it uses <u>both</u> within and between variability, whereas FE uses only within variation. Further, RE's theta is close to 1, indicating that the within and the RE data transformations underlying FE and RE result in similar demeaned data. Thus all further models analyzed here are based on model 5 estimated using some version of RE.

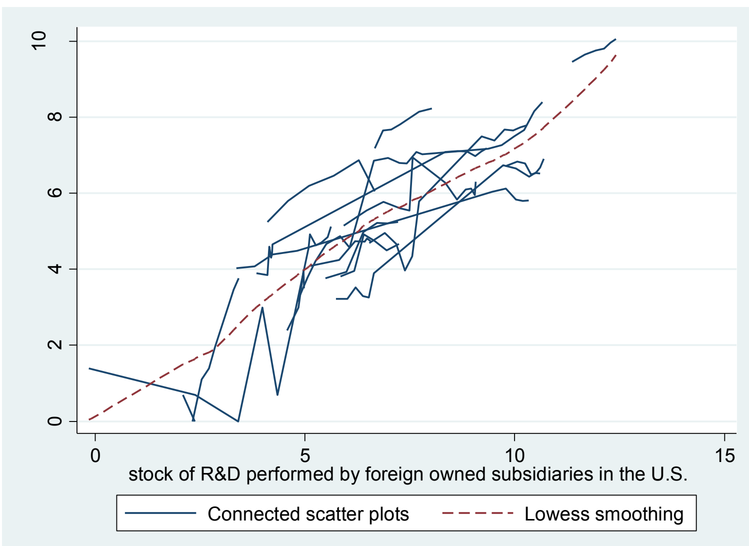
The MNC-trade model 5 for RDT exports and RDT imports was also examined using the likelihood ratio test against the restricted version (model 4) with just the MNC operations variables (with a null hypotheses that the added coefficients are jointly zero), after re-estimating each RE equation using MLE. An equivalent Wald test on the unrestricted model (model 5) was also conducted (with a null that the non-MNC variables are jointly zero). For RDT exports, both tests are unable to reject the null that the two trade variables and the USPTO control are jointly zero. However, the trade openness measure is highly significant. Given the theoretical importance of these three variables, all three are retained. For the RDT imports equation, again both tests cannot reject the null that the restricted model (model 4) is better. An alternative trade control was tested and retained for RDT imports, namely, the difference in corporate tax rates between the U.S. and its trading/investment partner countries.

Thus, so far the MNC-trade RDT imports equation differ from the MNC-trade exports equation by controlling for the difference in corporate tax rates, instead of the foreign patent registered at the USPTO by trading/investment partners countries. At this point we have an MNC-trade model (model 5) for RDT export and import equations, both estimated using RE MLE. (See column 4 in Appendix Tables A3 (exports) and B3 (imports).)

Random intercepts/coefficients specification of the MNC-trade model

In simple RE models unobserved or omitted factors are captured only by random intercepts since all slopes are assumed constant across panels. This is a drawback for our panel dataset as discussed in chapter 3 (see equation 3 and related text). Further, since plots of U.S. RDT services exports and imports against R&D by foreign subsidiaries of U.S. MNCs (RDMOFAS) and R&D by foreign owned subsidiaries in the U.S. (RDFDIUS) (all in natural logs) show that country lines (connected scatter plots) have not only different intercepts, but also slopes or coefficients (elasticities in our log-log equations) with respect to the MNC subsidiary R&D performance variables. See Figures 4-1 to 4-4 (separate short lines represent countries in the dataset; the overall trend line is estimated using lowess smoothing [locally weighted scatterplot smoothing] using Stata). These figures suggest that a RE mixed model that also allows unobserved heterogeneity in the slopes of the MNC R&D variables may result in a more robust model.[23]

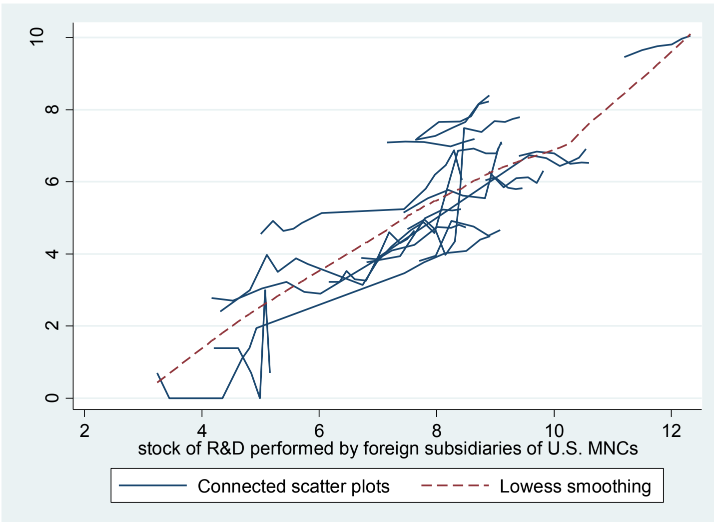
Figure 4-1 R&D services exports vs. stock of R&D performed by foreign owned subsidiaries in the U.S. (all in natural logs; 2006-2011 panel): Connected scatter plots for country panels, and overall predicted (smoothed) values for R&D services exports



Note: Predicted (smoothed) values use "lowess" smoothing: locally weighted scatterplot smoothing.

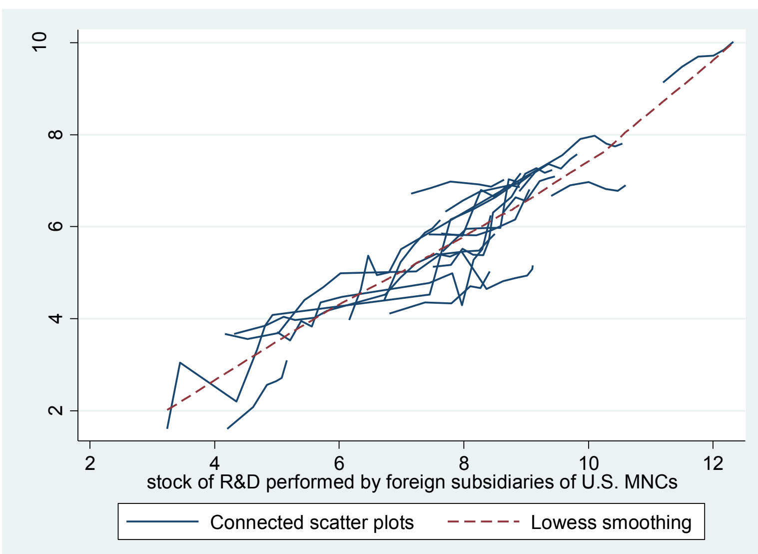
[23] Runs testing random coefficients for subsidiary value added variables showed that the standard deviation of their slopes was either not significant or resulted in similarly insignificant coefficients in both RDT exports and RDT imports equations.

Figure 4-2 R&D services exports vs. stock of R&D performed by foreign subsidiaries of U.S. MNCs (all in natural logs; 2006-2011 panel): Connected scatter plots for country panels, and overall predicted (smoothed) values for R&D services exports



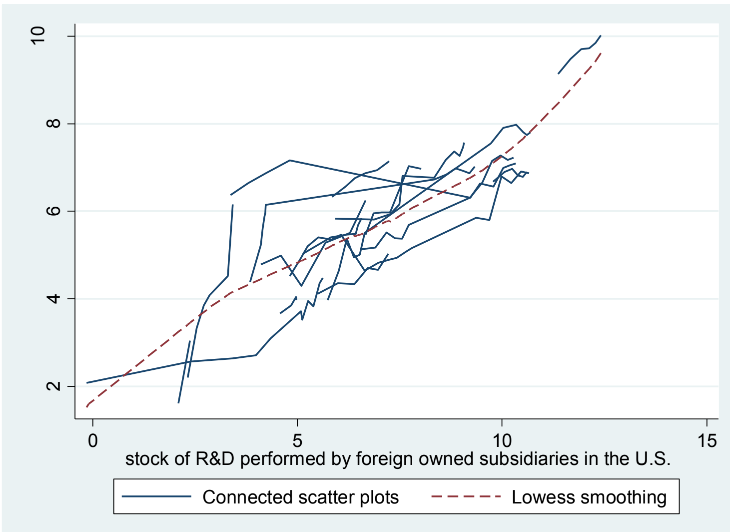
Note: Predicted (smoothed) values use “lowess” smoothing: locally weighted scatterplot smoothing.

Figure 4-3 R&D services imports vs. stock of R&D performed by foreign subsidiaries of U.S. MNCs (all in natural logs; 2006-2011 panel): Connected scatter plots for country panels, and overall predicted (smoothed) values for R&D services imports



Note: Predicted (smoothed) values use “lowess” smoothing: locally weighted scatterplot smoothing.

Figure 4-4 R&D services imports vs. stock of R&D performed by foreign owned subsidiaries in the U.S. (all in natural logs; 2006-2011 panel): Connected scatter plots for country panels, and overall predicted (smoothed) values for R&D services imports



Note: Predicted (smoothed) values use "lowess" smoothing: locally weighted scatterplot smoothing.

Several versions of random coefficients were tested for each equation (all with random intercepts as in the original RE estimations): only random RDMOFAS coefficients, only random RDFDIUS, and both RDMOFAS and RDFDIUS with random slopes. Statistical output for the RDT exports equation (standard error of the RDFIUS coefficient statistically significant different from zero and likelihood ratio tests) suggests that RDFIUS (but not RDMOFAS) should be considered random. Based on the same criteria, the coefficient for RDMOFAS (but not RDFDIUS) should be considered random in the RDT imports equation. Equations (5) and (6) are the working specifications to be further analyzed. These equations apply MNC-specific notation of equation 2 to the general mixed model equation 3 in chapter 3 with $z_{it}' = [1 \;\; \text{RDFDIUS}]$ and $u_i' = [\alpha_i \;\; \beta_{11i}]$ in equation (5), and $z_{it}' = [1 \;\; \text{RDMOFA}]$ and $u_i' = [\alpha_i \;\; \beta_{21i}]$ in equation (6), where 'i' indexes countries in the new β random slopes.

$RDT\ exports_{it} =$

$\beta_0 + \alpha_i + D_t + \beta_{11}$*RDFDIUS + β_{12}*VAFDIUS+ β_{21}*RDMOFAS+ β_{22}*VAMOFAS +

+ β_{11i}*RDFDIUS + controls + ε_{it},

i=1,2,…24; t=1, 2, …6 (5)

$RDT\ imports_{it} =$

$\beta_0 + \alpha_i + D_t + \beta_{11}$*RDFDIUS + β_{12}*VAFDIUS+ β_{21}*RDMOFAS+ β_{22}*VAMOFAS +

+ β_{21i}*RDMOFAS + controls + ε_{it},

i=1,2,…24; t=1, 2, …6 (6)

There are two further modeling considerations to be implemented. Given heteroskedasticity in the RDT trade panel, robust standard errors should be estimated for the mixed linear models. Secondly, the default estimation of mixed linear models assumes that random intercepts are uncorrelated with random coefficients (e.g. cov (α_i, β_{11j}) = 0 in equation 4).Thus, a test was conducted by running regressions where the covariance of these random variables were allowed to be non-zero ('unstructured covariance' in Stata language).

A likelihood ratio test comparing the unrestricted model (unstructured covariance) with the restricted version of the RDT exports equation (independent random effects) rejects at 10% confidence level the null that the restricted model is better, though not at 5%. This ambiguity shows up in an insignificant correlation between the intercept and the random coefficient under unstructured covariance. Nevertheless, the more demanding assumption of unstructured covariance (allowing correlation between random intercepts and random slopes) is retained for the RDT export equation. For the RDT import equation, the restricted model (uncorrelated random effects) is strongly not rejected (p=0.61) so the assumption of uncorrelated random intercepts is warranted. Thus the default uncorrelated covariance assumption is retained for the RDT imports equation.

In sum, the final model 5 equations for U.S. RDT services exports and imports feature a mixed panel model estimated using MLE with robust standard errors. Note that now the two RDT equations differ not only in one control variable, but also in the specific random slope included and in the covariance structure between random intercepts and slopes as just discussed. Table 4-1 shows estimated coefficients and key statistics for the final model 5 estimation of each equation.[24] Estimated equations are shown immediately below (fixed time effects were estimated but not shown). Recall that all variables are in natural logs. The random coefficients are discussed further below.

Predicted RDT exports_{it} =

$-7.47 + \alpha_i + D_t$ + 0.51*RDFDIUS - 0.01*VAFDIUS+ 0.63*RDMOFAS+

0.35*VAMOFAS + β_{11j}*RDFDIUS - 0.03*dist+ 0.75openness -0.23*uspto + residual

Predicted RDT imports_{it} =

$-4.36 + \alpha_i + D_t$ + 0.13*RDFDIUS + 0.15*VAFDIUS+ 0.33*RDMOFAS+

0.18*VAMOFAS + β_{21j}*RDMOFAS - 0.06*dist+ 0.95openness -1.25*corptaxdistance + residual

[24] Final sample for RDT exports equation = 137 (all countries except Argentina given no data on RDFDIUS for the sample period) and for RDT imports equation = 114 (all countries except Argentina, China, Singapore, South Africa, and Taiwan given no comparable data on corporate tax rates control).

Table 4-1. Random intercepts/random slopes (RIRS) estimation of 'MNC-trade' model 5 of U.S. trade in R&D services with robust standard errors (2006-2011 panel)

	log U.S. RDT exports (Model 5a)	log U.S. RDT imports (Model 5b)
log R&D stock MOFAS	0.631*	0.332*
	(0.247)	(0.133)
log R&D stock FDIUS	0.513**	0.131*
	(0.162)	(0.059)
log Value Added MOFAS	0.352	0.182
	(0.209)	(0.175)
log Value Added FDIUS	-0.014	0.152
	(0.093)	(0.105)
log distance	-0.026	-0.063
	(0.309)	(0.154)
log trade/GDP(%)	0.745***	0.951**
	(0.188)	(0.332)
log USPTO patents	-0.229	
	(0.183)	
log corptax(USA/country)		-1.257***
		(0.293)
Constant	-7.471**	-4.357
	(2.497)	(2.583)
sd (Random slope)	0.297***	0.0802***
	(0.0533)	(0.0150)
sd (Random intercept)	1.052	3.62e-09
	(0.371)	(.)
corr (slope, intercept)	-1.000	
	(2.61e-08)	
sd (Residual)	0.372***	0.233***
	(0.0612)	(0.0445)
year effects	Yes	Yes
aic	233.275	93.357
bic	282.915	134.400
chi2	6083.664	4489.583
P	0.000	0.000
N	137	114
df_m	12	12

Standard errors in parentheses.
* p<0.05, ** p<0.01, *** p<0.001

Notes: All variables are in natural logs. R&D stocks of MNC subsidiaries are lagged once. Statistical output was obtained from xtmixed command using Stata/IC 12.1 for Windows.

corr = correlation; sd = standard deviation
FDIUS = Majority-owned affiliates of foreign MNCs located in the U.S.
MOFAS = Majority-owned foreign affiliates of U.S. MNCs
USPTO = U.S. Patents and Trademark Office
RDT = R&D and testing services

Residual analysis, outliers, and robustness

Preliminary analyses showed substantial skewness and kurtosis of the raw variables in levels, a common feature of many economic and S&T activity statistics with activity often concentrated in few large advanced economies. Logarithmic transformation of the data made these two properties resemble normal distribution values, thus all continuous variables were logged in all models examined. At the same time, normality of residuals is typically required only for valid hypothesis testing, not for generating unbiased estimates of regression coefficients. However, since mixed linear estimation for the final specification of model 5 uses MLE, the overall error is assumed to be normal. Thus, checking for normality of residuals has an added significance in terms of statistical conclusion validity. Two diagnostic plots are examined: standardized residuals vs. fitted values, and a ‘kdensity’ plot of residuals with an overlay of the normal distribution. In properly specified models, predicted values should vary at random around a line for residuals=0, while in the second plot the estimated residuals should be close to the normal plot.

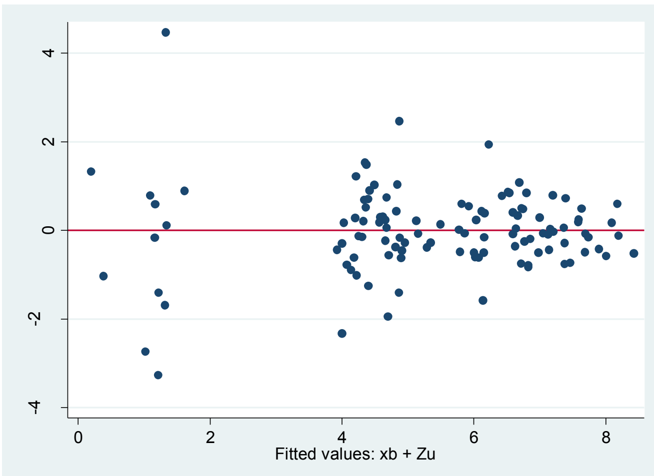
Judging by residuals-fitted plots and residual normality plots, both equations for the MNC-trade model 5 appear to be sound, though RDT exports equation appear to have a better fit based on these particular plots, compared with RDT imports equation (the latter is also estimated with a smaller sample). At the same time, the statistical significance of the positive sign of R&D by foreign subsidiaries of U.S. MNCs (RDMOFAS) in RDT imports (supporting hypothesis 4) was consistent or robust across several estimation methods, whereas the coefficient of R&D by foreign owned subsidiaries in the U.S.

(RDFDIUS) in RDT exports (hypothesis 1) was positive across several estimation methods, but significant at conventional levels *only* in cluster robust OLS and in the final mixed linear model with *unstructured* covariance. Thus, statistical support of hypothesis 1 has less empirical robustness compared with the support for hypothesis 4 based on the current panel data and modeling strategies. In short, the strongest support in terms of robustness of statistical significance across several estimation techniques was for hypothesis 4, consistent with reverse knowledge transfer by U.S. MNCs.

Further, some data points appear to be outliers. In particular, the exports equation does not do a good job modeling data associated with Chile and New Zealand, while the import equation has similar difficulties with data associated with Chile and Mexico. These outliers suggest that statistical results on the importance of MNC R&D operations on intangibles trade apply more forcefully to two-way FDI in R&D and two-way intangibles trade between larger and more developed economies. However, these three countries account for a relatively small share of the dependent variables and key explanatory variables over the sample period.

Figure 4-5 RDT services exports: Standardized residuals-fitted plot

Full model sample



Excluding Chile and New Zealand

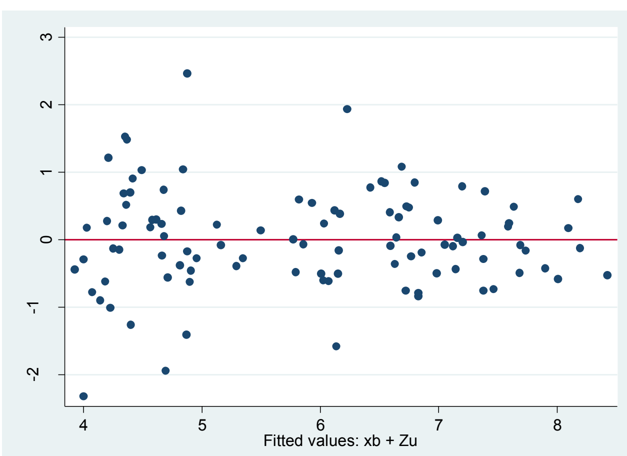
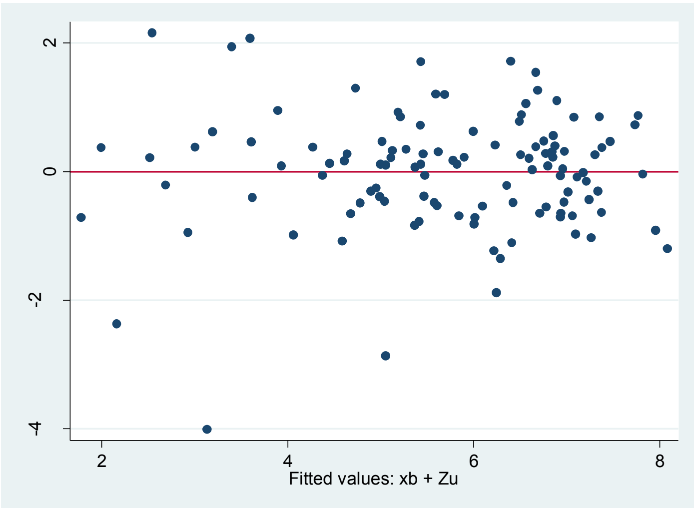


Figure 4-6 RDT services imports: Standardized residuals-fitted plot

Full model sample



Excluding Chile and Mexico

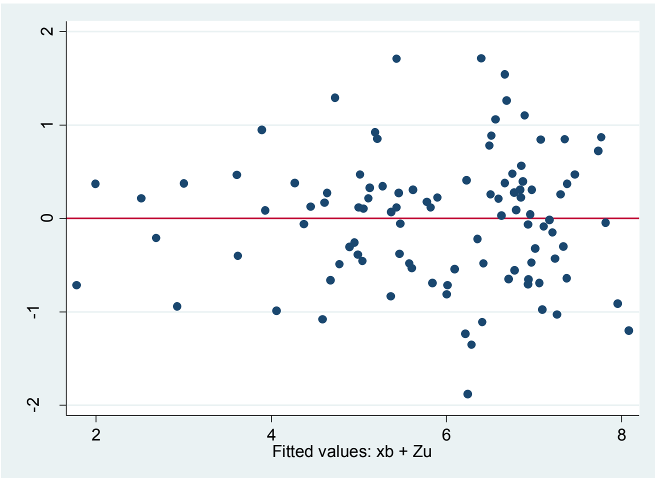
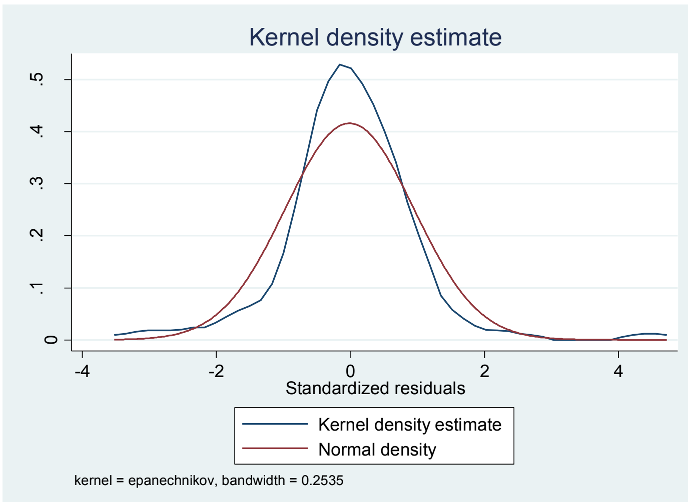


Figure 4-7 RDT services exports: Residual-Normal plots

Full model sample



Excluding Chile and New Zealand

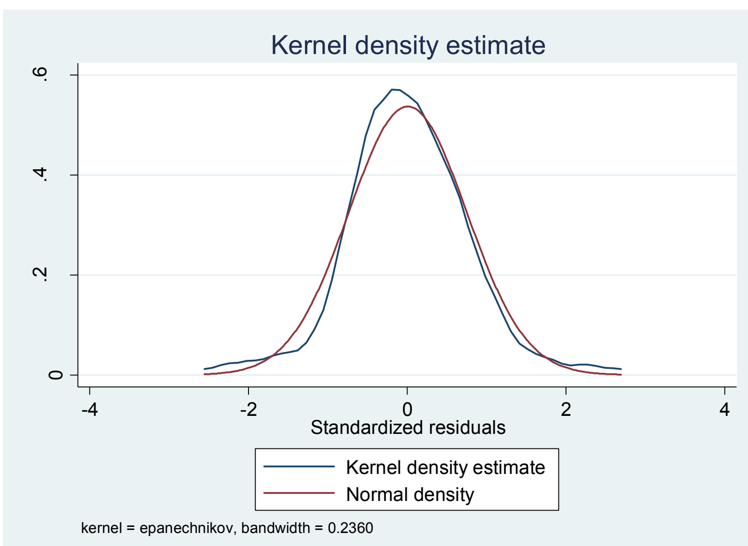
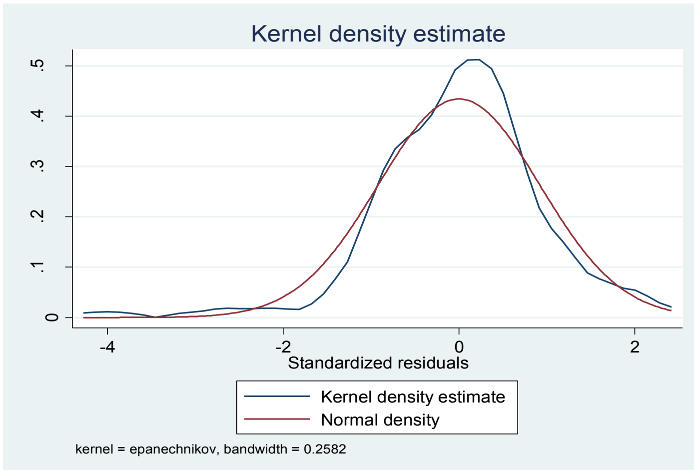
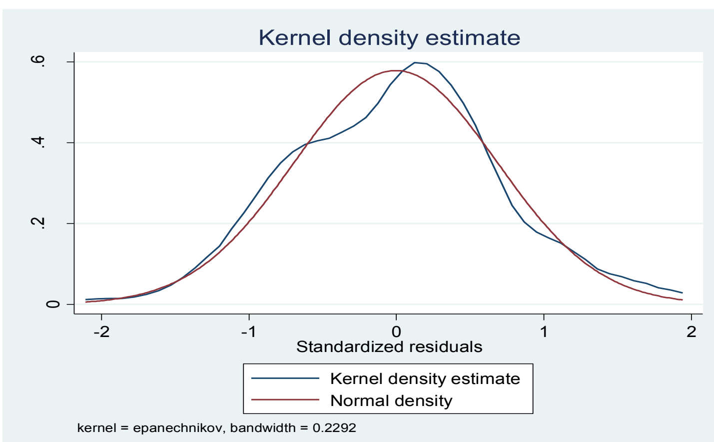


Figure 4-8 RDT services imports: Residual-Normal plots

Full model sample



Excluding Chile and Mexico



Discussion of findings from the MNC-trade model

Overview

The final mixed linear estimation of both equations for model 5 is consistent with hypotheses 1 and 4, though statistical support for hypothesis 1 was *less robust* across several panel estimation techniques. U.S. exports of RDT (R&D and testing) services are positively related (p=.002/2 for one-sided t-test) to R&D performed in the United States by subsidiaries of foreign-owned MNCs (RDFDIUS) (hypotheses 1). And U.S. RDT imports are positively related (p=.028/2 for one-sided test) to R&D performed by majority-owned foreign affiliates of U.S. MNCs (RDMOFAS) (hypotheses 4). Both of these hypotheses are consistent with reverse knowledge transfer (RKT) whereby MNC subsidiaries transfer disembodied technology or industrial knowledge back to the home country implied in Kuemmerle's home-based augmenting (HBA) R&D FDI strategy and with subsidiaries considered to be 'centers of excellence' within MNCs (Box 1 in chapter 2). In short, FDI in R&D to or from the United States –foreign owned U.S.-located subsidiaries (H1) and U.S.-owned overseas subsidiaries (H4)– appear to be related to subsequent intangible flows in the direction of MNC parent countries as captured in RDT trade statistics of the U.S. balance of payments.

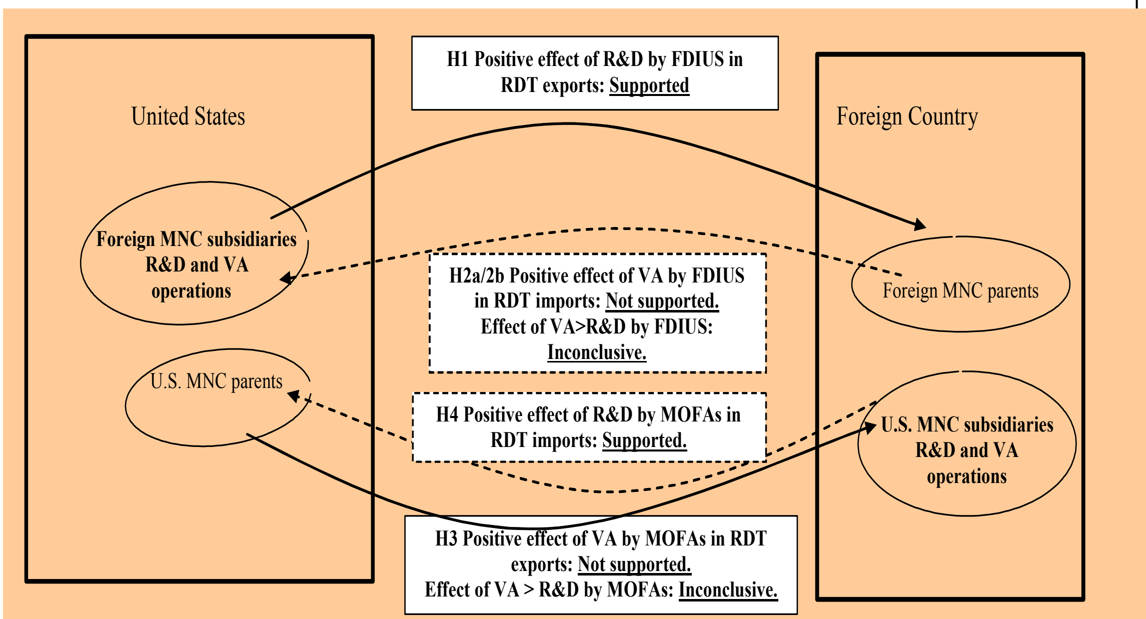
On the other hand, in the final empirical specifications the MNC value added variables (VAFDIUS and VAMOFAS) do not have the signs predicted by hypotheses 2a and 3a, respectively. Further, the statistical significance of the value added variables is not robust to the exclusion of large residual outliers for transactions with Chile, and also not robust to the exclusion of Ireland. The latter is problematic in light of known tax-driven transactions reported based on legal ownership of entities with little resemblance to economic ownership and production, use, or transfer of intangible property (Simpson, 2005). Therefore, there is *no statistical support* for hypotheses 2a and 3a. In turn, their sister hypotheses 2b and 3b are deemed *inconclusive*. The latter suggests no support for traditional knowledge transfer or home-base exploiting (HBE) (or asset exploiting strategies) based on the bilateral country panel data and modeling assumptions employed here. In sum, the analysis above finds statistical support only for hypotheses 1 and 4 involving the positive relationship of R&D by foreign owned subsidiaries in the U.S. with RDT exports and R&D by foreign subsidiaries of U.S. MNCs with RDT imports, respectively, both cases associated with reverse knowledge transfer (see Table 4-2 and Figure 4-9). The rest of the discussion focuses on results regarding fixed vs. random slopes addressed in hypotheses 1 and 4, and on additional significant findings involving estimated effects of MNC subsidiary R&D on RDT trade.

Table 4-2. Results of hypotheses testing based on random intercepts/random slopes robust estimation of 'MNC-trade' model 5 of U.S. trade in R&D services (2006-2011 panel)

	Dependent variables	
Explanatory variables: operations of MNC subsidiaries (R&D, value added)	U.S. RDT services exports	U.S. RDT services imports
Foreign owned subsidiaries located in the U.S. (majority-owned affiliates from FDI in the U.S.)	H1 R&D by foreign owned subsidiaries in the U.S. >0 Supported	H2a Value Added by foreign owned subsidiaries in the U.S. >0 Not supported H2b Value Added > R&D Inconclusive
Foreign subsidiaries of U.S. MNCs (majority-owned foreign affiliates or MOFAS)	H3a Value Added by foreign subsidiaries of U.S. MNCs >0 Not supported H3b Value Added > R&D Inconclusive	H4 R&D by foreign subsidiaries of U.S. MNCs >0 Supported

MNCs Multinational companies
RDT Research, development, and testing

Figure 4-9. Results of hypotheses testing based on MNC-trade model 5: RDT services trade and MNC subsidiaries.



Key: FDIUS = Foreign direct investment in the U.S. (operations of majority owned affiliates of foreign MNCs in the U.S.); MOFAs = Majority owned foreign affiliates of U.S. MNCs; R&D = Research & Development; RDT R&D and Testing services; VA = Value Added. Solid lines = exports; Dashed lines = imports. Circles with bold text = MNC subsidiaries.

RDT exports: fixed slopes

A one-percent increase in the stock of R&D of foreign owned subsidiaries located in the U.S. (RDFDIUS) in year t-1 results in an average year t increase of 0.51% in U.S. RDT exports within the sample period, assuming no changes in other factors (see also Table 4-1 and related text). This effect is consistent with reverse knowledge transfer (RKT) and home-based augmenting (HBA) implied by hypothesis one as noted earlier. This result is also consistent with the large ratio of domestic R&D performed to RDT exports for foreign-owned subsidiaries located in the U.S., relative to the same ratio for the aggregate of all companies, as discussed in chapter 3 (Table 3-7). More generally, the finding on the positive average effect of R&D by foreign MNCs and possible RKT strategies is conditional on the U.S. as a reference country, a well-known source of technology for other countries (Keller, 2010).

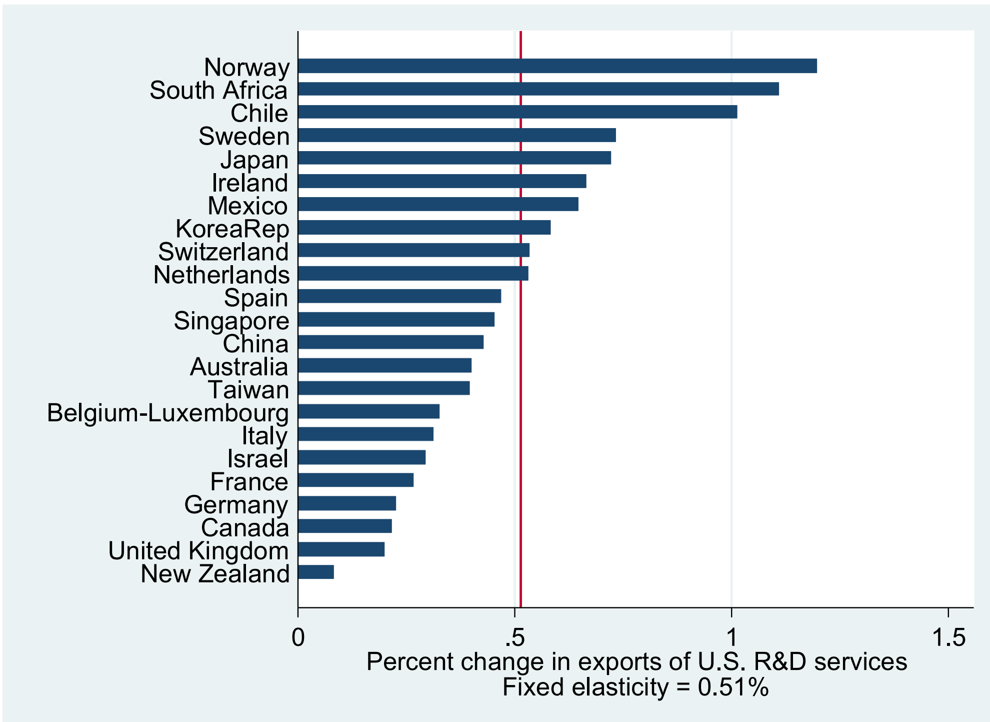
Separately, a 1% increase in the stock of R&D of foreign subsidiaries of U.S. MNCs (RDMOFAS) in year t-1 is also positively related with U.S. RDT exports, resulting in a 0.63% increase. Recall from chapter 3 that this study did not propose a predicted sign for this variable in reference to U.S. RDT exports since overseas subsidiary R&D may be a complement or substitute to these outflows. The resulting positive effect of MOFA R&D on U.S. RDT exports suggests that knowledge outflows are attracted by, or complementary to, local R&D activity of foreign subsidiaries of U.S. MNCs. Along with the lack of statistical support for the effect of value added variables associated with exploitation and adaptation of R&D (thus rejecting HBE as conceptualized here for aggregate subsidiary activity based on Kuemmerle 1999 firm level study), these findings suggest that a substantial share of R&D services exports is aimed at further knowledge combination/recombination abroad either well before value added activities are contemplated in the receiving country or aimed at production elsewhere. Information on 'research' vs. 'development' services components within RDT would allow further research on the nature of intangible trade at different stages of the innovation cycle using balance of payments data (microdata links with R&D surveys would be useful in this regard as discussed in Chapter 5).

RDT exports: random slopes

Focusing again on the original hypothesis 1 on the effect of R&D of foreign owned U.S.-located subsidiaries (RDFDIUS) on U.S. RDT exports, note that the positive expectation effectively refers to the fixed or cross-country average slope for the 2006-2011 RDT panel. Separately, the random component of the slope of RDFDIUS allows estimating the variability in reverse knowledge transfer behavior (suggested by the fixed component of the slope) across foreign parent countries receiving U.S. RDT exports. Figure 4-10 displays estimated elasticities of RDT exports (fixed plus random slopes) with respect to RDFDIUS. In this figure countries are both parent countries of foreign MNCs with U.S.-located subsidiaries and also the destination countries of RDT exports, recalling the joint MNC-trade theoretical approach of this study and the structure of the RDT trade panel dataset put together for the empirical analysis. The figure shows that for some relatively smaller parent countries, prior year stock of R&D of foreign owned subsidiaries located in the U.S. have twice as much effect on total US RDT exports as the average for all countries and compared with some relatively large economies such as France, Germany, UK, and Canada. Notably, the elasticities associated with R&D stocks of foreign-owned subsidiaries from MNC parents based in Norway, South Africa, and Chile are larger than 1 (recall that Chile was identified as an outlier in the residual analysis discussed in the previous section) . Small advanced countries are in the middle of this elasticity distribution (South Korea, Singapore, Taiwan, and Belgium). To the extent that the influence of R&D of foreign owned subsidiaries located in the U.S. reflects reverse knowledge strategies, this further finding suggests that companies based in smaller countries have more to gain from flows of disembodied knowledge from the U.S. – as measured in BOP statistics – compared with companies from larger economies.[25]

[25] Formal tests exploring these descriptive observations such as adding size variables or dummies such as for G7 countries to model 5 RDT equations, however, did not reveal additional statistically significant results.

Figure 4-10 Percent change in exports of U.S. R&D services with respect to 1% change in prior year R&D stocks of foreign owned subsidiaries in the U.S., 2006-2011 (total elasticity = fixed + random)



RDT imports: fixed slopes

The estimated elasticities with respect to R&D stocks of MNC subsidiaries are smaller for RDT imports compared to RDT exports. A 1% increase in the stock of R&D by MOFAs of U.S. MNCs abroad (RDMOFAS) in year t-1 is associated with 0.33% increase in year t RDT imports, all else equal (see also Table 4-1 and related text). This effect is consistent with reverse knowledge transfer (RKT) by U.S. MNCs implied by hypothesis 4. At the same time, an increase of 1% in the stock of R&D of foreign owned subsidiaries located in the U.S. (RDFDIUS) in year t-1 is also positively related with U.S.

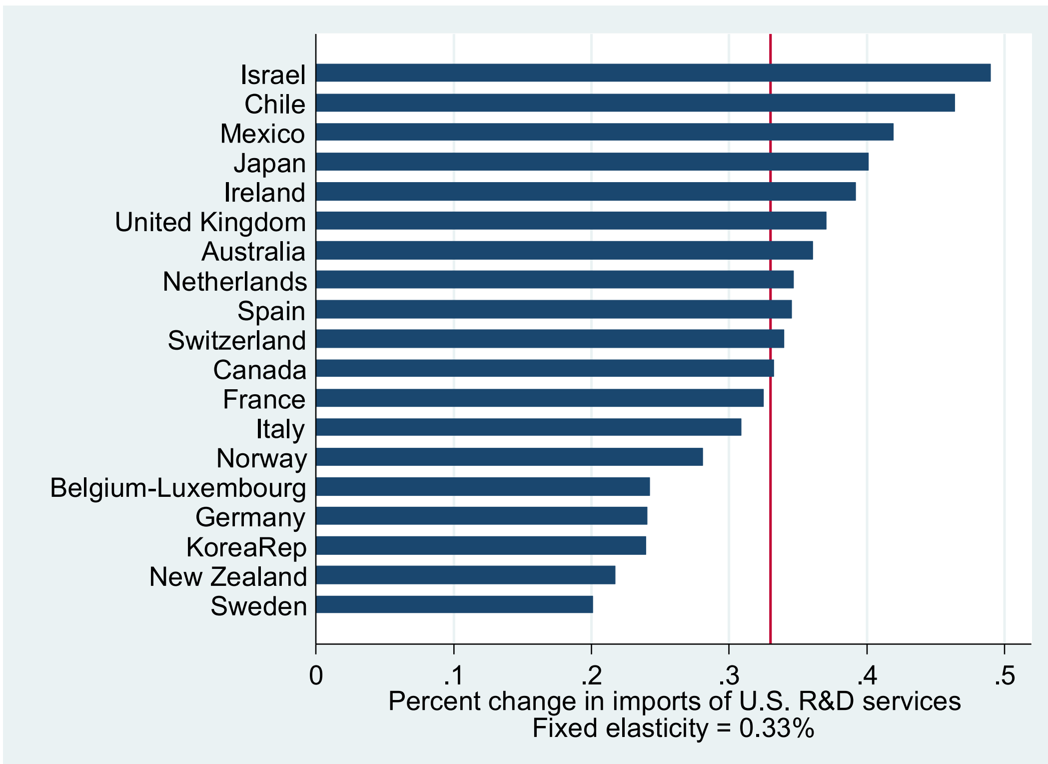
RDT imports, resulting in a 0.13% in in U.S. RDT imports in year t within the sample period. Recall from chapter 3 that this study did not propose a predicted sign for this variable in reference to U.S. RDT imports since R&D by U.S.-located foreign-owned subsidiaries may be a complement or substitute to inflows of R&D services. The estimated positive sign is another example of an apparent complementary relationship between incoming flows and local R&D.

RDT imports: random slopes

Similar to the analysis of exports, the random intercept/random slopes MNC-trade model for RDT services imports allows analyzing country specific effects of stocks of MNC R&D, in this case foreign subsidiaries of U.S. MNCs (RDMOFAS), as shown in Figure 4-11. In this figure, countries are both host of U.S. MOFAs and the source of U.S. RDT imports. Figure 4-11 shows that for RDT imports, estimated elasticities (fixed plus random) with respect to RDMOFAS by country do not exceed 0.5%. Also note that there is no apparent pattern among countries (e.g., large vs. smaller economies) in their relative size of elasticities.

Figure 4-11

Percent change in imports of U.S. R&D services with respect to 1% change in prior year R&D stocks of foreign subsidiaries of U.S. MNCs, 2006-2011 (total elasticity = fixed + random)



Discussion of other results

The effect of MNC R&D operations have somewhat larger point elasticities (based on fixed slopes) in the final RDT exports equation compared with the final estimated imports equation, but their 95% estimated confidence intervals overlap, i.e., they are not statistically different from each other. Similarly, within each RDT equation, the elasticities of U.S. MNCs' MOFA activity and foreign-owned subsidiaries R&D stocks were within each other's confidence intervals.

The point estimates for the effect of geographic distance are negative but not significant in the final specification. This finding suggests that internalizing R&D flows via FDI/MNC activity overcomes geographic localization of knowledge, consistent with learning and organizational theories of MNCs discussed in chapter 2. Nevertheless, simple measures such as geographic distance are not always good proxies for transfer and coordination costs. Secondly, in light of well-known difficulties to share or transfer tacit knowledge without face to face contacts, the insignificance of geographic distance in U.S. R&D services trade further suggests that these flows are closer to (easier to transfer) codified knowledge (thus probably closer to 'Development' rather than to 'Research'). The latter observation suggests the need to enhance statistics on R&D services trade with details on the type of R&D activities involved in these exchanges.

RDT trade equations show a rather high elasticity with respect to the proxy for overall openness to trade (total merchandise/services exports plus imports as percent of GDP). This result is consistent with complementarity between trade and technology diffusion, discussed elsewhere in the context of embodied technology trade (e.g., OECD 2008a). In the RDT exports equation the coefficient for country-level foreign patents registered at the USPTO has a 'wrong' negative sign (as a proxy for technological capacity of trading/investment countries) and it is not significant. Lastly, in the RDT imports equation, the difference in corporate taxes between the U.S. and other countries shows a highly significant negative elasticity greater than one. Based on the definition of the variable, countries with a smaller overall corporate tax rate compared with the U.S. in year t-1 receive less RDT imports in year t, all else equal, within the sampling period.[26]

In sum, reverse knowledge transfer (RKT) was observed in total U.S. RDT exports for 2006 to 2011 to the extent that R&D stocks of foreign owned subsidiaries with U.S. activities show an economically and statistical significant impact on RDT exports, with an elasticity of 0.51% over this period for 23 countries. However, the statistical significance of the influence of R&D stocks of foreign-owned MNC subsidiaries in U.S. RDT exports is not robust across several estimation techniques. R&D stocks of MOFAs of U.S. MNCs were associated with an elasticity of 0.33% on total U.S. RDT imports, also reflecting subsidiary to parent or RKT flows, for 19 countries with a full set of explanatory variables for the import equation. Further, the statistical significance of MOFA R&D stocks in U.S. RDT imports was robust across several estimation techniques.

Conclusion

The empirical work supported hypothesis 1, the positive relationship of R&D by foreign owned subsidiaries in the U.S. (RDFDIUS) with exports of R&D and testing (RDT)

[26] As discussed in Chapter 3 (Control Variables section), the difference in statutory corporate taxes is no more than a gross control for possible tax minimization behavior that may be captured in reported trade data. Further, the estimated negative elasticity applies to all companies contributing to aggregate U.S. RDT imports, including U.S. MNCs, foreign-owned MNCs with U.S-located subsidiaries, and non-MNCs that engage in R&D services trade, even though relative corporate taxes are likely to affect these companies differently. Indeed, to account systematically for the role of taxes in R&D services trade requires more granular data and the consideration of effective rates that are affected by general tax credits, R&D tax credits, and foreign tax credits (which themselves have an R&D component), and perhaps also control for withholding taxes for royalties.

services and hypothesis 4, the positive relationship of R&D by foreign subsidiaries of U.S. MNCs (RDMOFAS) with RDT services imports. Together they suggest that MNC activity have indeed an economically and statistically significant effect on trade in R&D services. Both of these hypotheses are consistent with reverse knowledge transfer (RKT) and 'home-base augmenting' (HBA) MNC strategies from R&D management and FDI in R&D literatures, while extending previous work to a) bilateral aggregate flows of disembodied technology, b) taking into account the simultaneous effects of two types of MNC subsidiaries associated with a given reference country. However, the statistical significance of the influence of R&D stocks of foreign-owned MNC subsidiaries in U.S. RDT exports (hypothesis 1) was not robust across several estimation techniques. Two additional results (the statistically significant positive relationship between U.S. RDT exports and RDMOFAS, and between U.S. RDT imports and RDFIUS) suggest complementarity between incoming cross-border RDT and local MNC R&D operations. The latter complementarity relationships at the country level are newly identified examples of interdependencies between local capabilities and acquisition of external knowledge studied elsewhere (e.g., Cassiman & Veugelers, 2004) but not documented before with balance of payment statistics. On the other hand, the subsidiary MNC value added (VA) variables (VAFDIUS and VAMOFAS) do not have the expected signs or are not statistically significant at conventional levels in the final specifications. Therefore, there is no statistical support for hypotheses 2a and 3a. In turn, their sister hypotheses 2b and 3b are deemed inconclusive. The latter suggests no support for traditional knowledge transfer or home-base exploiting (HBE) as conceptualized and empirically tested here.

Chapter 5: Conclusion

The first two sections of this concluding chapter revisit the research questions and findings, and summarize limitations of this study. The third section discusses the relevance of this study for official statistics on globalization, intangibles, and national accounts. The fourth section suggests how the approach to analyze intangibles trade developed here may be incorporated in S&T policy analysis. The last two sections discuss future research and data needs, and conclude the study.

Research Questions and Findings

The present study was based on a conceptual premise regarding intangibles trade inspired by trade, MNC, and innovation theories, leading to two research questions and four hypotheses. The main conceptual premise –that MNC operations have a substantial effect on aggregate cross-border flows of disembodied knowledge– was supported by findings based on a 2006-2011 panel of bilateral trade in R&D services based on U.S. BOP statistics. The conceptual framework and the hypothesized model (see Figures 2-1 and 3-6 and related text) integrated international business theory on MNC subsidiaries, reverse knowledge transfer (RKT), and FDI in R&D strategies with considerations from traditional trade theory (distance and transactions costs) and new trade theory that recognizes two-way, intra-firm trade from a macro perspective.

The first research question addressed the role of FDI in R&D in cross-border flows of disembodied technology in the form of R&D services. The empirical work supported two hypotheses (1 and 4) that together suggest MNC subsidiary activity has an economically and statistically significant effect on trade in R&D and testing (RDT) services, though the statistical significance of the influence of R&D stocks of foreign-owned MNC subsidiaries in U.S. RDT exports (hypothesis 1) was not robust across several estimation techniques. As explained in chapter 4, both of these hypotheses are consistent with reverse knowledge transfer (RKT) and 'home-base augmenting' (HBA) FDI by foreign-owned MNCs with U.S.-located subsidiaries and by U.S. MNCs.

Regarding the second research question on the extent that different MNCs subsidiaries affect intangibles trade, the significance of the activities of both MNC subsidiary groupings (based on foreign vs. domestic ownership) suggest that *investigating trading partner countries simultaneously as host and investing countries is an important feature of cross-border flows of intangibles*. Further, the random coefficients of R&D by foreign owned subsidiaries in the U.S. (RDFDIUS) in the RDT exports equation and of R&D by foreign subsidiaries of U.S. MNCs (RDMOFAS) in the RDT imports equation revealed different patterns in country-specific effects. On the other hand, (the fixed component of) the coefficients of MNC R&D stocks (of U.S. MNCs' MOFA activity and of foreign-owned subsidiaries) within and across each RDT trade equation are not statistically different from each other.

The negative findings on the role of value added operations (hypotheses 2 and 3) suggest that home-base exploitation (HBE) or traditional technology transfer, as operationalized here, is not as important as knowledge augmenting in aggregate terms, using the U.S. as the reference country.

Two additional results [the statistically significant positive relationship between U.S. RDT exports and stocks of R&D performed by U.S. MNCs MOFAs (RDMOFAS), and between U.S. RDT imports and stocks of R&D performed by U.S.-located foreign owned subsidiaries (RDFIUS)] suggest complementarity between incoming cross-border RDT and local MNC R&D operations. The latter complementarity relationships at the country level are newly identified examples of interdependencies between local capabilities and acquisition of external knowledge studied in innovation and R&D management studies (e.g., Cassiman & Veugelers, 2004) but not documented before with balance of payment statistics.

Limitations

Perhaps the most important threat to the validity of findings concerns the measurement validity of the dependent variables, exports and imports of R&D services. It is well known that transactions involving R&D and other intangibles are not always recorded, especially within large, global companies where knowledge may be exchanged without a fee (OECD, 2010: paragraph 5.2 and Annex E of Chapter 2). Since most business R&D is produced and consumed internally, external or independent valuation of exchanges is often not possible *even in a domestic context*. Further, to the extent that MNCs engage in income shifting to minimize worldwide tax burden, transfer prices (non-market prices set for internal MNC transactions) are likely to distort reported trade. At the same time, R&D

performance statistics used as key explanatory variables have a long tradition of internationally comparable statistics from which trade in R&D services benefit to the extent that services trade surveys rely on standard definitions of R&D.

On the other hand, measures of both intra-MNC trade (dependent variables) and MNC R&D performance (explanatory variables) are affected by accounting practices such as cost-sharing arrangements and cost allocations that may or may not correspond with actual R&D performance or flows (or disembodied technology transfer more generally), quite apart from valuation issues addressed by transfer prices concerns (Benshalom 2007; IRS 2009; UNECE/OECD 2014, paragraphs 3.51 and 4.17). Second, differences across host country locations in terms of 1) accounting regulations, 2) corporate tax law, 3) foreign tax credits and related rules on R&D expense allocation, and 4) withholding tax on royalties further complicate business recordkeeping and reporting of intangibles for global companies (Hines & Jaffe, 2001). Given this environment, businesses may employ rules of thumb and allocation formulas for reporting purposes that may not capture the economic substance of a transaction or adequately identify economic ownership (where the latter refers to which party retains economic risk in a production or transaction) that in principle guides reporting of intra-MNC exports and imports (UNECE/OECD 2014). In sum, data used to compile MNCs statistics in FDI/MNCs, services trade, and business R&D surveys may suffer from a combination of unintended errors given the inherent organizational, accounting, tax, and legal complexity of internal records and survey response processes, separate from presumed tax minimization goals noted above, affecting negatively the reliability of measures studied here.

The generalizability of the results from this study is limited to the extent that it is based on a single reference country. Further, residual analysis suggests that results showing the economically significant role of MNCs in bilateral flows of intangibles apply more forcefully to two-way FDI in R&D and two-way trade among larger and more developed economies. On the other hand, future research based on statistics from other reference countries with significant MNC R&D activity may be able to replicate or otherwise build on these results. The 2008-2009 financial crisis is in the middle of the 2006-2011 sampling period, but this does not seem to have changed long term trends in RDT trade. In fact, overall there were little year-to-year changes within country panels, compared to differences across trading/investing countries averaged over time.

Findings from this study are subject to aggregation bias where coefficients from aggregate data may have different size, sign, or significance compared with regressions on individual units (Garrett, 2002). Therefore, microdata research should be part of a long-term research agenda on intangibles trade that jointly considers trade and MNC factors as developed in this study. At the same time, some measurement issues such as those affecting transfer prices are *likely to be as problematic with microdata as with aggregate statistics*.

Lastly, in this study threats to statistical conclusion validity from endogeneity due to omitted variables were handled by panel methods that allowed for individual effects (including random slopes in the final specification). Possible endogeneity of regressors from simultaneity of MNC operations and trade activity was handled by lagging continuous explanatory variables (though single lags allowed by modest sample size may not fully account for this source of endogeneity). Endogeneity resulting from measurement error in the dependent and explanatory variables, however, suggests that results are still subject to possible bias of unknown size and direction. Specification tests, model diagnostics, and robustness checks were performed in several model building blocks inspired from received theory that resulted in an integrated MNC-trade model. Notwithstanding statistical controls and testing described in chapter 4, other potential validity threats discussed in chapter 3 apply to the final findings of this study (e.g., mono-operation bias [single measure of disembodied technology], mono-method bias [exclusive use of econometric analysis]).

Official Statistics on Globalization, Intangibles, and National Accounts

Recently both globalization and intangibles or intellectual property products (IPP) have been particularly active topics at official statistical units and research centers in the U.S., EU, OECD, IMF, and in other countries/regions and international bodies working on measurement needs for policy design and analysis (Feenstra et al., 2010; IMF, 2009; Jensen, 2009; NRC, 2014; OECD, 2010 [IPP Manual]; UNECE et al., 2011). By itself, the cross-border organization of MNCs and innovation creates its own difficulties to measure and even conceptualize what is 'national' production, who produces what inside an MNC or within global value chains, and who is the economic owner that receives the benefits from production or trade activity (UNECE et al., 2011; UNECE/OECD, 2014; Yorgason, 2007).

A second, related topic is the global production and transfer of intellectual property products (IPP) such as R&D and the impact on national economic accounts (BEA, 2014; OECD, 2005; OECD (2010) [IPP Manual]; Yorgason, 2007). R&D has long been recognized as one source of both private and public benefits in the form of business competitive advantage and broad technological change driving national productivity growth. However, only since the 2008 revision of the System of National Accounts (SNA) manual (UN et al., 2009), has R&D been 'capitalized' or recognized as a fixed asset (a produced asset used in further production for more than one year, generating benefits to its owner) within GDP and other National Income and Product Accounts (NIPAs). The U.S. Bureau of Economic Analysis (BEA) fully implemented R&D capitalization in 2013 after almost ten years of collaborative development work with the National Science Foundation's National Center for Science and Engineering Statistics, the official source of U.S. statistics on national R&D performance and funding (BEA, 2013). Further, R&D and testing services trade statistics studied in the present work are currently used by BEA to add 'R&D imports' to 'R&D output' (to obtain domestic R&D supply), and deduct 'R&D exports' and other items, to obtain gross fixed capital formation of R&D (OECD (2010) [IPP Manual], section 2.1 page 18 and section 14.1 pages 54-58). However, U.S. RDT trade statistics have been submitted to little systematic study prior to this study. Perhaps predicted RDT trade, controlling for MNC operations of both foreign owned companies and MOFAs of U.S. MNCs (and other controls) can be used by countries that are capitalizing R&D to adjust historical data on RDT exports or imports for GDP purposes to, for example, account for non-R&D testing services included in historical RDT statistics, among other reporting issues.

Knowledge Flows in Innovation Policy

The most immediate policy implication of this thesis is the potential for enhanced monitoring of cross-border diffusion of disembodied technology captured in trade statistics. Given the role of R&D in global value chains and the fragmentation of innovation activities, a key policy question is how R&D is performed and deployed by MNCs and others across different global locations (NRC 2014, p. 67). A separate but related question is how international knowledge flows may impact local economic results, such as GDP, productivity, and employment, in source or recipient countries (Keller 2010, p. 824; NRC 2014, p. 67).

This study addressed the first subject by analyzing a little used indicator of *non-spillover* knowledge flows. In particular, the direction and character of U.S. R&D services trade appear to be closely related to MNC R&D investments and strategies. In turn, a better understanding of knowledge flows may be an input into research on impacts and policy design to monitor and promote technology diffusion.[27] Trade, including technology trade, is particularly important for smaller countries, and technology imports have been historically important for less developed economies (e.g., Lynn, 1998).

[27] Well-known market failures associated to R&D production also apply to R&D exchanges (Arrow, 1962). Yet S&T policy tools, such as R&D tax credits may emphasize support for internal knowledge production, not exchange, depending on their design elements. For international strategic, legal, and theoretical aspects of R&D subsidies see Brander (1995) and Caiado & Berghaus (2012).

However, although the importance of knowledge flows within innovation systems or networks have been recognized for many years within policy circles (e.g., OECD, 1999, OECD/Eurostat, 2005), international transactions in intangibles in the form of technical/engineering services and R&D services, have yet to be integrated in the mainstream S&T policy literature. For example, macroeconomic indicators of S&T flows such as technology balance of payments (TBP) are typically absent in policy-oriented discussions of S&T indicators (for notable exceptions see NRC, 2014, pp. 62-63, 65-67 and WIPO, 2011).[28] This is due to a combination of factors. S&T aspects of international trade and investment policy and international agreements have emphasized manufacturing activity, embodied technology trade, and patented knowledge (e.g., trade-related aspects of intellectual property rights [TRIPS]), not technical services such as R&D or engineering services. This is related to the fact that services statistics, even at the national or domestic level, are not as developed as statistics on manufacturing activity and related merchandise trade. R&D services transactions have been part of international statistics since at least the 2002 version of the Manual on Statistics of International Trade in Services (MSITS), but few countries publish R&D-related details on these statistics (exceptions are discussed in de Haan et al., 2007; Moris, 2009; and Schellings, 2004).

A more subtle implication from the present study is the following. International policy documents and economic development literature often address technological knowledge inflows to host countries, especially developing host countries, involving either spillovers

[28] Relatedly, international policy documents often emphasize knowledge spillovers (not disembodied technology trade) arising from the activities of MNCs as sources for economic growth (e.g., Science and Technology chapter in OECD Guidelines for Multinational Enterprises (OECD, 2011b)).

from MNC subsidiaries or foreign technology purchases among unaffiliated parties. Potential inflows to home countries considered in this thesis, as suggested by two-way trade/FDI and ‘reverse knowledge transfer’ (RKT), receive less attention. In particular, *disembodied technology imports in the form of RKT* associated with MNC activities should matter also for *developing countries* in light of increased ‘South-to-North’ FDI (UNCTAD, 2013; Yao & Wang, 2014).

Future Research and Data Needs

In terms of innovation strategies to acquire and develop, transfer, and exploit industrial knowledge, MNCs rely upon a combination of internal activities, exchanges with unrelated parties, and spillovers from the external local environment (Foss & Pendersen, 2002; Michailova & Mustaffa, 2012). Aspects of country-level intangibles trade suggested by MNC and international business theory that were not empirically addressed in this study include lateral or horizontal trade (cross-border subsidiary to subsidiary flows), the role of subsidiary embeddedness in generating knowledge flows, unaffiliated trade, and the interaction of internal and external innovation networks. Another related research area not addressed in this study is the difference between acquisition of disembodied technology and actual local use and benefits such as increase in profits, labor productivity (at the country, industry, or firm level), or enhanced innovation outcomes such as increase in (quantity or quality of) subsequent patenting or larger market shares driven by new technology-based products (e.g., Fors, 1997; Keller, 2010).

Future research can also explore policy analysis needs and data challenges on R&D services and related indicators:

a) Characteristics of disembodied knowledge flows and relationship with other S&T activities

- Are flows of R&D services more or less concentrated in terms of industry classification, technology focus, company size, or geography compared with R&D production/performance? To what extent MNCs and non-MNCs vary in terms of these characteristics?
- What is the relationship between R&D *funding* by level of sending/recipient country and RDT services trade by sending/recipient country? (see IMF (2014), paragraph 12.138; NRC (2014): 65-67; UNECE/OECD (2014) paragraphs 4.17, 4.29(c), 3.48, 3.51, 11.13(d);)
- What is the extent of cross-border cash grants and in-process or completed R&D transferred without a fee, as in-kind grants or transfers, within MNCs? (IMF, 2009 [BPM6] paragraph 12.1; UNECE/OECD (2014) paragraph 4.17)
- What is the relationship between affiliated trade in R&D services and affiliated cross-border royalties and license fees? How do transfer price issues vary across exchanges of different types of IPP? How do transfer price issues vary across parents of domestically-owned MNCs and resident foreign-owned companies?

b) Adequacy of policy tools

- To what extent are differences in observed cross-border flows identified in (a) the result of purposeful innovation strategies across industries or forms of disembodied technology vs. difficulties/barriers in exchanging IPPs (market or innovation system failures)?[29]

- Should incentives to R&D production be extended to R&D performed overseas by U.S. MNCs if output is intended to support U.S. product development (resulting in R&D imports)?
- What are the domestic economic benefits (or disadvantages) from exported R&D?
- Should RDT imports or exports be subsidized? Should RDT trade incentives (if any) vary by company size, age and company structure (independent startups vs. established companies or MNC subsidiaries), or industrial focus of recipient or sender?

c) Data development needs and guidance on official statistics on intangibles

Data improvements may facilitate incorporating research along the lines pursued in this study in broader policy analysis and policymaking. First, efforts to enhance *domestic services statistics* in the U.S. (Bosworth & Triplett, 2007) should specifically incorporate tracking production and transactions in *intangibles and knowledge intensive services*. Secondly, enhancements on *domestic services statistics* are often disconnected from improvements or continuing needs on *international service statistics and services offshoring* (Hoekman & Stern, 1991; Houseman & Ryder, 2010; Jensen, 2009; Sturgeon, 2006; United Nations Statistical Commission, 2012), especially those involving *flows of*

[29] In particular, two recent topics in innovation systems research have so far been studied separately. On the one hand, some studies acknowledge international innovation systems, especially in the EU context (Archibugi & Iammarino, 1999; Meyer-Krahmer & Reger, 1999; Soete et al., 2010). Other work emphasizes 'systemic failures' (Wieczorek & Hekkert, 2012) involving difficulties in interaction and knowledge flows among domestic system components such as university and business sectors. This suggest the need for systems research to identify system 'failures' in an international context to investigate the adequacy of policy tools for cross-border technology transfer.

disembodied knowledge.[30] Though the classification of services in the UN's Central Product Classification (CPC) version 2 appears to reflect R&D-related updates in BPM6 and has been otherwise reconciled with the Extended BOP Services Classification System (EBOPS) in the 2010 MSITS, it is unclear to what extent domestic surveys on services are consistent with international transaction surveys counterparts within the same country in the area of intangibles.[31] Consistency between domestic and international services statistics in this area is necessary to support *policy tools to jointly address* national and international aspects of innovation systems.

In terms of future research questions noted above, the first three under (a) likely requires microdata survey links within countries involving business R&D surveys, FDI/MNC surveys, and international services trade surveys (e.g., Moris, 2012). These links are not only substantively complex but also logistically difficult when surveys are conducted by separate agencies. And data needs on industry, country, and ownership information for intangibles trade imply larger sample sizes and survey resources. Possible research questions on transfer prices (the last bullet under (a)) involve expertise in international business accounting and corporate tax law as summarized earlier in this chapter, well beyond survey methodology and statistical issues. Interdisciplinary and multi-agency

[30] For example, the 2010 MSITS (UN et al., 2011) calls for collecting separately licensing vs. outright IP purchases and R&D services vs. non-R&D testing services (see also United Nations Statistical Commission, 2014). These changes support data needs for R&D capitalization discussed earlier.

[31] For more on CPC version 2 see http://unstats.un.org/unsd/cr/registry/cpc-2.asp; BPM6 paragraph 10.61 and Appendix 7; and 2010 MSITS paragraphs 2.47 - 2.49, 2.63, and 3.47. For more on EBOPS see 2010 MSITS paragraph 2.63, chapter III sections F and G, and Annex I. For a reconciliation of CPC version 2 and the 2010 EBOPS see http://unstats.un.org/unsd/tradeserv/TFSITS/msits2010/annexes.htm. For information on the North American Product Classification System (NAPCS) see http://www.census.gov/eos/www/napcs/. For a discussion of IP in the North American Product Classification System see Mohr & Murphy (2002).

research support may be able to target this expertise to advance data development on MNC's R&D and intangibles trade.

Further survey development (e.g., new or modified survey questions) implementing recent updates in international guidance for R&D/IPP production and trade is needed to explore the above questions across countries. See examples of possible survey questions in Annexes C and E of chapter 2 in OECD (2010). See also UNECE/OECD (2014); UN et al. (2011) [2010 MSITS]; and UNECE et al. (2011).[32] Data limitations also affect country comparability and broader use of intangibles trade statistics. For example, the OECD publishes TBP statistics only as the sum of transactions in R&D services, computer services, engineering services, royalties and license fees, and other items. These figures are too aggregate for meaningful S&T policy and economic analysis. More importantly, these cross-country statistics are apparently compiled based on guidance from the TBP Manual (OECD, 1990) that has been outdated by changes in the statistical trade and globalization manuals cited here. The forthcoming revised Frascati Manual (OECD guidance for R&D statistics) will feature a new chapter on R&D globalization taking into account these updates (OECD, 2015). Intra-country and cross-country collaboration on R&D, FDI, and trade statistics will be required over the long term to address challenges for national statistical offices and company respondents everywhere.[33]

[32] Countries are starting to implement MSITS guidance on IPP in their international accounts. For ongoing and planned updates in the U.S. see http://www.bea.gov/international/modern.htm. For information on international collaboration in this area see https://www.imf.org/external/np/sta/itserv/methdev.htm.

[33] In some countries, the international transactions reporting system (ITRS), an example of administrative information based on foreign exchange records from "banks and companies at the level of individual transactions" (IMF 2014, paragraph 4.2), can complement services trade surveys. For example, ITRS may be used to track current transfers to government received through the banking system (IMF 2014, paragraphs 12.150, 12.157). However, further investigation is warranted since current reporting thresholds and activity detail may not support data needs on R&D services (IMF 2014, paragraph 12.141).

Questions regarding possible policy tools to facilitate cross-border knowledge flows under (b) above are intertwined with more general, unresolved policy questions on the domestic impact of MNC activities. For example, to what extent overseas R&D by domestically owned companies substitutes for or complement R&D performed in home countries, and in turn impact domestic jobs and wages (Slaugther, 2014). Enhanced measures and research on international knowledge flows and their relationship with R&D performed domestically and overseas may facilitate evidence-based policy measures addressing these complex policy questions.

Conclusion

In light of the public goods aspects of disembodied knowledge and related market imperfections, cross-border intangibles trade in the business sector occurs mostly within MNCs. Yet, in spite of the apparent importance of MNCs activities for subsequent transactions of intangibles, previous studies on intangibles trade (or 'technology balance of payments' (TBP) or its components) have not considered the operations of MNC subsidiaries as explanatory variables. Theoretically, the thesis introduced the concept of intra-MNC 'reverse knowledge transfer' from international business research to the study of bilateral intangibles trade. As an example of reverse knowledge transfer, a U.S.-located European-owned subsidiary may perform basic research as input for further pharmaceutical R&D by the MNC parent company and possibly also by units elsewhere. In international trade, reported fees for R&D outcomes between an affiliate abroad and the MNC parent are part of total R&D services transactions published in balance of payments statistics. This thesis also extended work on bilateral diffusion of disembodied technology to take into account the simultaneous effect of separate groupings of MNC subsidiaries (domestic vs. foreign owned) and their underlying strategies for FDI in R&D, as well as the simultaneous role of countries as trade partners and host or investing countries.

The main conceptual premise of this study –that operations of MNC subsidiaries have a substantial effect on cross-border flows of disembodied knowledge– was supported by empirical findings linking micro research on MNC knowledge flows to bilateral aggregate flows of disembodied technology. In particular, U.S.-owned MNCs subsidiaries abroad and U.S.-located subsidiaries of foreign MNCs appear to engage in knowledge seeking R&D investments that influence transactions captured in balance of payment statistics, though the statistical significance of the influence of R&D stocks of foreign-owned MNC subsidiaries in U.S. exports of R&D services was not robust across several estimation techniques. At the same time, value added operations of MNC subsidiaries were not statistically significant, failing to support home-base exploiting as modeled here. Some of the validity threats such as modest sample size and aggregation bias may be addressed by future research using microdata. On the other hand, measurement errors on market-based knowledge flows involving transfer prices and missing transactions are likely to be as problematic with microdata, underscoring needs on data development at all levels of aggregation.

More generally, the present study suggests that a systematic theory of intangibles trade and knowledge transfer at the country level should incorporate macro and microeconomic theories of trade, MNCs, and innovation. Any such theory should be empirically consistent with observed data (two-way FDI in R&D among advanced economies; two-way intra-MNC flows of knowledge that dominate country-level flows; and external collaboration and exchanges), recognize the coexistence of different firm-level strategies to develop and exploit knowledge across borders, and incorporate multiple roles of geography in intangibles trade. The simple MNC-trade model of intangibles trade proposed and tested in this study should be considered only a first step in a larger research agenda along the lines summarized here. Further, aggregate characterizations modeled in this study can complement firm-level research based on proprietary/confidential or case specific data as an input into policy analysis and policymaking in the area of intangibles flows. Secondly, analysis of aggregate R&D services trade may complement studies on industrial knowledge flows based on other S&T statistics (e.g. patent royalty and license fees, patent citations, S&T worker mobility, offshoring of other technical services) or empirical methodologies (e.g. spillovers), and enhance the ability to regularly monitor and analyze trade in disembodied knowledge much as it is done with other globalization indicators such as trade in high-tech products. Enhanced statistics on IPP-related services at the domestic level and internationally, along with microdata linkages involving FDI, R&D, and services trade surveys, are also necessary to 1) further study trends in this area, 2) identify possible systemic failures or inefficiencies involving interaction across and within innovation networks, and 3) explore the design or modification of S&T policy tools to further support global innovation and knowledge flows involving the business sector.

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Appendix

Table A1. OLS and panel data analysis of U.S. exports of R&D services: models 1 (quasi-gravity trade) and 2 (FDI)

Models 'a': dependent variable = log U.S. RDT exports	1a OLS	1a FE	1a RE_FGLS	2a OLS	2a FE	2a RE_FGLS
log distance	-1.062		-0.953*			
dummy contiguous country	-2.691*		-2.633**			
dummy English language	0.651		0.828			
log trade/GDP(%)	2.078	2.118	2.480*			
log GDP	1.227*	2.267*	1.312**			
log USA GDP	1.506		1.861			
log corptax(USA/country)	0.210	-0.978	-0.720			
log R&D/GDP ratio				1.132*	0.856	1.135***
log inward FDI/GDP%				0.528*	0.059	0.371***
log outward FDI/GDP%				0.309	-0.048	0.297
Constant	-35.550	-33.943*	-44.970*	0.673	4.510*	1.316
year effects	Yes	Yes	Yes	Yes	Yes	Yes
r2	0.429	0.329		0.710	0.314	
r2_a	0.367	0.277		0.691	0.269	
Rmse	1.569	0.373	0.404	1.064	0.378	0.422
Aic	433.729	104.245	.	393.834	122.395	.
Bic	466.458	126.064	.	419.642	145.336	.
r2_w		0.329	0.324		0.314	0.285
r2_b		0.220	0.424		0.428	0.729
r2_o		0.220	0.419		0.417	0.706
chi2			91.542			325.941
P	0.000	0.000	0.000	0.000	0.000	0.000
N	113.000	113.000	113.000	130.000	130.000	130.000
F	11.532	7.339		35.276	15.971	
df_m	11.000	7.000	11.000	8.000	7.000	8.000
df_r	18.000	18.000		21.000	21.000	

Table A2. OLS and panel data analysis of U.S. exports of R&D services: models 3 (S&T) and 4 (MNCs)

Models ‘a’: dependent variable = log U.S. RDT exports	3a OLS	3a FE	3a RE_FGLS	4a OLS	4a FE	4a RE_FGLS
log busR&D exMOFARD	-0.028	0.193	0.134			
log USbusR&D exFDIUSRD	-82.019**	-26.279	-35.134*			
log S&E papers	-0.470	1.020	0.066			
log USPTO patents	0.634	-0.047	0.333			
log R&D stock MOFAS				0.397	0.866*	0.769***
log R&D stock FDIUS				0.355*	-0.019	0.090
log Value Added MOFAS				0.123	0.050	0.160
log Value Added FDIUS				0.066	-0.011	0.012
Constant	1015.968**	317.865	433.797*	-1.883	-1.627	-2.878
year effects	Yes	Yes	Yes	Yes	Yes	Yes
r2	0.453	0.347		0.725	0.364	
r2_a	0.416	0.302		0.705	0.319	
Rmse	1.468	0.358	0.394	1.035	0.361	0.401
Aic	525.171	120.018	.	407.878	116.952	.
Bic	554.800	146.683	.	437.077	143.232	.
r2_w		0.347	0.334		0.364	0.354
r2_b		0.231	0.385		0.629	0.691
r2_o		0.233	0.382		0.615	0.674
chi2			111.378			170.135
P	0.000	0.000	0.000	0.000	0.000	0.000
N	143.000	143.000	143.000	137.000	137.000	137.000
F	15.105	11.416		12.809	12.976	
df_m	9.000	8.000	9.000	9.000	8.000	9.000
df_r	23.000	23.000		22.000	22.000	

Table A3. OLS and panel data analysis of U.S. exports of R&D services: model 5 (MNC-trade model)

Models 'a': dependent variable = log U.S. RDT exports	5a OLS	5a FE	5a RE_FGLS	5a RE_MLE	5a RE_RIRS
log R&D stock MOFAS	0.380	0.778	0.708**	0.709***	0.631*
log R&D stock FDIUS	0.373*	-0.021	0.102	0.101	0.513**
log Value Added MOFAS	0.194	0.045	0.215	0.214	0.352
log Value Added FDIUS	0.173	-0.021	0.039	0.039	-0.014
log distance	0.222		0.027	0.025	-0.026
log trade/GDP(%)	0.785**	1.448	0.805*	0.806*	0.745***
log USPTO patents	-0.153	0.018	-0.021	-0.021	-0.229
Constant	-7.861*	-7.278	-6.885	-6.868	-7.471**
sigma_u					
Constant				0.912***	
sigma_e					
Constant				0.383***	
lns1_1_1					
Constant					-1.213***
lns1_1_2					
Constant					0.051
atr1_1_1_2					
Constant					-10.818
lnsig_e					
Constant					-0.988***
year effects	Yes	Yes	Yes	Yes	Yes
r2	0.791	0.375			
r2_a	0.771	0.321			
Rmse	0.913	0.360	0.403		
Aic	376.192	118.518	.	237.423	233.275
Bic	414.152	150.638	.	281.223	282.915
r2_w		0.375	0.356		
r2_b		0.584	0.749		
r2_o		0.573	0.729		
chi2			227.765	81.951	6083.664
P	0.000	0.000	0.000	0.000	0.000
N	137.000	137.000	137.000	137.000	137.000
F	19.611	9.664			
df_m	12.000	10.000	12.000	12.000	12.000
df_r	22.000	22.000			

Table B1. OLS and panel data analysis of U.S. imports of R&D services: models 1 (quasi-gravity trade) and 2 (FDI)

Models 'b': dependent variable = log U.S. RDT imports	1b OLS	1b FE	1b RE_FGLS	2b OLS	2b FE	2b RE_FGLS
log distance	-0.635		-0.791			
dummy contiguous country	-1.255		-1.554			
dummy English language	1.386**		1.380**			
log trade/GDP(%)	1.704*	0.774	1.486*			
log GDP	1.170**	1.717	1.062***			
log USA GDP	4.663***		5.438***			
log corptax(USA/country)	-0.656	-1.758**	-1.431**			
log R&D/GDP ratio				0.608	0.985	0.749*
log inward FDI/GDP%				0.331*	0.133	0.271**
log outward FDI/GDP%				0.574**	0.415	0.596***
Constant	-88.680***	-20.521	-97.391***	0.373	1.915	0.531
year effects	Yes	Yes	Yes	Yes	Yes	Yes
r2	0.643	0.683		0.810	0.643	
r2_a	0.604	0.659		0.797	0.619	
Rmse	0.922	0.227	0.248	0.650	0.263	0.317
Aic	316.372	-8.141	.	267.577	28.198	.
Bic	349.207	13.748	.	293.454	51.199	.
r2_w		0.683	0.678		0.643	0.636
r2_b		0.298	0.621		0.750	0.811
r2_o		0.309	0.625		0.740	0.807
chi2			350.654			506.055
P	0.000	0.000	0.000	0.000	0.000	0.000
N	114.000	114.000	114.000	131.000	131.000	131.000
F	23.621	25.815		57.455	40.459	
df_m	11.000	7.000	11.000	8.000	7.000	8.000
df_r	18.000	18.000		21.000	21.000	

Table B2. OLS and panel data analysis of U.S. imports of R&D services: models 3 (S&T) and 4 (MNCs)

Models 'b': dependent variable = log U.S. RDT imports	3b OLS	3b FE	3b RE_FGLS	4b OLS	4b FE	4b RE_FGLS
log busR&D exMOFARD	-0.103	0.420	0.341			
log USbusR&D exFDIUSRD	-50.862**	-27.664***	-30.744***			
log S&E papers	0.529	1.935**	0.657*			
log USPTO patents	0.171	-0.312	-0.089			
log R&D stock MOFAS				0.525**	-0.079	0.355*
log R&D stock FDIUS				0.188	0.065	0.118
log Value Added MOFAS				0.281	0.419*	0.315
log Value Added FDIUS				-0.115	0.152	0.078
Constant	626.662**	326.542***	375.489***	-1.641	-0.214	-1.975
year effects	Yes	Yes	Yes	Yes	Yes	Yes
r2	0.568	0.722		0.823	0.638	
r2_a	0.539	0.703		0.811	0.612	
Rmse	0.966	0.238	0.270	0.617	0.268	0.297
Aic	408.388	2.445	.	268.018	35.570	.
Bic	438.086	29.173	.	297.291	61.916	.
r2_w		0.722	0.700		0.638	0.625
r2_b		0.445	0.488		0.641	0.824
r2_o		0.446	0.504		0.628	0.806
chi2			281.504			390.328
P	0.000	0.000	0.000	0.000	0.000	0.000
N	144.000	144.000	144.000	138.000	138.000	138.000
F	37.223	34.433		34.443	39.291	
df_m	9.000	8.000	9.000	9.000	8.000	9.000
df_r	23.000	23.000		22.000	22.000	

Table B3. OLS and panel data analysis of U.S. imports of R&D services: model 5 (MNC-trade model)

Models ‘b’: dependent variable = log U.S. RDT imports	5b OLS	5b FE	5b RE_FGLS	5b RE_MLE	5b RE_RIRS
log R&D stock MOFAS	0.427	0.063	0.286	0.297*	0.332*
log R&D stock FDIUS	0.142	0.044	0.100	0.104	0.131*
log Value Added MOFAS	0.155	0.150	0.228	0.232	0.182
log Value Added FDIUS	0.089	0.139	0.130	0.127	0.152
log distance	-0.185		-0.161	-0.153	-0.063
log trade/GDP(%)	0.120	1.085	0.671	0.637	0.951**
log corptax(USA/country)	0.048	-1.701*	-1.238**	-1.151**	-1.257***
Constant	-0.084	-2.418	-2.059	-2.123	-4.357
sigma_u					
Constant				0.585***	
sigma_e					
Constant				0.242***	
lns1_1_1					
Constant					-2.523***
lns1_1_2					
Constant					-19.437
lnsig_e					
Constant					-1.457***
year effects	Yes	Yes	Yes	Yes	Yes
r2	0.844	0.686			
r2_a	0.825	0.652			
Rmse	0.613	0.229	0.253		
Aic	224.052	-3.138	.	98.500	93.357
Bic	259.623	26.960	.	139.543	134.400
r2_w		0.686	0.675		
r2_b		0.646	0.816		
r2_o		0.641	0.806		
chi2			559.816	138.899	4489.583
P	0.000	0.000	0.000	0.000	0.000
N	114.000	114.000	114.000	114.000	114.000
F	45.094	38.704			
df_m	12.000	10.000	12.000	12.000	12.000
df_r	18.000	18.000			

Table 3-2. Correlation coefficients (pairwise correlations with maximum N = 144) for all variables except two dummies (English language and contiguous country)

Dependent variables: U.S. RDT exports, U.S. RDT imports

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	log U.S. RDT exports	1.0000																	
2	log U.S. RDT imports	0.7567*	1.0000																
3	log R&D stock MOFAS	0.7966*	0.8864*	1.0000															
4	log R&D stock FDIUS	0.8175*	0.7982*	0.8051*	1.0000														
5	log Value Added MOFAS	0.6564*	0.7388*	0.7134*	0.6628*	1.0000													
6	log Value Added FDIUS	0.7811*	0.7391*	0.7981*	0.9154*	0.6847*	1.0000												
7	log busR&D exMOFARD	0.4469*	0.6089*	0.6911*	0.5545*	0.4309*	0.5235*	1.0000											
8	log USbusR&D exFDIUSRD	0.0476	0.1481	0.1701*	0.0864	0.0172	-0.0088	0.0316	1.0000										
9	log S&E papers	0.4242*	0.6492*	0.7188*	0.5942*	0.5769*	0.5727*	0.9267*	-0.0081	1.0000									
10	log USPTO patents	0.5736*	0.6358*	0.7401*	0.7288*	0.4298*	0.6702*	0.8773*	-0.0048	0.8359*	1.0000								
11	log distance	-0.3140*	-0.4118*	-0.3421*	-0.3392*	-0.5400*	-0.4114*	-0.0200	0.0166	-0.1657*	-0.0712	1.0000							
12	log trade/GDP	0.2535*	0.0455	0.1056	-0.0383	-0.0746	0.0002	-0.2440*	0.0394	-0.3204*	-0.0836	0.0344	1.0000						
13	log GDP	0.2090*	0.4971*	0.5066*	0.3437*	0.5604*	0.3341*	0.8326*	0.0332	0.8512*	0.5862*	-0.1400	-0.4615*	1.0000					
14	log USA GDP	0.1116	0.2211*	0.2315*	0.1691*	0.0821	0.0670	0.0778	0.9408*	0.0449	0.0644	0.0000	0.0346	0.0729	1.0000				

15	log corptax (USA/country)	-0.0096	-0.1914*	-0.2545*	-0.2043*	-0.1257	-0.3213*	-0.6493*	0.1344	-0.6275*	-0.5276*	0.0161	0.5213*	-0.5360*	0.1084	1.0000			
16	log R&D/GDP	0.6094*	0.4742*	0.6295*	0.6247*	0.1652	0.5100*	0.5630*	0.0162	0.4753*	0.7781*	0.0720	0.0985	0.0468	0.0527	-0.3047*	1.0000		
17	log inward FDI/GDP	0.8116*	0.8378*	0.8623*	0.8987*	0.7770*	0.9371*	0.6760*	-0.0032	0.7232*	0.7882*	-0.4136*	-0.0037	0.5066*	0.0753	-0.3622*	0.5418*	1.0000	
18	log outward FDI/GDP	0.5040*	0.6964*	0.5796*	0.4565*	0.7785*	0.5230*	0.3929*	0.0417	0.5151*	0.3326*	-0.4238*	0.0609	0.5759*	0.0880	0.0352	-0.0555	0.6550*	1.0000