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Three Essays on International Technology Transfer

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Abstract

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Three Essays on International Technology Transfer

Thesis directed by Professor Wolfgang Keller

The transfer of technology is central to modern economic discourse because of its implications for economic growth and long-run convergence of incomes. In this dissertation, I investigate questions on channels and modes of technology transfer, analyzing cross-border flows of goods, ideas and people.

In the first chapter, I examine the significance of technological distance for the mode of international knowledge transfer within multinational corporations. The technology transfer within multinationals can happen directly, when the affiliate licenses the technology from the parent, or indirectly, when the affiliate imports intermediate goods with embodied technology. This paper estimates the effect of the affiliates' productivity relative to the frontier – the technology gap – on the choice to license the technology or import it through intermediate goods. The main finding is that a large technology gap of an affiliate favors indirect knowledge transfer through imports.

In the second chapter, we examine (with Wolfgang Keller) the importance of cross-border labor flows for innovation. Face-to-face communication may be particularly important for the transfer of technology because technology is best explained and demonstrated in person. This paper studies the role of short-term cross-border labor movements for innovation by estimating the recent impact of U.S. business travel to foreign countries on their patenting rates. The results indicate that business travel has a significant effect on patenting rates

above and beyond technology transfer through the channels of international trade and foreign direct investment. This study provides initial evidence that international air travel may be an important channel through which cross-country income differences can be reduced.

In the final chapter I analyze whether short-term labor movements matter for technology sourcing from abroad. As knowledge creation is concentrated in several countries, it is especially important for developing countries to tap into foreign knowledge. This paper focuses on a novel channel of technology sourcing: international business travel. Business travelers coming to a high-technology country can learn about technological knowledge through face-to-face communication and bring it back to their home country. This paper finds that business travel to the U.S. from foreign countries increases their domestic innovation.

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Contents

1 "Technology Gap and International Knowledge Transfer: New Evidence from the Operations of Multinational Corporations"

1.1 Introduction

There has been a significant increase in the levels of global trade in goods and services. Two components of this increase are noteworthy: currently, global trade in ideas is reaching annual levels of $200 billion (World Development Indicators),[1] and trade in intermediate inputs comprises 57% of total trade in goods in OECD countries (Miroudot, Lanz and Ragoussis 2009).

The United States is a major seller of technology, accounting for around 50% of world royalties and license fee receipts (World Development Indicators), and trade in intermediate inputs in the U.S. accounts for half of total trade in goods (Miroudot et al. 2009). U.S. Multinational Corporations (MNC) are important conduits of technology transfer, with around two-thirds of royalties and license receipts coming from intra-firm transactions and approximately 60% of total trade within U.S. multinationals being trade in intermediate inputs (The U.S. Bureau of Economic Analysis).

A MNC can transfer its technology to foreign affiliates in disembodied form (know-how, industrial processes, computer software) or in embodied form (intermediate inputs). Flows of royalty and license receipts from affiliates to parents for the use of intangible technology is evidence of disembodied technology transfer, while exports of goods for further processing from parents to affiliates can indicate embodied technology transfer. It is well known that

[1] Trade in disembodied ideas is measured by world receipts (or payments) of royalties and license fees.

technology transfer is an important determinant of long-term cross-country income, economic growth and convergence of countries. However, the mode of technology transfer in embodied versus disembodied form has a differential impact not only on access to current knowledge and economic growth, but also on innovation, economic welfare, and convergence. The history of the soft drink "Fanta", which was invented by the German affiliate of the Coca-Cola Company, offers one example. Possessing the recipe for Coca-Cola but lacking all the required ingredients due to a shortage in World War II-era Germany, Coca-Cola Deutschland invented this new soft drink by using the only available ingredients instead. In addition, the mode of technology transfer might also affect the degree of knowledge spillovers from multinational affiliates to domestic firms, which improves the productivity of the latter.[2]

What determines the mode of technology transfer within a MNC? This paper provides new evidence that the technology gap of U.S. MNC foreign affiliates, defined as their productivity compared to the productivity frontier, is associated with the decision of U.S. multinationals to export tangible goods versus intangible technology within the MNC. The example of Intel Corporation illustrates the hypothesis behind this paper. For 25 years, Intel Corporation has had plants in China where chips (intermediate goods) are shipped for assembly and testing. But in October 2010, the company announced the opening of a new wafer fabrication facility (fab) in China capable of using the blueprint to make the actual chips. At the same time, Intel announced the opening of a chip assembly factory in Vietnam (Takahashi 2010a; 2010b). One of the reasons why Chinese affiliates of Intel Corporation currently receive technology in the form of blueprints while Vietnamese affiliates receive technology

[2] See Keller (2010) for a survey of evidence on technology spillovers from international trade and foreign direct investment.

in the for of intermediate goods is that the former are currently closer to the productivity frontier, while the latter are farther from the frontier.

A panel data on the activities of U.S. multinationals in 47 host countries and across 7 manufacturing industries is employed to analyze the relationship between the affiliate's technology gap and the share of importing technology versus inputs. Focusing on the activities of U.S. MNCs is attractive as there is information on both the technology and input flows within firms. These data come from legally mandated benchmark surveys, conducted every five years by the Bureau of Economic Analysis (BEA), which enable the identification of U.S. parent-affiliate tangible and intangible technology transfers across FDI host countries and industries. The technology gap is measured as the deviation of the affiliate's labor productivity from the parent productivity in the same industry and year. The main finding of this paper is that the technology gap is negatively related to the share of disembodied versus embodied technology transfer, with a 10 percent increase in the technology gap on average decreasing the share of licensing versus importing inputs by 5 percent.

The significance of this paper stems from the realization that, based on industry patterns, MNCs tend to share know-how with country affiliates that are more productive, but export intermediate goods to the less productive ones. The fact that affiliates which are far from the frontier receive technology in the form of goods and not disembodied ideas, leads to policy implications that for developing less-productive countries the reduction in the technology gap would involve direct access to knowledge and ideas. This not only gives such countries access to current information, but also stimulates the creation of new knowledge which in itself is important for long-run economic growth and convergence.

The theory on multinational enterprises identifies horizontal and vertical directions for

Foreign Direct Investment (FDI). Horizontal FDI arises when multinationals replicate their production in host countries to gain market access (Markusen 1984), whereas vertical FDI arises when different stages of production are fragmented to take advantage of differences in factor prices (Helpman 1984), intra-industry considerations (Alfaro and Charlton 2009), or international transaction costs (Keller and Yeaple 2012).[3] Country empirical studies have found that market sizes, country similarity, factor endowments, and barriers to trade are among the most important determinants of FDI, while country-industry studies find that these factors have a differential impact on FDI in various industries.[4]

This paper contributes to the growing body of literature on vertical production sharing within multinationals, where part of production takes place locally in affiliates while the other is imported from parents (Hanson, Mataloni and Slaughter 2005; Fouquin, Nayman and Wagner 2007; Keller and Yeaple 2012). Hanson and coauthors find that MNC foreign affiliate's demand for imported inputs is higher in affiliate countries with lower trade costs, lower wages for less-skilled labor, and lower corporate income tax rates (Hanson, Mataloni and Slaughter 2005). Keller and Yeaple (2012) formalize and empirically confirm that knowledge intensity is another important determinant for the location of intermediate input production, where it is more difficult to transfer technology in more knowledge-intensive industries.[5] This paper differs from the work of Hanson and colleagues and Keller and Yeaple by employing a direct measure which differentiates between transfer of tangible intermediate inputs versus intangible technology from U.S. parents to affiliates.

[3] Ekholm, Forslid, and Markusen (2007) formalize "export-platform" FDI with both horizontal and vertical motivations.

[4] See Carr, Markusen and Maskus (2001), Bergstrand and Egger (2007), Brainard (1997) for country studies, and Helpman, Melitz and Yeaple (2004) and Awokuse, Maskus and An (2012) for country-industry studies.

[5] Keller and Yeaple (2008) provide key theoretical microeconomic foundations.

A second body of literature has documented the importance of productivity differences in subsidiaries of foreign companies for knowledge flows within MNCs.[6] Bjorn and coauthors find that the larger the technology gap, the more important the foreign parent as a source of codified knowledge, defined as patents, licenses and R&D (Bjorn, Johannes and Ingmar 2005). Their study used survey data for foreign firms in Eastern European countries, but did not include knowledge embodied in intermediate goods.[7] A related study by Driffield, Love and Menghinello (2010), finds that Total Factor Productivity (TFP) of foreign affiliates in Italy is important for technology transfer from affiliates to parents (sourcing), but not important for technology transfer from parents to affiliates (exploiting).[8] Using data on French multinationals, Fouquin, Nayman and Wagner (2007) find that labor productivity of countries is positively associated with imported-input demand for affiliates in developed countries, but is negatively related for affiliates in developing countries.

This paper adds to the first body of literature a relative measure of embodied and disembodied technology to empirical analysis of multinationals' vertical production networks. In relation to the second body of literature, this paper explicitly identifies two forms of knowledge transfer within MNCs and highlights within-firm productivity differences of affiliates as an important factor in determining the mode of technology transfer. As the decision of transfer occurs within the firm, affiliate productivity may be endogenously determined by MNCs. This is addressed in the present study relying on a theory of trade, FDI, and technology

[6] Martin and Salomon (2003) discuss general knowledge transfer capacities in multinational corporations.

[7] See also Gupta and Govindarajan (2000). Using country-level analysis, they find that knowledge flows within multinationals from home to host country are higher the lower the relative level of economic development of the host country (measured by GDP per capita).

[8] The survey used in Driffield et al. (2010) is based on a binary response to whether there was transfer of scientific and technological knowledge from parent to affiliate, which does not distinguish between tangible (intermediate goods) and intangible (patents, licenses, software) forms.

transfer (Keller and Yeaple 2012). Furthermore, across country and across year variation in labor productivity of affiliates of U.S. MNCs within the same manufacturing industry is used to identify not only the direction of the impact, but also parameter estimates. A limitation of this paper is the usage of aggregated country-industry level data due to inaccessibility of confidential firm-level data from the U.S. Bureau of Economic Analysis.

The remainder of the paper is organized as follows. The next section highlights the theoretical foundation. Section 3 presents the empirical estimation strategy and discusses estimation issues. Section 4 details data sources, variable construction, and descriptive statistics. The results are presented in section 5. Section 6 concludes.

1.2 Theoretical Foundation

The objective of this paper is to estimate whether there is a connection between the technological gap of MNC affiliates and the mode of international knowledge transfer from the multinational parents to affiliates across countries and industries. This paper focuses on one parent country's (the United States) affiliates abroad as it imposes certain homogeneity in terms of affiliate activities. Assume that U.S. multinationals decided where to locate their foreign affiliates.[9] The remaining decision involves the type of knowledge transfer, which is measured by the transfer of technology (know-how, industrial processes) versus intermediate goods from the U.S. parents to host country affiliates.[10] Direct measures of technology licensing payments and imports of goods for further processing are used to specifically pin

[9] Since the analysis in this paper is based on industry data, it prevents the study of questions related to the firm-level location decisions of the U.S. MNC affiliates abroad.

[10] This paper does not include arm's length technology transfer of U.S. multinational corporations to other unaffiliated domestic or foreign entities. Within-firm technology transfer in the form of intermediate inputs and ideas from U.S. parents to affiliates is the main focus of this paper. Other types of embodied technology might include capital goods and people, which are beyond the scope of this paper.

down the share of disembodied versus embodied technology transfer from the U.S. parents to affiliates. The technology gap of an affiliate is measured by the deviation of its labor productivity from the parent's labor productivity in the same industry and year.

The approach for estimating the relationship between the technology gap and international knowledge transfer is as follows. I specify that the share of technology transfer (in intangible and tangible forms) to an affiliate country c in industry i, TT_{ci} is a function Φ of the technology gap of an affiliate country c in industry i, TG_{ci} and of other observed and unobserved determinants, Z_{ci}:

$$TT_{ci} = \Phi(TG_{ci}, Z_{ci,}\Theta), \qquad (1)$$

where Θ is a vector of unknown parameters. The equation (1) can serve as a reduced-form of a model of technology transfer within multinational corporations. The theoretical model that motivates the empirical analysis that follows is based on Keller and Yeaple (2012). This model of trade, FDI, and international technology transfer builds on the transaction costs of international activities. There exist shipping costs to transfer intermediates that embody technological information from the U.S. parents to affiliates and communication costs to transfer disembodied technology. Shipping costs of moving goods across borders increase with distance from the parent, while communication costs of transferring disembodied technology are higher in more knowledge-intensive industries than in less knowledge-intensive industries.

According to this theory, it is harder to transfer technology in more knowledge-intensive industries because technology is tacit and hard to codify, which means it is best conveyed face-to-face.[11] In the absence of in-person communication, the technology transfer may be more imperfect the more knowledge-intensive the industry is. Multinational firms face a tradeoff between trade costs and technology transfer costs, which explains why there is a gravity of multinational sales, where affiliate sales fall with distance from the home country.

Since affiliate sales are positively related to productivity, this theory serves as a conceptual framework to explain what drives productivity differences across affiliate countries and industries. Trade costs and technology transfer costs increase with distance to the U.S., which is reflected in the lower productivity of affiliates. Furthermore, for a given distance from the U.S., a more knowledge-intensive industry, on average, receives lower affiliate sales (lower productivity). The theoretical framework suggests taking into account trade costs and technology transfer costs in driving productivity differences across host countries and industries. The following section discusses the empirical methodology.

1.3 Empirical Methodology

Based on the theoretical framework described above, the following estimation equation is employed:

$$Lic\_imp\_share_{cit} = \alpha + \beta TechGap_{cit} + \gamma X1_{cit} + \theta X2ct + \delta_c + \mu_t + \varepsilon_{cit}, \tag{2}$$

where c indexes affiliate countries, i indexes industries, t indexes time. Licensing-import share is defined as

[11] For a discussion of the importance of face-to-face communication for transfering technology, see for example Koskinen and Vanharanta (2002) and Hovhannisyan and Keller (2011).

$$Lic\_import\_share_{cit} = \frac{Royalty\_license\_\ receipts_{cit}}{Royalty\_licence\_receipts_{cit} + Exports\_goods\_manuf_{cit}}, \quad (3)$$

where royalties and license receipts of the U.S. parents from the affiliates is a measure of payments for the usage of disembodied technology, and U.S. exports of goods for further manufacture from U.S. parents to affiliates is a measure of embodied technology in the form of intermediate goods.

Technology gap is defined as

$$TechGap_{cit} = \frac{ParentLabprod_{it} - Labprod_{cit}}{ParentLabprod_{it}} \quad (4)$$

where $ParentLabprod_{it}$ is parent labor productivity in an industry and year, and $Labprod_{cit}$ is affiliate labor productivity in a country, industry and year.

Based on theory described above (Keller and Yeaple 2012), the productivity of affiliates falls with distance from the United States due to increasing trade costs and technology transfer costs. Furthermore, technology transfer in more knowledge-intensive industries is more costly than in less knowledge-intensive industries. Thus, the labor productivity of affiliates is weighted by the relative distance of the affiliate country from the U.S., as well as the relative knowledge-intensity of the industry. The weighted labor productivity $Labprod_{cit}$ is constructed as

$$Labprod_{cit} = \frac{1}{Dist_c \times KI_{it}} \times \widetilde{Labprod}_{cit} \quad (5)$$

where $Dist_c$ is geographical distance between the U.S. and the affiliate country, KI_{it} is knowledge-intensity of an industry measured by parent R&D expenditures over sales (following Keller and Yeaple 2012), and $\widetilde{Labprod}_{cit}$ is unweighted labor productivity of affiliates.

Turning to remaining variables of equation (2), $X1$ is a vector of control variables at the country-industry-year such as trade costs, $X2$ is a vector of control variables at the country-year level such as population, GDP per capita, and human and physical capital per worker, δ_c are country fixed effects, and μ_t are time fixed effects. It is expected that the coefficient on β will be negative, implying that the smaller the technology gap of an affiliates is (closer to frontier productivity), the more the affiliate will import technology directly (paying royalties and license fees) relative to importing goods for further processing.[12]

It is important to mention that licensing-import share is bounded between 0 and 1 with clusters of values at extreme points. We can employ a two-part Tobit model which is a widely used estimation method for censored data. Greene (2004) shows that maximum likelihood estimates of Tobit with fixed effects exhibit almost no bias, and incidental parameter problems do not need special adjustment. An alternative to Tobit is fractional logit model, suggested by Papke and Wooldridge (1996; 2008), where conditional mean is modeled as a logistic function. Before turning to the empirical analysis and results, the next section gives an overview of the data and descriptive statistics of the main variables.

[12] In the robustness analysis, other measures of frontier will be employed as well.

1.4 Data

1.4.1 Main Variables

The primary data used in this paper are based on operations of U.S. MNCs abroad and come from the United States Bureau of Economic Analysis (BEA). The data cover 47 countries where U.S. multinationals have affiliates, span 7 NAICS manufacturing industries, and include 2 benchmark survey years (1999 and 2004). The manufacturing industries used in the analysis are food, chemicals, primary and fabricated metals, machinery, computers and electronic products, electrical equipment, appliances and components, and transportation equipment. The list of affiliate countries used in the analysis is given in Appendix 1. The analysis is restricted to the benchmark survey years because part of the data is available only in these surveys.[13] Additionally, industry classification has changed from SIC to NAICS, which prevents using earlier benchmark years.[14]

Licensing-Import Share is constructed using data on royalties and license fees received by U.S. parents and on U.S. exports of goods shipped to majority-owned affiliates for further processing. Royalties and license receipts, net of withholding taxes, received by U.S. parents from its affiliates comes from the balance of payments and direct investment position data in 1999 and 2004.[15,16] Data on royalties and license receipts offer an appropriate measure of

[13] U.S. exports of goods for further manufacture, processing and assembly is only collected in benchmark survey years.

[14] The other benchmark survey years are 1989 and 1994. The publicly available data from BEA by country-industry are based on broadly defined industries. Due to a change in classification from SIC to NAICS, the Computers and Electronic Products manufacturing category was added, which would not allow direct comparison across industries with earlier benchmark years.

[15] A more precise measure would be royalties and license receipts by U.S. parents from its majority-owned foreign affiliates or payments to U.S. parents by its majority-owned foreign affiliates. Unfortunately, benchmark surveys of 1999 and 2004 do not provide that type of detailed data broken down by country-industry. Overall, around 90% of royalties and license fee receipts by U.S. parents from foreign affiliates are from majority-owned foreign affiliates.

[16] Using data on royalties and license fees which are net of withholding taxes, tax policy differences across

direct technology as these receipts are for the use or sale of intangible property or rights such as patents, industrial processes, trademarks, copyrights, franchises, manufacturing rights, and other intangible assets or proprietary rights (U.S. Direct Investment Abroad: Final Results from the 1999 Benchmark Survey, 2004).[17] Overall, approximately 50% of royalties and license fee payments from foreign affiliates to U.S. parents are for industrial processes which are most closely related to the payments for the usage of disembodied technology.[18]

Royalty and license receipts reflect the value of technology transfer, which could reflect changes in the volume of technology or changes in price. There are widely known difficulties with pricing and units of output of intangibles (Robbins 2009). Robbins notes that royalty payments for licensing of industrial processes often consist of a lump-sum payment and a royalty as a percentage of receipts.[19] In terms of price, transfer pricing is such that under U.S. law multinationals are required to charge the same price for intra-firm transactions on intangible assets as for unrelated arm's length transactions (Feenstra et al. 2010). Another difficulty with royalty and license receipts lies in the value of technology transfer that firms report, particularly coming from different countries. Branstetter and coauthors argue that under U.S. tax codes and the laws of foreign countries, there are restrictions on how U.S. multinationals make and value royalty payments. Furthermore, U.S. multinationals charge the same royalties for affiliates in different countries in order to avoid scrutiny from tax

affiliate countries should be mitigated.

[17]See Howestine (2008) who describes various innovation-related data in the BEA international economic surveys.

[18]Data on royalties and license fees broken down by the type of intangible asset between affiliated parties is available starting from 2006. On average in the period 2006-2009, U.S. parents' receipts of royalties and license fees from affiliates included 50% of receipts for industrial processes, 30% for general use computer software, 15% for trademarks, and 5% for franchise fees, with the remainder to other categories.

[19]Vishwasrao (2007) explores the factors determining the type of payments (up-front fees, royalties, or a combination of both) for the technology transfer based on firm and industry characteristics for subsidiaries as well as for unaffiliated firms.

authorities (Branstetter et al. 2006).

Data on the U.S. exports of goods comes from 1999 and 2004 benchmark surveys and is measured by the United States (either from the U.S. parent or another party) exports of goods shipped to majority-owned affiliates for further processing, assembly, or manufacture.[20,21] In 2004, exports for further processing from the U.S. parents to foreign affiliates were 60% of total exports and 90% within the manufacturing industry (BEA).

Technology gap is constructed using data on the gross product and number of employees of U.S. MNC parents and majority-owned foreign affiliates from the BEA. First, labor productivity of MNC parents is calculated as gross product (value added) divided by the number of employees for a given industry and year. It is taken as the frontier for a given industry and year. Then, labor productivity of majority-owned foreign affiliates is calculated as gross product (value added) divided by the number of employees for a given country, industry and year.[22] Finally, labor productivity of affiliates is weighted according to equation (3), where distance data is obtained from CEPII and R&D data from the BEA. The technology gap of a given affiliate is constructed as a relative difference from the frontier labor productivity (see equation 4). In this form, differences in productivity across industries are controlled for, and the identification of technology gap comes from variation across affiliate countries and years in a given manufacturing industry.

[20] Although the U.S. exports of goods for further manufacture includes goods shipped from the U.S. parents or other U.S. entities, overall around 85% of imports by affiliates from the United States is from the U.S. parents.

[21] Because of non-disclosure and confidentiality, the BEA does not provide small portion of data for royalties and license fees and for U.S. exports of goods for further manufacture broken down by country and industry. Data given in a range [-$500,000; $500,000] is coded as $500,000; data is filled in with the same number for observations where country-industry data is available for one year and missing for another (11% for exports, and 3% for royalties).

[22] Due to confidentiality, a small portion of employment figures is given in ranges; in those cases, the midpoint of the range is taken.

1.4.2 Controls

Research & Development expenditures (R&D) are considered an important determinant of technology transfer. Overall, affiliate R&D expenditures in manufacturing comprise around 15-17% of parent R&D expenditures in the period of analysis (U.S. BEA). However, there are considerable differences of aggregate industry-level affiliate R&D expenditures as a fraction of parent R&D expenditures. For example, in 1999 food industry affiliates performed around 40% of expenditures compared to U.S. parents, while in the electronics industry in the same year the figure was around 5%. Therefore, to control for these differences, R&D ratio of affiliate R&D expenditures to parent R&D expenditures is constructed from U.S. BEA data. To account for potential endogeneity of R&D expenditures, previous year's R&D data is used for both parents and affiliates. It is expected that the more R&D affiliates perform, compared to their U.S. parents in that industry, the larger will be the share of imported technology versus goods, as in these industries affiliates' ability to use know-how directly will be increased. One possible reason is that if an affiliate performs R&D itself, it can understand the technology better as technology tends to be tacit.

Although the empirical analysis controls for country and year fixed effects, there may still be differences across host country affiliates over time, and across industries. One of the most important factors that will impact licensing-import share is trade costs, as it is costly to transfer goods across borders. Following Hanson and colleagues (2005) and Keller and Yeaple (2012), ad-valorem trade costs at country-industry-year level are constructed as a sum of freight costs and tariffs:

$$\tau_{cit} = 1 + freight_{cit} + tariff_{cit}, \tag{6}$$

Both freight costs and tariff measures at the country-industry-year level are constructed following the methodology of Hanson and coauthors (2005) and Keller and Yeaple (2012).[23,24] Freight costs are calculated as the ratio of import charges over customs value of imports. Tariffs are obtained from the TRAINS database using WITS software of the World Bank.[25]

There are vast differences across affiliate countries in the level of development, size, factor endowments and other economic factors that might drive differences in U.S. FDI. To control for host country's development level and size, population and GDP per capita are obtained from Penn World Tables (PWT 6.3). Intellectual Property Rights Protection (IPR) in affiliate countries might also be an important determinant for the transfer of technology from the U.S. parent to affiliate.[26] The IPR protection index is obtained from Park (2008). Human capital per worker is constructed using data from Barro and Lee (2010) Educational Attainment Dataset for average years of schooling for individuals over 25 and employment figures from *Yearbook of Labor Statistics* (International Labor Organization). Physical capital per worker is constructed using perpetual inventory method and data from Penn World Tables (PWT 6.3) and the International Labor Organization.[27]

[23] Using highly disaggregated data on U.S. imports in HS classification from www.internationaldata.org for 1999 and 2004, freight cost value is calculated as import charges (freight, insurance and other charges) over customs value of imports. To aggregate these figures to BEA industry classification, freight cost value is weighted by the relative importance of a given HS code in BEA code based on U.S. exports to that country.

[24] I am grateful to Wolfgang Keller and Stephen Yeaple for help with trade cost data.

[25] Weighted tariffs in 4-digit SIC classification is extracted from WITS software of the World Bank and matched to BEA classification.

[26] Branstetter et al. (2006) find connection between stronger IPR and increased technology transfer within multinational corporations.

[27] In addition, there might be location-based differences and interdependencies in knowledge acquisition across affiliate countries (see e.g. Leonardi 2010), which are mitigated by including country fixed effects.

1.4.3 Descriptive Statistics

The final sample is an unbalanced panel of 47 countries, 7 manufacturing industries, and 2 years (1999 and 2004). Summary statistics of the main variables are presented in Table 1.[28] On average, exports of goods for further manufacture is around 8 times larger than royalties and license receipts.[29] Both royalties and license fees and exports of goods for further processing are quite dispersed with a large standard deviation. Licensing-import share, representing a technological measure of preference between imports of goods versus technology, is bounded between 0 and 1 by construction, with the smaller values representing a preference towards importing of intermediates and the larger values preference towards licensing the technology. Figure 1 presents a histogram of licensing-import share which shows that around 30% of observations are close to zero, with 15% of values being strictly zero and 2% of values being 1.[30]

Table 2 presents industry averages of licensing-import share and technology gap variables. On average, the highest licensing-import share is observed in the food industry (0.431), and the lowest in computers (0.102). The technology gap varies on average from 0.516 in food to 0.937 in computers. Country averages of licensing-import share and technology gap are presented in Table 3. On average, the lowest licensing-import share is in Brazil (0.043) and the highest licensing-import share across countries is in Saudi Arabia (0.914). The variation

[28] In this analysis, I focus on positive numbers of technology gap, as my analysis does not apply to the case when weighted labor productivity of affiliates is larger than parent labor productivity. Since weighted labor productivity is based on distance, Canada is a large outlier which is dropped from the analysis.

[29] Feenstra et al. (2010) discuss various reasons for mismeasurement of international trade in ideas. Particularly, they note that the values of receipts from sales of intangible assets are relatively small because of possible underreporting of affiliates and/or high threshold values for mandatory reports.

[30] Around 34% of royalties and license fees are zero, and around 24% of U.S. exports of goods for manufacture are zero, which by construction results in 15% of zero values in licensing-import share variable.

in technology gap ranges from 0.5 in Switzerland to 1.050 in Ecuador on average.[31]

The empirical strategy controls for country and year fixed effects, so general differences across affiliate countries and across years are controlled. Additionally, since labor productivities differ across industries, technology gap compares labor productivities *within the same industry-year.*

The next section presents the empirical results.

1.5 Results

The goal of the empirical analysis is to estimate a relationship between the technology gap of U.S. multinationals foreign affiliates and licensing-import share: import of technology versus import of goods. Table 4 presents initial estimation results of the equation (2) using Ordinary Least Squares (OLS). All columns include year fixed effects, columns 1 to 5 include country fixed effects, while in column 6 country fixed effects are omitted to analyze across host country affiliate differences. Robust standard errors, which allow for clustering by country-year, are shown in parentheses. Column 1 shows that there is a strong negative correlation between affiliates' technology gap and their licensing-import share: within an industry, foreign affiliates with a large technology gap from parents import relatively less technology in the form of blueprints and designs and more in the form of intermediate goods.

The addition of trade costs in column 2 decreases the coefficient of technology gap only slightly from -0.188 to -0.164 while it remains highly significant at 1 percent. As expected,

[31] There were industries where Ecuador had negative gross product which resulted in a technology gap higher than 1.

trade costs are estimated to be positive and significant, showing that import of goods is negatively related to trade barriers, resulting in a larger licensing-import share. In column 3 the ratio of industry-level R&D expenditures of affiliates to parents is added. The R&D ratio results in a positive coefficient, meaning that affiliate industries with high R&D relative to parent R&D are licensing more disembodied technology rather than technology embodied in intermediate goods. However, the coefficient is not significant.

Additional country-year level controls are added in column 4. The coefficient on population is negative though not significant, while GDP per capita has a positive effect on licensing-import share. In column 5, IPR protection index and endowments of human and physical capital are added. With the addition of these variables, population becomes significant, and IPR protection index is estimated to be positive and significant. The negative coefficient on population is somewhat surprising, but may indicate that in countries with smaller populations there is relatively more disembodied technology transfer. As expected, IPR protection index is estimated to be positive, implying that countries with strong protection of intellectual property receive more technology in the form of blueprints relative to intermediate goods. With the inclusion of all control variables, the coefficient of technology gap is around -0.15.

What is the magnitude of the estimated coefficient? The mean of licensing-import share is 0.25, while the mean of technology gap is 0.78 (see Table 1). Based on the estimated coefficient, this means that at the mean a 10% increase in the technology gap of a U.S. MNC affiliate, compared to the parent in the same industry, decreases the share of licensing versus importing inputs embodying the technology by 5%.[32] The magnitude of the estimated

[32] At the mean, the regression is $[0.25 = -0.15 * 0.78]$, thus a 10% increase in the right hand side is 0.0117,

coefficient is economically sizeable.

To gauge general across-country differences in technology gap and licensing-import share, country fixed effects are dropped in column 6. The technology gap is still negative and significant, although the magnitude of the coefficient decreases from around -0.15 to around -0.118. It is surprising that GDP per capita becomes negative and significant, while IPR protection becomes insignificant. Overall, the results from table 4 indicate that there is a significant effect of technology gap on licensing-import share.

Although the OLS results reported in Table 4 provide important benchmark estimates, additional econometric models are estimated in Table 5. For convenience, column 1 repeats the OLS regression presented in Table 4 (column 5), while other econometric specifications are presented in columns 2 to 5. Alternative estimation methods to OLS are median and robust regressions which are presented in columns 2 and 3. Robust regression is using iteratively reweighted least squares. Looking at column 2, the coefficient of robust regression is much smaller (-0.065 compared to -0.150), while it is highly significant. The coefficients on controls are similar to OLS results. Median regression has an advantage over OLS in the presence of outliers. It is performed as a quantile regression which minimizes the sum of absolute errors. However, quantile regression does not allow clustering of standard errors. The coefficient on technology gap is negative and significant, and the magnitude of the coefficient is somewhat smaller compared to OLS (-0.108 compared to -0.150). Overall, the signs of all variables are similar to the OLS results.

As mentioned previously, the dependent variable is a share with values strictly between 0 and 1 and around 15 percent of zeroes. The possible reason for the existence of zeroes is

which lowers the licensing-import share by $0.0117/0.25 = 5\%$

that data on both royalties and license receipts and exports of goods for further manufacture are recorded only when a certain threshold is passed. Therefore, equation 1 is estimated as a two-way censored Tobit model in column 4. Column 4 shows that technology gap has a negative and significant effect on licensing-import share, however the magnitudes of the estimates are not directly comparable with OLS. Fractional logit estimates, which model conditional mean as a logistic function, are presented in column 5. The general direction of coefficient estimates is similar in the latter model, but the magnitudes are different. On the whole, in all alternative econometric specifications, the technology gap variable is estimated negative and highly significant.

Licensing-import share is constructed by combining data on embodied and disembodied technological transfer. To understand the differences between these two types of technology transfer, decomposition of the dependent variable is performed in Table 6. For convenience, column 1 of Table 6 repeats the benchmark estimates of Table 4 (column 5) with licensing-import share as the dependent variable. In column 2, the dependent variable is intermediate goods import intensity, constructed as U.S. exports of goods for further manufacture divided by affiliate sales. As expected, the coefficient on technology gap is estimated to be positive and significant, implying that affiliates with a large technology gap on average import more intermediate goods. Additionally, the coefficient on trade costs is negative and significant, meaning that trade costs decrease intermediate goods import intensity. Turning to column 3, where the dependent variable is disembodied technology transfer intensity (royalty and license fees divided by affiliate sales), as expected the coefficient is negative although not significant. The sign of the coefficient implies that affiliates with large technology gap receive relatively less technology in disembodied form. The fact that technology gap in this case is not significantly estimated probably has to do with small values of royalty and license fees. Overall, the decomposition analysis of licensing-import share conforms to our expectations.

The technology gap of affiliates is constructed using parent productivity as the frontier and is based on weighted labor productivity of affiliates (see equations 4 and 3). Table 7 presents results using alternative measures of technology gap. Column 1 repeats the benchmark estimates of Table 4 (column 5) for convenience. Recall that labor productivity is weighted by the relative distance of affiliate country and relative knowledge intensity of an industry (see equation 3). In column 2, technology gap is constructed based on unweighted labor productivity. The coefficient on technology gap is still negative and significant, however the magnitude of the coefficient decreases from -0.150 to -0.117. The weighted coefficient is larger, which shows that it is important to account for differences in proximity of affiliates of U.S. parents to home, as well as the knowledge-intensity of an industry.

Another feasible option for defining technology gap involves using a different frontier measure. To test the robustness of using parent productivity as a frontier, we can define the frontier as the most productive affiliate in the same industry and year, as it is possible that parents and affiliates perform different tasks. Then, the technology gap of a given affiliate is defined as a relative difference from the most productive affiliate in the same industry and year. It is important to note that in all cases, the frontier affiliate comes from a high-income country affiliate. The results of this exercise are reported in column 3 of Table 7. Using affiliate frontier, the coefficient on technology gap is estimated to be negative and significant and close to the benchmark (-0.147 compared to benchmark -0.150). Additionally, the signs and estimates of the controls are very similar to the benchmark estimates. This shows that the results are not sensitive to the definition of the frontier.

As an additional robustness check, technology gap based on productivity per *affiliate* versus productivity per *worker* is constructed. Using data on the number of affiliates separately by country and by industry, the number of affiliates by country-industry is calculated. Productivity per affiliate is constructed as gross product divided by the number of affiliates. In a similar fashion, productivity per parent is constructed. Then, the technology gap is calculated as a relative deviation of productivity per affiliate from productivity per parent. The results using productivity per affiliate are presented in column 4 of Table 7. The estimated coefficient on technology gap using productivity per affiliate is not significantly estimated. However, the sign of the coefficient is still negative. Overall, this table shows that the main results of this paper are not sensitive to the definition of frontier used in the construction of technology gap. In all four cases, technology gap is negatively associated with licensing-import share.

1.6 Conclusions

Multinational corporations are the main mediators of the worldwide increase in technology trade. Intermediate inputs and know-how are the two forms of technology (tangible and intangible) transferred within multinational corporations that this paper has examined. This paper analyzed what determines the decision of multinationals on the form of technology transfer to its affiliates, using data on U.S. multinational activity in 47 countries, 7 manufacturing industries and 2 years. Detailed data on exports of goods for further processing, as well as royalties and license payments observed between U.S. MNC parents and their affiliates, enables us to specifically identify two types of knowledge transfer from parents to affiliates.

The main finding of this paper is that the technology gap, measured as the relative labor productivity difference from the frontier, is negatively related to the share of direct versus indirect transfer of knowledge from U.S. parents to affiliates. Relatively more productive affiliates get technology in the form of know-how, industrial processes, etc., while relatively less productive affiliates receive technology in the form of intermediate inputs. The magnitude of the effect is sizeable: a 10 percent increase in the technology gap of affiliates decreases the share of licensing versus importing inputs by 5 percent, on average. These results suggest that productivity of affiliates is an important determinant for knowledge transfer within multinational corporations.

The transfer of technology is central to modern economics because of its implications for long-term cross-country income, economic growth and convergence of countries. Access to knowledge and know-how are obtained by MNC affiliates from their parents, as well as via spillovers from those affiliates to domestic firms. Regardless of how such knowledge is gathered, it amounts to an avenue for innovation and income growth. Based on the results mentioned above, this study points to policy implications for countries to raise their productivity levels. Taking into account that the presence of MNC affiliates and the performance of those affiliates are contributing factors to the productivity levels of a country, policymakers should also think about creating more appealing atmosphere for MNCs, including such factors as favorable entry criteria and tax implications.

While this paper provides initial evidence on the relationship between the technology gap and the mode of technology transfer in multinational corporations, there are important extensions that should be considered in future work. First, obtaining firm-level or more disaggregated industry data will enable to the examination of this question without potential aggregation bias. Second, it would be interesting to add a direct measure of technology, and explicitly model the process of innovation in the framework of technology transfer. Third, it would be useful to extend this analysis to other samples to see if the results continue to hold. A promising avenue involves the use of data on Swedish multinationals. In addition, there are complementarities between productivity and R&D expenditures that this paper has not addressed. Finally, there are important questions on whether the type of FDI matters for the mode of technology transfer.

1.7 Tables and Figures

Table 1: Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max
Royalties & license receipts ($mln)	612	19.603	66.554	0	904
US exports of goods for manufacture($mln)	585	161.411	470.192	0	4924
Licensing-Import share	458	0.249	0.290	0	1
Technology gap	514	0.782	0.249	0.001	1.940
Trade costs	583	0.134	0.105	0.008	1.120
R&D ratio (affiliate/parent)	612	0.181	0.082	0.042	0.369
Population	612	10.185	1.425	8.025	14.077
GDP per capita	612	9.412	0.833	6.798	10.597
Intellectual property protection	599	1.201	0.309	0.207	1.541
Human capital per worker	598	-7.088	1.562	-11.592	-4.958
Physical capital per worker	579	5.841	2.211	-0.276	10.028

The sample includes 47 countries, 7 manufacturing industries and 2 years (1999 and 2004). Trade costs, population, GDP per capita, IPR, human capital and physical capital per worker are in natural logarithms.

Figure 1: Distribution of Licensing-Import Share

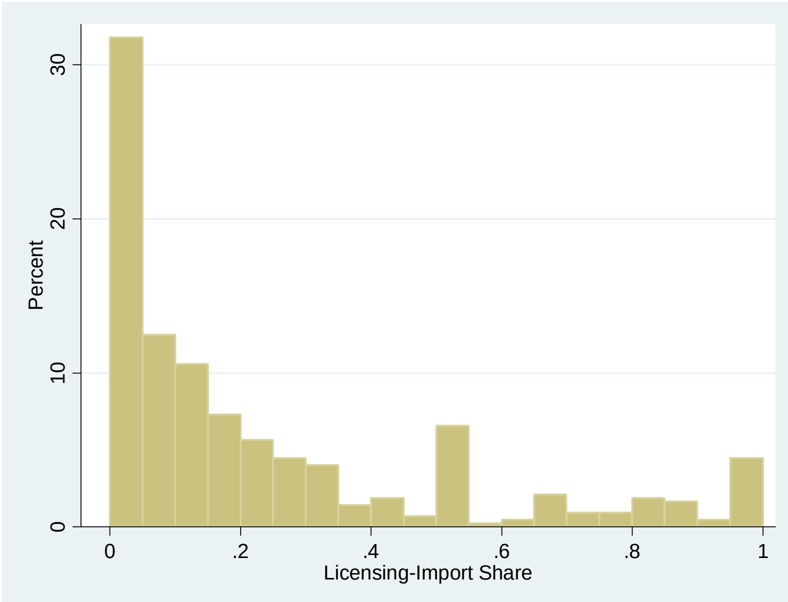

Table 2: Industry Averages of Main Variables

Industry	*Mean of licensing-import share*	*Mean of technology gap*
Chemicals	0.354	0.899
Computers	0.102	0.937
Electronics	0.236	0.744
Food	0.431	0.516
Machinery	0.24	0.752
Metals	0.238	0.559
Transportation	0.158	0.826

Table 3: Country Averages of Main Variables

Country	*Mean of licensing-import share*	*Mean of technology gap*	*Country*	*Mean of licensing-import share*	*Mean of technology gap*
Argentina	0.052	0.878	**Italy**	0.261	0.746
Australia	0.159	0.713	**Japan**	0.178	0.705
Austria	0.320	0.551	**Korea: Republic of**	0.205	0.773
Belgium	0.171	0.654	**Malaysia**	0.194	0.843
Brazil	0.043	0.746	**Mexico**	0.050	0.742
Chile	0.148	0.833	**Netherlands**	0.141	0.687
China	0.212	0.903	**New Zealand**	0.114	0.845
Colombia	0.081	0.752	**Norway**	0.218	0.702
Costa Rica	0.230	0.783	**Peru**	0.493	0.831
Czech Republic	0.397	0.842	**Philippines**	0.363	0.892
Denmark	0.211	0.676	**Poland**	0.358	0.806
Ecuador	0.163	1.050	**Portugal**	0.499	0.746
Egypt	0.589	0.921	**Russia**	0.365	0.904
Finland	0.247	0.692	**Saudi Arabia**	0.914	1.016
France	0.152	0.679	**Singapore**	0.091	0.800
Germany	0.168	0.705	**South Africa**	0.176	0.854
Greece	0.810	0.699	**Spain**	0.327	0.726
Honduras	0.292	0.654	**Sweden**	0.366	0.687
Hong Kong	0.079	0.864	**Switzerland**	0.365	0.500
Hungary	0.379	0.719	**Taiwan**	0.081	0.726
India	0.131	0.904	**Turkey**	0.814	0.863
Indonesia	0.334	0.950	**United Kingdom**	0.101	0.717
Ireland	0.221	0.556	**Venezuela**	0.326	0.672
Israel	0.123	0.806			

Table 4: Benchmark Regression

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable			Licensing-Import Share			
Technology gap	-0.188***	-0.164***	-0.163***	-0.156**	-0.150**	-0.118*
	(0.063)	(0.058)	(0.062)	(0.060)	(0.061)	(0.062)
Trade costs		0.398**	0.396**	0.421**	0.504**	0.640***
		(0.188)	(0.196)	(0.201)	(0.233)	(0.194)
R&D ratio			0.012	0.021	0.028	0.075
			(0.182)	(0.182)	(0.187)	(0.179)
Population				-0.513	-1.330***	-0.016
				(0.386)	(0.344)	(0.101)
GDP per capita				0.371***	0.233*	-0.160*
				(0.135)	(0.133)	(0.082)
IPR protection index					0.089*	0.106
					(0.053)	(0.116)
Human capital per worker					-0.333	-0.068
					(0.204)	(0.094)
Physical capital per worker					-0.027	0.087
					(0.057)	(0.054)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	No
Observations	425	408	408	408	398	398
R-squared	0.363	0.378	0.378	0.383	0.381	0.095

Notes: All specifications include year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Various Econometric Specifications

	OLS	Robust Regression	Median Regression	Tobit	Fractional Logit
	(1)	(2)	(3)	(4)	(5)
Dependent variable	Licensing-Import Share				
Technology gap	-0.150**	-0.065**	-0.108***	-0.168**	-0.990***
	(0.061)	(0.027)	(0.000)	(0.068)	(0.361)
Trade costs	0.504**	0.673***	0.678***	0.606**	3.317**
	(0.233)	(0.087)	(0.000)	(0.271)	(1.448)
R&D ratio	0.028	-0.136	-0.140***	-0.051	0.202
	(0.187)	(0.087)	(0.000)	(0.215)	(1.149)
Population	-1.330***	-1.010**	-0.931***	-1.531***	-7.282***
	(0.344)	(0.434)	(0.000)	(0.432)	(2.276)
GDP per capita	0.233*	0.112	0.090***	0.272*	1.711**
	(0.133)	(0.141)	(0.000)	(0.157)	(0.686)
IPR protection index	0.089*	0.061	0.120***	0.086	0.593
	(0.053)	(0.065)	(0.000)	(0.062)	(0.373)
Human capital per worker	-0.333	-0.001	-0.328***	-0.331	-2.132*
	(0.204)	(0.159)	(0.000)	(0.246)	(1.225)
Physical capital per worker	-0.027	0.025	0.075***	-0.012	-0.451
	(0.057)	(0.029)	(0.000)	(0.073)	(0.433)
Observations	398	398	398	398	398
R-squared	0.381	0.763			

Notes: All specifications include country and year fixed effects. Robust standard errors are reported in parenthesis. Robust standard errors which allow for clustering by country-year are reported in models (1), (4) and (5). *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Decomposition of Licensing-Import Share

Dependent variable	(1) Licensing-Import Share	(2) Intermediate goods import Intensity	(3) Royalty & license fee intensity
Technology gap	-0.150**	0.035**	-0.000
	(0.061)	(0.016)	(0.002)
Trade costs	0.504**	-0.166***	0.023***
	(0.233)	(0.063)	(0.009)
R&D ratio	0.028	-0.107*	-0.017*
	(0.187)	(0.060)	(0.009)
Population	-1.330***	0.037	-0.041*
	(0.344)	(0.166)	(0.021)
GDP per capita	0.233*	0.041	-0.002
	(0.133)	(0.061)	(0.006)
IPR protection index	0.089*	-0.027	0.002
	(0.053)	(0.019)	(0.002)
Human capital per worker	-0.333	-0.034	-0.011
	(0.204)	(0.045)	(0.008)
Physical capital per worker	-0.027	-0.006	-0.001
	(0.057)	(0.007)	(0.001)
Observations	398	385	385
R-squared	0.381	0.417	0.213

Notes: All specifications include country and year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Alternative Measures of Technology Gap

	(1)	(2)	(3)	(4)
Dependent variable		Licensing-Import Share		
Technology gap (weighted)	-0.150**			
	(0.061)			
Technology gap (unweighted)		-0.117**		
		(0.055)		
Technology gap (affiliate frontier)			-0.147**	
			(0.073)	
Technology gap using number of affiliates				-0.132
				(0.081)
Trade costs	0.504**	0.583**	0.728***	0.572**
	(0.233)	(0.248)	(0.261)	(0.265)
R&D ratio	0.028	0.338**	0.442**	0.559***
	(0.187)	(0.167)	(0.182)	(0.205)
Population	-1.330***	-1.245***	-1.452***	-1.295***
	(0.344)	(0.426)	(0.443)	(0.340)
GDP per capita	0.233*	0.122	0.254*	0.347***
	(0.133)	(0.133)	(0.146)	(0.096)
IPR protection index	0.089*	0.102*	0.110*	0.080
	(0.053)	(0.055)	(0.057)	(0.049)
Human capital per worker	-0.333	-0.301	-0.380*	-0.381**
	(0.204)	(0.204)	(0.196)	(0.192)
Physical capital per worker	-0.027	0.002	-0.023	-0.044
	(0.057)	(0.044)	(0.058)	(0.041)
Observations	398	396	486	472
R-squared	0.381	0.399	0.338	0.361

Notes: All specifications include year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

2 "International Business Travel: An Engine of Innovation?" (with Wolfgang Keller)

2.1 Introduction

Throughout history the cross-border flows of workers had major effects on the innovative activity and growth of countries. In the year 1789, for example, at a time when England had banned the international movement of skilled craftsmen so as to keep important technology from spreading, a certain Samuel Slater succeeded to disguise himself and slipped out on a ship to the United States, where he built the first water-powered textile mill and became known as the father of the American Industrial Revolution. Today blueprints can be transferred electronically over the Internet, or technologies are shipped at relatively low costs as capital goods. Does this mean that cross-border labor movements play no role anymore for innovation? In this paper we provide new evidence on this question by studying the impact of short-term business travel.

Cross-border worker flows bring domestic entrepreneurs into personal contact with foreigners who are familiar with foreign technology. Domestic innovation may rise because innovation is incremental, and knowledge of prior art helps. Technology is also often tacit – it is difficult to fully characterize –, and face-to-face communication is more effective than other forms for transferring technology.[33] Nevertheless we know quite little on the impact of cross-border worker flows on innovation. In this paper, we employ a new industry-level

[33] Polanyi (1958) discusses the tacitness of technological knowledge. See Koskinen and Vanharanta (2002) on the role of face-to-face communication in overcoming problems arising from the tacitness of technology, and Forbes (2009) as well as Harvard Business Review (2009) on the general preference of business executives for face-to-face meetings over phone or web-based communications.

dataset to examine the impact of business travelers from the United States on patenting in 36 countries over the period of 1993 to 2003. Our main finding is that business travelers coming to a country have a positive impact on that country's rate of innovation. Quantitatively, a 10% increase in business travelers increases patenting on average by about 0.3%, and in the typical case business travel from the United States accounts for about 1% of the total difference in patenting across countries. Moreover, we find evidence that the impact of inward business travel on patenting is increasing in the technological knowledge carried by each particular traveler.

While international trade in goods and foreign direct investment (FDI) have long been the subject of investigation, there is much less research on international trade in services, even though by now services trade is substantial in many countries. For example, services exports are now close to 40% of U.S. goods exports.[34] This paper sheds new light on the impact of international air travel. This provides new information for the gains from services liberalizations, both bilaterally (such as the Open Skies Agreement) and multilaterally among the members of the World Trade Organization.[35] While researchers have started to look at the role of international business travel in facilitating goods trade (Poole 2010, Cristea 2011), we examine the role of business travel on innovation taking the trade in goods as well as FDI as given.

The diffusion of knowledge and ideas is central to macroeconomics because of its implications for the long-run convergence of incomes (Lucas 1993, Aghion and Howitt 1998, Howitt 2000, Jones 2002, and Alvarez, Buera, and Lucas 2008). It is an open question whether

[34] News release of the U.S. Bureau of Economic Analysis, May 11, 2011.

[35] The Open Skies Agreement seeks to liberalize air travel to and from the United States, see http://www.state.gov/e/eeb/tra/ata/. WTO (2006) discusses key multilateral issues.

knowledge can be transferred exclusively in disembodied form (as a blueprint) or whether knowledge transfer also requires the movement of people, for example the Western settler migration that brought new ideas of institutions to the New World (Acemoglu, Johnson, and Robinson 2001). In some recent research knowledge is indeed assumed to be fully embodied in people (Burstein and Monge-Naranjo 2009) so that international travel is crucial for knowledge diffusion.

The importance of personal contacts for international technology transfer has been established in micro empirical work by a number of researchers. Common ethnicity may lower the cost of transferring knowledge from one country to another (Kerr 2008).[36] Moreover, movements of scientists themselves can be a conduit of international knowledge flows (Oettl and Agrawal 2008, Kim, Lee, and Marschke 2006). While we focus on knowledge transfer that comes about through face-to-face meetings in a large number (more than 100,000) of business trips, these papers are complementary to our research.

There are a few papers that have considered air travel as a conduit for technology transfer. Results have been mixed. Gambardella, Mariani, and Torrisi (2009) in their analysis of European regions find that air passengers are not significantly related to productivity differences once other determinants are controlled for. In contrast, Andersen and Dalgaard (2011) employ World Tourism Organization data to show that the number of air travelers relative to population can explain cross-country productivity differences.[37] A concern with data on international travel is that the definitions vary substantially across countries – inter-

[36] Network membership often lowers the costs of interaction (Rauch 2001), and to verify membership face-to-face meetings will often be useful. See also Singh (2005), Agrawal, Cockburn, and McHale (2006), and Agrawal, Kapur, and McHale (2008).

[37] See also the work by Le (2008) and Dowrick and Tani (2011).

national travel data is not nearly as consistent across countries as data on FDI or on trade in goods. In this paper this issue is addressed by focusing on travel data collected by a single country (the United States). We can also separate business from leisure travelers, which is important because leisure travelers should matter much less for technology transfer. Finally, our research is unique in analyzing the impact of business travel on patenting as opposed to productivity. Patenting is an activity that we can directly observe in the data. This makes the analysis less prone to confounding factors compared to studying the effects of travel on productivity, because the latter is difficult to measure with the available data.[38]

The remainder of the paper is as follows. The next section gives an overview of the empirical analysis and also highlights important aspects of the estimation methods. Section 3 describes the data that will be used, with more details given in the Appendix. All empirical results are presented in section 4, while section 5 contains a concluding discussion of our findings.

2.2 An Empirical Model of Innovation through Cross-Border Movements

We are interested to estimate the impact of international business travel on the rate of innovation across countries and industries. Innovation is measured in terms of the countries' patents at the level of 37 industries. The industry dimension is important because industries vary greatly in terms of patenting activity. While patent data is available even by industry, information on business travel is much more scarce. This paper employs data on outward

[38]Productivity often captures not only technical efficiency but also demand shocks and market power, factor market distortions, and product mix changes (Foster, Haltiwanger, and Syverson 2008, Hsieh and Klenow 2009, and Bernard, Redding, and Schott 2010, respectively). See Keller (2004) for more discussion.

business travel of U.S. residents (who are predominantly U.S. citizens) to other countries.[39] The focus on one source country means that the spells of business travel are more comparable than if we had used data from multiple countries that might use different approaches in data collection. Moreover, we limit the analysis of patenting to patent applications in the United States, both to ensure a common quality standard across countries and because the United States is an important market for all of the countries in our sample.

Our approach is straightforward. We specify patenting in a particular country c in industry i, P_{ci} as a function Ψ of inward business travelers from the United States, B_c and of other observed and unobserved determinants, Z_c :

$$P_{ci} = \Psi\left(B_c, Z_c, \Theta\right), \tag{1}$$

where Θ is a vector of unknown parameters. Equation (1) can be thought of as the reduced form of a model in which technological knowledge diffuses abroad through business travel and other channels. Specifically, Keller and Yeaple (2012) analyze firms that decide whether to produce intermediate goods that are inputs in a final good either at home or abroad. Since home managers have the necessary know-how for production, the manufacturing of any intermediate at home entails only the trade cost as the intermediate is shipped for assembly abroad. If, however, the intermediate is to be produced abroad the know-how has to be transferred between home and host country managers, which is subject to communication frictions because technological knowledge has frequently tacit elements. The model posits a trade-off of technology transfer in embodied form through trade and through direct commu-

[39] Thanks go to Jennifer Poole who shared the outcome of her NSF-funded data collection with us.

nication associated with FDI production. A role for business travel in enhancing technology transfer naturally arises if home country managers can travel to the host country. Face-to-face time enhances technology transfer but it may also mean that unaffiliated host country agents learn about the technology.

The theoretical framework suggests that for estimating the impact of business travel on innovation it will be important to condition on FDI- and trade relations between countries. Moreover, below we will adopt a control function approach to address endogeneity issues, in particular the possibility that patenting and business travel are both related to a common shock. Another aspect of our analysis is that the number of patents, P_{ci}, is a non-negative count variable. Consequently least-squares, which assumes unbounded support, is not appropriate. Instead the analysis will rely on negative binomial regressions, which is a well-established model for count data. The negative binomial model assumes that the dependent variable follows a Poisson-type process. The main difference compared to a Poisson regression is that the negative binomial model does not assume equality between the mean and the variance.[40]

Before presenting the estimation equation and turning to the results, the next section gives an overview of the data.

[40] Cameron and Trivedi (2005) discuss count data models more generally; see also the arguments for Poisson-like regression models put forward in Santos Silva and Tenreyro (2006).

2.3 Data

2.3.1 Innovation

The dependent variable in our analysis is the number of U.S. patents to foreign country inventors in the years 1993 to 2003 in 37 industries as recorded by the United States Patent and Trademark Office (USPTO). As noted above, focusing on foreign patents in the U.S. ensures that all inventions surpass the same quality standard, and moreover, patent protection in the United States will typically be important for major inventions given the importance of the U.S. market. This data comes from the custom data extracts of the USPTO database, which has information on country of residence for each of possibly several inventors per patent, original USPTO patent classification, as well as the application month and year.[41] In the case of $n > 1$ inventors, we assign a fraction of $1/n$ to each inventors country of residence. Based on USPTO classification, patents are assigned to NBER 37 technological subcategories (or, industries).[42] A list of industries is provided in table A1 of the Appendix. The main dependent variable in the empirical analysis is the sum of these fractional patent counts aggregated by foreign country and industry for each quarter during the period 1993 to 2003.[43]

In addition, we employ the USPTO individual inventor database to separate out foreign patents that have a U.S. co-inventor. These patents are of particular interest because the traveler might in fact be the U.S. co-inventor on that patent. For this reason, we believe

[41] We focus on the date of application as opposed to the date of when the patent is granted; this ensures that differences in the processing time of patents do not play a role.

[42] See Hall, Jaffe and Trajtenberg (2001).

[43] The use of fractions means that our data is not strictly speaking count data; despite this we prefer to employ count data regression models. More information on the patent data construction is given in the Appendix.

that the relationship between business travel and domestic innovation might be particularly strong for these patents. How frequent are patent applications that have a U.S. co-inventor? We find that on average about one in 60 of all foreign patent applications in the United States during the sample period had foreign and U.S. co-inventors.

It is well-known that a principal determinant of the rate of innovation is the country's R&D expenditures. We have obtained this data from OECD Statistics.[44] We also include two other measures of innovation, namely a country's total patent applications in a particular year, both by residents of that country as well as by non-residents (source: World Intellectual Property Organization).[45] These variables control for innovative cycles in each country that are general in the sense that they are not specifically related to travel from the United States. In addition, including all patents on the right hand side controls for the patent family effect, namely that a patent application in the U.S. reflects only the fact that a given technology has been invented and patented at home in the same period.

2.3.2 Travel

The information on international air travel in this paper comes from the Survey of International Air Travelers (SIAT) which is conducted by the International Trade Administration, U.S. Department of Commerce. This survey provides information on travel from the United States to foreign countries for U.S. residents for each quarter during the years 1993 to 2003. The data has information on the travelers' U.S. county of residence, the foreign city of destination, the purpose of the travel, and the traveler's occupation. Matching this information

[44] OECD statistics provide Gross Domestic Expenditure on R&D for OECD and also some non-member countries.

[45] The assignment of these patents to countries is based only on the first inventor.

on travel with other parts of our data set required aggregation, and the basic unit of observation is resident travelers from a U.S. state to a given foreign country for each quarter during the years 1993 to 2003.

While we do not have specific information on the technological knowledge carried by each traveler, we account for differences in this respect by incorporating information on patent stocks (a measure of technological prowess) at the level of the U.S. states and industries. Our business traveler variable, B_{cqti}, is defined as follows:

$$B_{cqti} = \sum_{s \epsilon S} \underbrace{\frac{P_{sqt}}{GSP_{sqt}}}_{State} \times \underbrace{P_{iqt}}_{Industry} \times \tilde{B}_{scqt}, \forall i, q, t, \tag{2}$$

where the variable P_{sqt} is the patent stock of U.S. state s in quarter q of year t, GSP_{sqt} is the state's gross product, P_{iqt} is the patent stock of U.S. industry i in quarter q of year t, and $\tilde{B}_{scqt}$ is the raw (unweighted) number of business travelers from state s to foreign country c in quarter q of year t. Equation (2) captures two dimensions of differences in technological knowledge. First, U.S. travelers coming from a state with a high patent-to-GSP ratio are more likely to affect innovation abroad than travelers that come from low-patenting states. This origin effect is the part labeled *State* in equation (2). Second, a given traveler is more likely to carry knowledge relevant for industry i if that industry in the United States is large in terms of its patenting; this effect is labeled *Industry* in equation (2). The patent figures by state and industry come from the files of the U.S. Patent and Trademark Office (USPTO), and the gross product levels by state come from the U.S. Department of Commerce's Bureau of Economic Analysis. U.S. state and industry-level patent statistics are summarized in Table A2 of the Appendix.

Analogously to the weighted number of business travelers from the United States according to equation (2), we also compute the numbers of travelers who are visitors, are traveling for religious reasons, are retired, or are homemakers. These variables will be employed in our empirical analysis in form of a control function discussed below.

2.3.3 Other Variables

The size and level of development of a country affects its patenting in the United States, and for this reason we include information on population size and GDP per capita (source: Penn World Tables, version 6.2). As noted above it is also important to control for other channels of international technology transfer, such as international trade and FDI (see the review in Keller 2010). The regressions include U.S. exports to each of the sample countries, as well as the total sales of U.S. majority-owned multinational affiliates in each of the sample countries.

Summary statistics of the data are presented in Table 1. The first two rows show some descriptive statistics on fractional patent counts by foreign inventors and joint U.S./foreign patent counts. There is a lot of variation in U.S. patenting by foreign countries and industries as evidenced by the standard deviation in both foreign U.S. patent counts as well as joint U.S. patent counts. A list of the 36 countries that are included in this analysis is given in Table A3 of the Appendix. The following four rows in Table 1 present (in natural logarithms) U.S. resident travel data for business, religious, and visitor purposes, along with data on travelers that are retired and homemakers.[46] As can be seen from the table, the number of

[46] In this analysis we focus on positive numbers of business travelers, as our analysis does not necessary apply to patenting in the case when there is no business travel.

travelers for the purpose of business and visitor are close in magnitude, while the number of observations for religious travel and retired and homemaker travel is much smaller.

We now turn to the empirical results.

2.4 Empirical Results

The estimation equation we will be using is as follows:

$$E\left[P_{cqti}|B_{cqti}\right] = \exp\left[\alpha \ln B_{cqti} + \beta \ln X_{cqti} + \mu_c + \mu_q + \mu_t + \mu_i + \varepsilon_{cqti}\right] \quad (3)$$

where P_{cqti}, the expected patent counts of a country c in the United States in quarter q of year t and industry i is a function of B_{cqti}, the number of business travelers at that time between country c and the U.S. (from equation 2), other determinants X_{cqti} of country c's patenting in the U.S. (such as R&D expenditures), country-, quarter-, year- and industry fixed effects (the μ's), and an error term, ε_{cqti}. In our data, the variance of patents exceeds its mean (overdispersion) and the negative binomial model is generally preferred to the Poisson model.[47] We begin with simple negative binomial regressions before moving to a control function approach to deal with possible endogeneity.

The initial results are shown in Table 2. In columns 1 to 5, the dependent variable is the foreign country's patent counts taken out at the U.S. patent office, while in column 6 the dependent variable is foreign patents that have U.S. coinventors. All regressions include country, year, quarter and industry fixed effects. Robust standard errors which allow for

[47] We have also considered 'zero-inflated' negative binomial regressions, however, they do not lead to a major improvement in empirical fit.

clustering by country-year are reported in parentheses.[48] Column 1 shows that there is a strong correlation between patenting and travel from the United States, which is only slightly reduced with the inclusion of controls for size and level of development in column 2: the coefficient on business travel decreases from 0.056 to 0.053.

Next we include controls for domestic technology investments as well as international technology transfer. U.S. FDI and U.S. exports have a positive coefficient, although only FDI is significant. The inclusion of these variables lowers the business travel coefficient slightly. In column 4, we include R&D expenditures, which has a highly significant impact on patenting. With the inclusion of R&D expenditures, U.S. FDI becomes insignificant, while in contrast the coefficient on business travel is largely unchanged.

Recall that the left-hand side variable is a country's industry-level patenting in the United States. In column 5 the patenting of the country in *all* countries of the world is added, where we distinguish resident from non-resident patenting. This controls for technology and other shocks that lead to changes in a country's overall patenting. We see that resident patenting is more strongly correlated with the country's patenting in the United States, a plausible result that holds throughout our analysis. With the inclusion of all control variables, the business travel coefficient is estimated at just under 5%. Population size, domestic R&D expenditures and resident patent applications are associated with higher patenting in the U.S., while neither U.S. FDI nor U.S. exports have a significantly positive effect on the rate of patenting.

We now turn to a preliminary analysis of the economic magnitude implied by these

[48] We cluster by country-year because some of the variables do not vary by quarter and by industry; for example, GDP per capita for a given year is employed for all four quarters of that year and all industries. In contrast, patents on the left and the business variable on the right-hand side vary by quarter and industry.

estimates. The size of the business travel coefficient suggests that a 10% increase in business travelers from the U.S. is associated with an about 0.5% higher number of patent applications in the United States. If we focus on foreign patents with U.S. co-inventors, the coefficient estimate for business traveler is about 0.07, see column 6, compared to 0.05 for all U.S. patents in column 5. The finding of a larger coefficient for U.S. business travelers when U.S. persons are co-inventors on certain patents is consistent with stronger international transfer through travel for these technologies.[49]

In the previous regressions the relationship between patenting and business travel may be affected by unobserved shocks which would lead to biased estimates. In particular, we are concerned that $E[B_{cqti}, \varepsilon_{cqti}] > 0$, because this would lead to an upward bias in the business travel coefficient. One possible reason for this may be shocks to the business climate in a country that attract both U.S. business travelers while at the same time stimulating patenting activity in a country. Our approach is to construct a control function such that when it is included in the regression the correlation of business travel and the new regression error is zero.[50] The control function that we propose is the residual of a regression of business travel on visitor travel. Consider the following ordinary least-squares regression:

$$\ln B_{cqti} = \gamma_c + \gamma_q + \gamma_t + \gamma_i + \gamma_1 \ln V_{cqti} + \gamma_2 X_{cqti} + \omega_{cqti}, \tag{4}$$

where V_{cqti} is the number of visitor travelers between the U.S. and country c in quarter q

[49] An interesting result is that U.S. FDI is negative and significant at 10% when the dependent variable is foreign patents with U.S. co-inventors. A possible explanation for this is that if a U.S. person has a joint patent with a foreign inventor, the former is less likely to engage in FDI in that country to protect the invention.

[50] Control function approaches have been widely applied in the estimation of productivity, perhaps starting with Olley and Pakes (1996); Blundell and Powell (2003) give an overview and provide general results on the control function approach.

of year t and industry i, where visitor travel is defined as travel intended to meet family and friends. Note that the estimated residual $\hat{\omega}_{cqti}$ of this regression will tend to be high whenever business travel is high relative to visitor travel, conditional on all covariates. This residual will serve as the control function in our setting.

For example, a new direct air connection between a particular U.S. state and a particular foreign country c will typically lead to an increase in business travel but it will also increase visitor travel. Thus there are many instances in which business and visitor travel will be correlated. In Figure 1, we show the 10-year differences for visitor versus business travel in our data by country. There is a strong correlation, which also exists for shorter periods of time.

The logic of the control function approach lies in the fact that $\hat{\omega}_{cqti}$ will pick up instances when the relationship of business to visitor travel is unusual (in the sense of away from the regression line shown in Figure 1). For example, if foreign country c improves its business conditions by lowering corporate taxes, this will tend to increase business travel. Because the lower taxes might also stimulate patenting in country c, this would not constitute the exogenous variation that is needed to estimate the causal impact of business travel on patenting. However, augmenting the estimating equation with the (time-varying) control function $\hat{\omega}_{cqti}$,

$$E\left[P_{cqti}|B_{cqti},\hat{\omega}_{cqti}\right]=\exp\left[\alpha\ln B_{cqti}+\beta\ln X_{cqti}+\mu_c+\mu_q+\mu_t+\mu_i+\hat{\omega}_{cqti}+\varepsilon_{cqti}\right] \quad (5)$$

allows to consistently estimate the impact of business travel on patenting because the reduction in taxes will raise business travel relative to visitor travel, which according to equation (4) will increase the control function $\hat{\omega}_{cqti}$. In sum, identification in this control function approach comes from changes in business travel conditional on changes in profitability, technological capability, and all other factors that are captured by shifts in the business-visitor traveler relationship.

The main identification assumption is that visitor travelers do not transfer technology. Of course, visitor travel might convey basic information about foreign countries and their economies, but this is likely already captured by country-, industry-, and time fixed effects. Arguably the identification assumption is reasonable because the primary motive of visiting family and friends is to maintain personal relations. While the assumption cannot be tested, we will present some evidence indicating that it holds in the present context in Table 6 below.

Table 3 shows the results from a number of control function regressions (equation 4 above). Column 1 corresponds to visitor travel as the only control variable, while columns 2, 3, 4 and 5 successively include additional control variables, namely the number of persons traveling who are retired, the number of persons who travel for religious reasons, and the number of travelers that are homemakers. As for visitors, persons who travel for religious purposes or are, in terms of their occupation, retired or homemakers, it is reasonable to assume that they are not importantly involved in the transfer of technological knowledge. The results for these regressions indicate that all control variables are positively correlated with business travel, and all with the exception of religious travel are significant. The most important predictor is visitor travel, probably because visitor travel is relatively common, see the summary statistics in Table 1.

Table 4 shows the results of the control function approach. The control functions $\hat{\omega}_1$ to $\hat{\omega}_5$ from Table 3 are included in the negative binomial regressions, as in equation (5). The first column repeats the baseline results from Table 2, column 5 with a coefficient of 4.9% for the business traveler variable. If endogeneity generates an upward bias in this coefficient, upon inclusion of the control function it is expected that the coefficient on business travel will decrease, and that the coefficient on $\hat{\omega}$ itself is positive. Indeed, we find that the coefficient on the business travel variable falls, from 4.9% in column 1 to around 2.8% and significant in columns 2 to 6. The control function point estimates are between 5.8% and 6.5%, highly significant at 1%. Turning to the results for foreign patent applications in the United States with U.S. co-inventors on the right side of Table 4, we see that the control function correction has qualitatively the same effect on the business travel coefficient, which comes down from about 7 to 6%, while here the control function is not significant. The likely reason for lower precision in the control function is the relatively small set of joint foreign and U.S. patents.[51] Overall, these results indicate that there is a significant effect of business travel on domestic innovation.

What are the economic magnitudes that our estimates yield? Take Austria and Belgium, two countries of similar size and level of development. It turns out that during the sample period covered by the survey around 2,300 business travelers from the United States went to Belgium, compared to just below 1,400 that went to Austria. This overall difference makes for about 3 U.S. business travelers in our sample going to the average industry per year in Belgium, whereas the number of U.S. business travelers per industry and year going to Austria was about 2. At the same time, the mean patenting in Belgium was 5.7, compared to 4.5 in Austria.

We can use our estimates from Table 4 to gauge the importance of international busi-

[51] When using U.S. joint patents as a dependent variable, visitor only control function turns very small (virtually zero), most likely because of small set of joint foreign and U.S. patents.

ness travel from the U.S. in accounting for this difference of 1.2 in mean patenting. The coefficient on business travel is 0.028, so the predicted patenting premium in Belgium over Austria attributable to the higher number of U.S. business travelers is about 0.012 (equal to $\exp[0.028 \times \ln(3)] - \exp[0.028 \times \ln(2)]$), or about 1% of the total difference. While this is a relatively small number, this effect comes from travel from a single (albeit important) country, the United States. The contribution of travel from *all* countries in explaining variation in the patenting rates across countries is probably a small multiple of that. Another way to assess the economic importance of business travel for patenting is to compare it with domestic R&D expenditures. We calculate that business travel is 1/5 as important as domestic R&D in accounting for patenting differences using marginal effects of our estimated coefficients. Overall, our results suggest that international business travel explains a significant and small to moderate portion of differences in the rate of patenting across countries.

These results come from a large sample of industries, where patenting is much more important is some industries than in others. In the following we examine whether the estimated relationship between business travel and innovation holds for high versus low patenting industries.[52] The results are shown in Table 5. Column 1 repeats for convenience the baseline estimates without the control function (from Table 4, column 1), while in columns 2 and 3 in addition to business travel an interaction of business travel with high patenting dummy (based on median or mean) is included. It is apparent that the impact of business travel on innovation is greater in high patenting industries: the coefficient on business travel in high

[52] In order to correctly identify high versus low patenting industries, we take into account that our sample spans vastly different countries some of which patent more than others. For the following table median and mean of patents are created based on country-industry combination. High patenting dummy is defined to be 1 if patent counts for a given country c in quarter q of year t and industry i is higher than median/mean.

patenting industries is around 0.3 compared to business travel overall 0.05 (column 1). It is somewhat of a puzzle that business travel has a negative impact in low-patenting industries, however, this may be due to correlation among the independent variables.

In columns 4 to 6, we show analogous results using the preferred control function approach. Baseline estimates with the control function (Table 4, column 6) are repeated in column 4. Columns 5 and 6 present estimates with control function for pure business travel coefficient as well as a separate control function for interaction. The results show that both without and with the control function correction, business travel has a more sizeable effect on innovation in high patenting industries.

Next we perform two important specification checks, see Table 6. In the first part of the table (columns 1-5) we examine the importance of differences in terms of technological knowledge of the travelers, which we account for by weighing travel by the U.S. states' and industry patent stocks (equation 2 above). In columns 1-5 results from employing unweighted business travel variables are shown, in comparison to our baseline (weighted) business travel variable. In the basic specification in column 2, the coefficient on business travel is essentially zero as opposed to about 0.03 (Table 4). Specifically, for all foreign patent applications in the U.S., the point estimate falls from 3% to essentially zero. In the case of the foreign patents with U.S. co-inventors, the unweighted business travel estimate is also very small, whereas the patent-stock weighted business travel has a coefficient of about 0.06. We conclude that accounting for technological knowledge heterogeneity is very important in studying the impact of business travel on domestic innovation.

To check the importance of business versus visitor travel, both (weighted) business and visitor travel are included in the same regression, columns 6 and 7 of Table 6. In column

6 where the dependent variable is all U.S. patent applications, with the addition of visitor travel the size of the business travel coefficient increases (still significant) while visitor travel turns negative. This may be due to collinearity of the business and visitor traveler variables shown in Figure 1. In the case with joint foreign/U.S. patents, business travel remains highly positive and significant, while the coefficient on visitor travel is virtually zero. This supports our assumption that it is business travel that matters for international technology transfer, and not other types of air travel.

We have also conducted a number of other robustness checks. First, we have employed the domestic patenting variable (resident and non-resident) lagged by one year so as to reduce the possibility that patent applications in the U.S. simply mirror domestic patent applications. This turns out to yield similar results. Second, we have lagged the business traveler variable by one year, exploring the idea that it might take some time until business travel from the U.S. translates into domestic innovation. Also this leads to similar although somewhat lower estimates. Overall this analysis indicates that the estimated impact from U.S. business travel on foreign countries' rates of innovation is robust.

We now turn to a concluding discussion.

2.5 Conclusions

We have argued that face-to-face meetings might be particularly important for the transfer of technology, because technology is tacit, and therefore best explained and demonstrated in person. Along these lines this paper has examined the impact of inward business travelers in raising a country's rate of innovation at the industry level by looking at business travel from the United States to thirty-six other countries during the years 1993-2003. The results indicate that international business travel has a significant effect. Quantitatively, the impact of business travel on innovation is sizable. It accounts in the typical industry for about 1% of the total difference in patenting rates, and its contribution is about one fifth of the contribution of domestic R&D spending. Moreover, there is strong evidence that the impact on innovation depends on the quality of the technological knowledge carried by each business traveler.

While international migration has long been a hot topic in debates on labor market policies, some recent work has started to address another set of policy questions by linking long-term immigration to innovation in an economy (Peri 2007, Hunt and Gauthier-Loiselle 2010, Stuen, Mobarak, and Maskus 2012). In contrast, our research informs policymakers by examining how strongly short-term cross-border movements affect innovation. In particular, given that entry requirements will tend to reduce a country's number of business travelers, our results provide some initial guidance on the cost of visa or other entry requirements in terms of innovation that can be compared to the benefits entry barriers might have. Our analysis also provides a new perspective on other key policy questions, for example the liberalization of international trade in services. Specifically, the finding that business air travel raises innovation suggests that the liberalization of international passenger air travel, by lowering fares, might yield substantial gains in terms of economic growth across countries. Our analysis also highlights the need for good statistical data on international business travel, a key input for future work on this topic.[53]

While our results suggest that short-term international labor movements could be an

[53]Fortunately, there are some signs that international agencies are moving into this direction. In particular, the 2008 guidelines of the World Tourism Organization aim at distinguishing business and professional from leisure travelers more clearly; see http://www.unwto.org/statistics/irts/annex.pdf

important way through which cross-country income differences can be reduced, more work needs to be done. One, it will be interesting to compare our results to studies employing alternative sources of identification, such as policy changes and quasi-natural experiments. Two, an important question is whether the strength of the effect depends strongly on country and sectoral characteristics, as has been shown for technology transfer through trade and FDI (see De Loecker 2007 and Keller and Yeaple 2009, respectively). In our setting, a promising direction of future work may be to include more geographic detail, perhaps isolating key states, such as California. Three, it would be interesting to see whether a country's own outward business travel is affecting innovation as strongly, or even more strongly, as the inward business travel from the United States. Finally, there are important questions regarding the degree of complementarity between cross-border travel, trade, and FDI that future work needs to address.

2.6 Tables and Figures

Figure 1: 10-year Differences of Business and Visitor Travel, 1993-2003

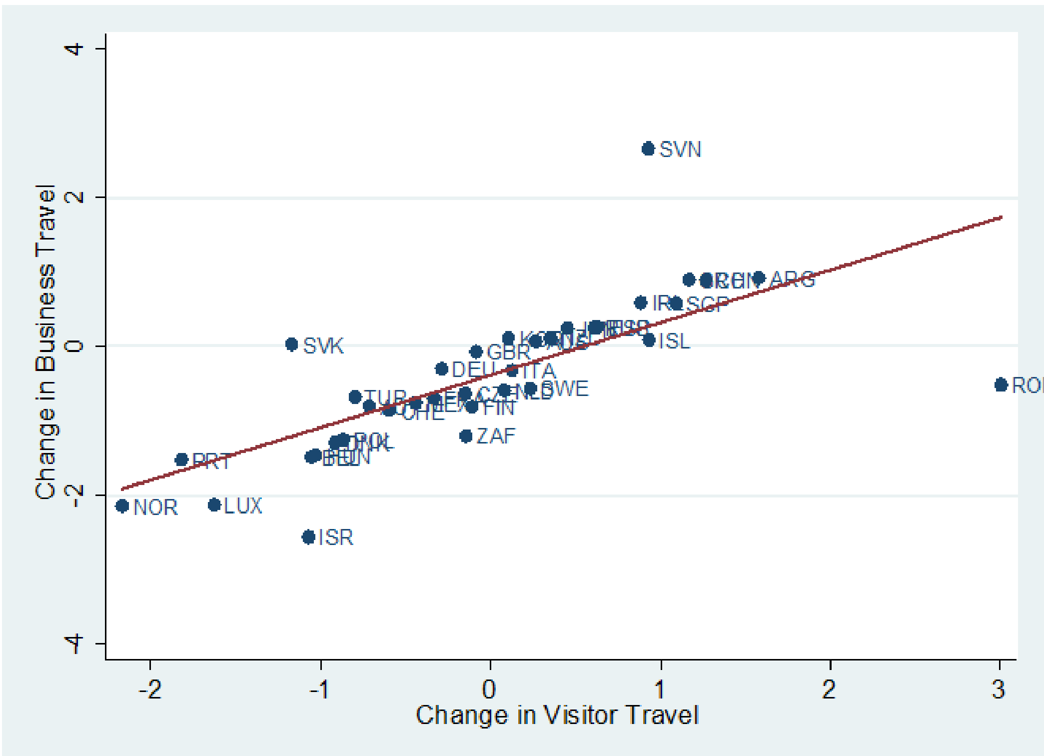

Table 1. Descriptive Statistics

Variable	Mean	Standard Deviation	Min	Max
US Patenting				
US patent counts	26.306	81.471	0	930
Joint US patent counts	0.443	1.541	0	40
US Resident Travel				
Business travel	0.843	0.987	0	7.294
Visitor travel	0.732	0.995	0	7.305
Religious travel	0.021	0.158	0	3.945
Retired travel	0.412	0.762	0	6.355
Homemaker travel	0.214	0.537	0	6.087
Other Variables				
Population	10.230	1.504	5.609	14.068
Real GDP per capita	9.718	0.577	7.599	10.843
US exports	22.745	1.388	18.062	25.436
US FDI	24.069	1.617	16.300	26.734
R&D expenditures	22.684	1.408	18.672	25.385
Patent applications, non-residents	7.824	1.852	0	10.958
Patent applications, residents	8.259	2.197	0	12.859

Number of observations for all variables is 16,992. All variables, except US Patent Counts and Joint US Patent Counts are in natural logarithms. Real GDP per capita, US exports, US FDI and R&D expenditures are in dollars. US FDI is total sales of majority owned multinational firms.

Table 2: Baseline Results

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable			US patents			Joint US patents
Business travel	0.056**	0.053**	0.052**	0.050**	0.049**	0.067**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.017)
Population		5.300**	4.467**	2.299**	1.980**	0.185
		(0.729)	(0.754)	(0.705)	(0.681)	(1.346)
Real GDP per capita		1.947**	1.050**	0.492	0.417	1.030*
		(0.374)	(0.367)	(0.320)	(0.299)	(0.511)
US exports			0.102	0.015	-0.056	0.737**
			(0.137)	(0.118)	(0.115)	(0.195)
US FDI			0.291**	0.129	0.114	-0.267+
			(0.097)	(0.091)	(0.087)	(0.147)
R&D expenditures				0.872**	0.775**	-0.107
				(0.140)	(0.133)	(0.267)
Patent applications, non-residents					0.079	0.182*
					(0.051)	(0.081)
Patent applications, residents					0.180**	1.001**
					(0.043)	(0.153)
Observations	16992	16992	16992	16992	16992	16992
Log likelihood	-42068	-41876	-41855	-41810	-41749	-7791

Notes: Negative binomial regressions. All specifications include country, year, quarter and industry fixed effects. Robust standard errors allow for clustering by country-year and are shown in parenthesis; + p<0.10, * p<0.05, ** p< 0.01

Table 3: Control Function Regressions

	(1)	(2)	(3)	(4)	(5)
Dependent variable			Business travel		
Visitor travel	0.738**	0.673**	0.673**	0.624**	0.624**
	(0.006)	(0.009)	(0.009)	(0.010)	(0.010)
Retired travel		0.112**	0.111**	0.093**	0.092**
		(0.011)	(0.011)	(0.011)	(0.011)
Religious travel			0.036		0.021
			(0.028)		(0.029)
Homemaker travel				0.155**	0.155**
				(0.012)	(0.012)
Population	-0.594**	-0.548**	-0.549**	-0.540**	-0.540**
	(0.191)	(0.189)	(0.189)	(0.188)	(0.188)
Real GDP per capita	-0.051	-0.023	-0.024	-0.003	-0.004
	(0.087)	(0.085)	(0.085)	(0.084)	(0.084)
US exports	0.034	0.030	0.030	0.026	0.026
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
US FDI	0.016	0.012	0.012	0.008	0.008
	(0.018)	(0.018)	(0.018)	(0.017)	(0.017)
R&D expenditures	0.066*	0.064+	0.064+	0.057+	0.057+
	(0.034)	(0.033)	(0.033)	(0.033)	(0.033)
Patent applications, non-residents	0.007	0.008	0.008	0.009	0.009
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Patent applications, residents	0.004	0.006	0.006	0.005	0.005
	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
Observations	16992	16992	16992	16992	16992
R-squared	0.833	0.836	0.836	0.839	0.839

Notes: All specifications include country, year, quarter and industry fixed effects. Robust standard errors in parentheses, + p< 0.10, *p<0.05, ** p<0.01

Table 4: Patent Counts with Control Function

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable				US patents			US joint patents	
Business travel	0.049**	0.029*	0.028*	0.028*	0.028*	0.028*	0.067**	0.060**
	(0.010)	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.017)	(0.022)
Population	1.980**	2.002**	2.006**	2.006**	2.004**	2.004**	0.185	0.196
	(0.681)	(0.680)	(0.680)	(0.680)	(0.681)	(0.681)	(1.346)	(1.345)
Real GDP per capita	0.417	0.420	0.420	0.420	0.417	0.417	1.030*	1.029*
	(0.299)	(0.299)	(0.299)	(0.299)	(0.299)	(0.299)	(0.511)	(0.512)
US exports	-0.056	-0.059	-0.058	-0.058	-0.058	-0.058	0.737**	0.734**
	(0.115)	(0.115)	(0.115)	(0.115)	(0.115)	(0.115)	(0.195)	(0.195)
US FDI	0.114	0.116	0.116	0.116	0.117	0.117	-0.267+	-0.264+
	(0.087)	(0.086)	(0.086)	(0.086)	(0.086)	(0.086)	(0.147)	(0.147)
R&D expenditures	0.775**	0.772**	0.771**	0.771**	0.772**	0.772**	-0.107	-0.107
	(0.133)	(0.133)	(0.133)	(0.133)	(0.133)	(0.133)	(0.267)	(0.267)
Patent applications, non-residents	0.079	0.080	0.080	0.080	0.080	0.080	0.182*	0.182*
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.081)	(0.081)
Patent applications, residents	0.180**	0.179**	0.179**	0.179**	0.179**	0.179**	1.001**	1.001**
	(0.043)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.153)	(0.153)
Controls		0.058*	0.063**	0.063**	0.065**	0.065**		0.027
		(0.023)	(0.024)	(0.024)	(0.023)	(0.023)		(0.038)
Control function type		*Vz*	*Vz, Rt*	*Vz, Rl, Rt*	*Vz, Rt, Hm*	*Vz, Rl, Rt, Hm*		*Vz, Rl, Rt, Hm*
Observations	16992	16992	16992	16992	16992	16992	16992	16992
Log-likelihood	-41749	-41744	-41744	-41743	-41743	-41743	-7791	-7791

Notes: Negative binomial regressions. All specifications include country, year, quarter and industry fixed effects. Robust standard errors allow for clustering by country-year and are shown in parenthesis; + p<0.10, * p<0.05, ** p< 0.01. Types of travel variables for Control Function (CF): Vz-visitor, Rl-religious, Rt-retired, Hm- homemaker.

Table 5: High versus Low Patenting Industries

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable			US patents			
Business travel	0.049**	-0.099**	-0.111**	0.028*	-0.098**	-0.113**
	(0.010)	(0.014)	(0.015)	(0.012)	(0.016)	(0.017)
Business travel *High patents (median)		0.276**			0.259**	
		(0.021)			(0.021)	
Business travel* High patents (mean)			0.289**			0.274**
			(0.020)			(0.021)
Population	1.980**	2.178**	2.094**	2.004**	2.216**	2.132**
	(0.681)	(0.672)	(0.657)	(0.681)	(0.664)	(0.650)
Real GDP per capita	0.417	0.689*	0.664*	0.417	0.680*	0.657*
	(0.299)	(0.286)	(0.275)	(0.299)	(0.284)	(0.273)
US exports	-0.056	-0.091	-0.100	-0.058	-0.086	-0.096
	(0.115)	(0.105)	(0.099)	(0.115)	(0.104)	(0.098)
US FDI	0.114	0.103	0.106	0.117	0.105	0.108
	(0.087)	(0.081)	(0.079)	(0.086)	(0.081)	(0.079)
R&D expenditures	0.775**	0.721**	0.735**	0.772**	0.711**	0.727**
	(0.133)	(0.124)	(0.120)	(0.133)	(0.123)	(0.119)
Patent applications, non-residents	0.079	0.059	0.059	0.080	0.060	0.060
	(0.051)	(0.042)	(0.042)	(0.051)	(0.042)	(0.042)
Patent applications, residents	0.180**	0.143**	0.140**	0.179**	0.143**	0.140**
	(0.043)	(0.040)	(0.041)	(0.042)	(0.040)	(0.040)
Control function				0.065**	0.000	0.008
				(0.023)	(0.031)	(0.029)
Control function: interaction					0.094*	0.080*
					(0.037)	(0.035)
Observations	16992	16992	16992	16992	16992	16992
Log-likelihood	-41749	-41279	-41232	-41743	-41268	-41223

Notes: Negative binomial regressions. All specifications include country, year, quarter and industry fixed effects. Robust standard errors allow for clustering by country-year and are shown in parenthesis, + p<0.1, * p<0.05, ** p<0.01. Control Function (CF) in columns (4)-(6) is visitor, religious, retired and homemaker travel.

Table 6: Specification Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable		US patents		US joint patents		US patents	US joint patents
Business travel (unweighted)	0.010	0.002	0.000	-0.003	0.001		
	(0.009)	(0.013)	(0.012)	(0.016)	(0.024)		
Business travel (weighted)						0.087**	0.067*
						(0.018)	(0.030)
Visitor travel (weighted)						-0.043*	0.001
						(0.017)	(0.030)
Population	1.986**	1.992**	1.995**	0.070	0.067	2.037**	0.184
	(0.677)	(0.678)	(0.678)	(1.348)	(1.350)	(0.680)	(1.344)
Real GDP per capita	0.413	0.418	0.417	1.005*	1.002*	0.423	1.030*
	(0.300)	(0.299)	(0.300)	(0.510)	(0.509)	(0.298)	(0.512)
US exports	-0.069	-0.071	-0.072	0.743**	0.745**	-0.061	0.737**
	(0.116)	(0.116)	(0.116)	(0.193)	(0.192)	(0.115)	(0.196)
US FDI	0.118	0.118	0.119	-0.262+	-0.262+	0.115	-0.267+
	(0.087)	(0.087)	(0.087)	(0.146)	(0.146)	(0.086)	(0.146)
R&D expenditures	0.784**	0.784**	0.783**	-0.089	-0.089	0.768**	-0.107
	(0.133)	(0.133)	(0.133)	(0.266)	(0.266)	(0.133)	(0.267)
Patent applications, non-residents	0.079	0.079	0.079	0.186*	0.185*	0.079	0.182*
	(0.051)	(0.051)	(0.051)	(0.079)	(0.079)	(0.051)	(0.080)
Patent applications, residents	0.181**	0.182**	0.182**	1.012**	1.012**	0.179**	1.001**
	(0.043)	(0.042)	(0.042)	(0.153)	(0.153)	(0.042)	(0.153)
Control function		0.017	0.023		-0.010		
		(0.020)	(0.020)		(0.047)		
Control function type		*Vz*	*Vz, Rl, Rt, Hm*		*Vz, Rl, Rt, Hm*		
Observations	16992	16992	16992	16992	16992	16992	16992
Log-likelihood	-41767	-41767	-41766	-7803	-7803	-41744	-7791

Notes: Negative binomial regressions. All specifications include country, year, quarter and industry fixed effects. Robust standard errors allow for clustering by country-year and are shown in parenthesis, + p<0.1, * p<0.05, ** p<0.01. Types of travel variables for Control Function (CF): Vz-visitor, Rl-religious, Rt- retired, Hm- homemaker.

3 "Technology Sourcing through International Business Travel"

3.1 Introduction

It is well-known that knowledge creation is concentrated in several countries. Gaining access to foreign knowledge is important for the economic growth and convergence of countries who are behind the technological frontier. How does a country tap into foreign knowledge? There is evidence of technology sourcing through Foreign Direct Investment (FDI), international trade and immigration, but do short-term people flows matter for technology sourcing from abroad?

This paper addresses the question of the importance of a country's outward short-term cross-border people flows for domestic innovation. Business case studies and business journals stress the importance of face-to-face communication for negotiating deals and selling products.[54] However, as technology is tacit and is hard to codify (Polanyi 1958), personal contact might indeed be especially important for the transfer of technology. International business travel can facilitate information exchange and knowledge acquisition, which promotes innovation through inward business travel where foreigners bring knowledge and ideas with them (Hovhannisyan and Keller 2011). Do foreigners bring technological knowledge with them, or does a country send its travelers to source such knowledge from abroad? The hypothesis behind this paper is that business travelers who visit a high-technology country like the United States can learn about technological knowledge through communication and face-to-face interaction and can bring that knowledge back to their home country.

This paper provides new evidence that outward business travel impacts domestic inno-

[54] See surveys of business executives in Harvard Business Review (2009) and Forbes (2009).

vation, using quarterly data on 84 countries' business travel to the United States between 1993 and 2003. The estimates suggest that on average, a 10 percent increase in outward business travel increases domestic patenting by 0.3 percent. The approach of estimating the causal impact of international business travel on innovation uses instruments from variation of post-September 11, 2001 and relative changes in U.S. visa policy towards Visa Waiver Program (VWP) and non-VWP countries (Poole 2010, Neiman and Swagel 2009). The VWP program enables citizens of certain countries to travel to the United States without a visa for business or pleasure not to exceed 90 days. These are countries with good ties with the United States, who offer reciprocal visa waiver to U.S. citizens, and who are not considered a threat to U.S. national security.[55] Instrumenting business travel by the exogenous shock of 9/11 combined with variation from countries with and without travel restrictions, a 10 percent increase in outward business travel to the U.S. from a country increases the country's domestic patenting by 3 percent.

There is a vast body of literature on technology sourcing through Foreign Direct Investment and international trade.[56] Outward FDI as a method of sourcing foreign technology has been studied by a number of authors (e.g. Griffith, Harrison and van Reenen 2006; Branstetter 2006; Almeida 1996). Griffith and coauthors find evidence of positive home country productivity effects from outward FDI in the U.S, while Branstetter and Almeida find positive effects on cross-country patent citations. There is also evidence on learning effects of increased productivity through international trade. A new direction of research has addressed the importance of business travel for stimulating trade relationships (Poole

[55] Source: U.S. Department of Homeland Security, Yearbook of Immigration Statistics.
[56] See Keller (2010) for a survey.

2010, Cristea 2011). This previous research reinforces the importance of controlling for FDI and international trade in the present study.

The second strand of the literature addresses the importance of labor flows as an avenue for international technology transfer. While the effects of immigration on technology transfer have been widely studied, research on the effects of short-term international labor flows on innovation (Hovhannisyan and Keller 2011) and productivity (Andersen and Dalgaard 2011; Gambardella, Mariani and Torrisi 2009; Dowrick and Tani 2011; Le 2008) is still developing. Hovhannisyan and Keller find that inward business travelers to another country from the United States raise that country's level of innovation as measured by patenting. In terms of productivity, Andersen and Dalgaard find that intensity of air passenger travel scaled by population helps explain Total Factor Productivity (TFP) differences among countries. A related study by Dowrick and Tani shows that business travel positively affects industry-level productivity in Australia.

This paper is also related to the literature on the role of social and personal contacts on easing technology transfer. The role of collaborative networks for interregional and interfirm technology transfer has been studied by a number of researchers (Singh 2005; Agrawal, Cockburn and McHale 2006). Choudhury (2010) finds evidence that inventor mobility within multinational firms is important for knowledge creation. The role of ethnic communities in international technology transfer has been emphasized by Kerr (2008).

This paper contributes to the first strand of literature by providing evidence on technology sourcing through short-term labor flows, as business travel creates an observable channel of knowledge transmission. In relation to the second body of the literature, this paper finds that outward business travel to a country is yet another significant conduit of technology transfer. The data used in this paper allows us to specifically differentiate business travelers from other types of travelers, and to use the exogenous variation in post 9/11 travel and U.S. visa policy changes. This paper also adds to the literature on the importance of face-to-face communication for knowledge creation and transfer.

The remainder of the paper is organized as follows. Section 2 details the empirical methodology. Section 3 describes the data and presents descriptive statistics. Empirical results are summarized in section 4, while conclusions are discussed in section 5.

3.2 Empirical Methodology

The goal of this paper is to estimate the relationship between a country's short-term cross-border labor flows and innovation. Outward business travel from a country to the United States over eleven years, from 1993-2003, is related to a country's level of innovation as measured by the domestic patent applications of its residents. Since the United States is one of the most technologically advanced countries, looking for evidence of technology sourcing through travel to the United States is important.

Patenting in a particular country c in year t, P_{ct} is specified to be a function Φ of outward business travel to the United States, B_{ct} and of other observed and unobserved determinants, Z_{ct}:

$$P_{ct} = \Phi(B_{ct}, Z_{ct}, \Theta) \tag{1}$$

where Θ is a vector of unknown parameters. The following equation will be estimated

$$E[P_{ct}|B_{cqt}] = \exp[\alpha \ln B_{cqt} + \beta \ln X_{ct} + \delta_c + \delta_t + \varepsilon_{ct}], \tag{2}$$

where P_{ct} is expected domestic patent counts by residents in a country c in year t; B_{cqt} is resident business travelers from country c going to the U.S in quarter q of year t; X_{ct} are other determinants of country c patenting in year t, such as income etc.; and δ's are country -, and year- fixed effects. It is expected that the coefficient on α will be positive, implying that business travel increases innovation.

Business travel to the United States from foreign countries can further be disaggregated by the destination state. States within the U.S. differ in their degree of technological advancement, and therefore travel to a high-technology state might have more important benefits for knowledge transfer than travel to a low-technology state. Therefore, business travel to a U.S. state is weighted by the U.S. state's patent stock relative to the state's Gross Domestic Product (GSP) and aggregated over states as follows

$$B_{cqt} = \sum_{s \in S} \frac{P_{sqt}}{GSP_{sqt}} \times \widetilde{B}_{scqt}, \tag{3}$$

where P_{sqt} is the patent stock of state s in quarter q of year t, GSP_{sqt} is real GSP of state s in quarter q of year t , and $\widetilde{B}_{scqt}$ is the number of business travelers coming to a U.S. state s from country c in quarter q of year t.

Although the estimation equation (2) presents an initial benchmark on estimating the relationship between business travel and innovation, the time period as well as a vast sample of 84 countries with travelers to the U.S. (see the list of countries in Appendix Table A2) allows us to identify a more causal link. To study the causal impact of travel on innovation, this paper employs variation from global conflict of September 11, 2001 and Visa Waiver Program countries (VWP). The Visa Waiver Program, which was founded in 1986, allows citizens of certain countries to visit the United States without a visa for business or pleasure not to exceed 90 days. The list of Visa Waiver Program countries during 1993-2003 is presented in the Appendix Table A1. Of the 84 countries employed in the empirical analysis (see Appendix Table A2), 24 countries were members of the VWP during some time during the estimation period. The list of countries used in the analysis which were also VWP countries can be found in Appendix Table A3.

Travel restrictions in terms of visa requirements and other barriers tend to reduce travel flows, so that in general, travel to the United States from countries that do not require a visa (VWP countries) is more frequent than for countries that do (non-VWP countries). However, increased security checks and delays at the airports, as well as general psychological factors might impact VWP and non-VWP countries differently.

This paper uses a two-stage analysis to first estimate business travel from exogenous variation of unexpected conflict of September 11, 2001 and variation from travelers from VWP versus non-VWP countries. Following Poole (2010), business travel in the first stage is estimated using Ordinary Least Squares (OLS) as follows

$$\ln B_{cqt} = \alpha + \beta Sept11_{qt} + \gamma VWP_{cqt} + \theta Sept11 \times VWP_{cqt} + \delta_c + \delta_t + \varepsilon_{cqt}, \quad (4)$$

where B_{cqt} is weighted business travel to the U.S. from country c in quarter q of year t, Sept11 is a dummy equal to one for all quarters and years after Sept 11, 2001, VWP_{cqt} is a dummy equal to 1 for Visa Waiver Program country c in quarter q of year t; δ's are country-, and year- fixed effects. Including the interaction effect of Sept11 and VWP program countries $Sept11 \times VWP_{cqt}$, will allow us to estimate the differential effect of 9/11 on countries with and without travel restrictions. Further, the predicted business travel from the first stage is used to estimate equation (2) using methods appropriate for the count data.

Before turning to the empirical results, the next section discusses the data sources and presents descriptive statistics of the main variables.

3.3 Data

The travel data for this paper comes from the Survey of International Air Travelers (SIAT), conducted by the Office of Travel and Tourism Administration, International Trade Administration, U.S. Department of Commerce. SIAT collects data on non-U.S. residents traveling to the U.S. and on U.S. residents traveling overseas. This paper uses data on foreign resident travelers coming to the United States for each quarter between 1993 and 2003.[57] It is an individual-level dataset which includes travelers' purpose of the trip, occupation, country of residence, country of citizenship and U.S. destination county. Individual-level data is expanded by the main and secondary purposes of the trip, as well as by destination states in the U.S. if a particular individual traveled to distinct states. Further, expanded individual travel observations are aggregated by the purpose of the trip by foreign country of residence and destination U.S. state. Since the empirical analysis will use variation from entry requirements and the Visa Waiver Program, U.S. citizens are dropped from the analysis. As a result, numbers on business travelers are obtained coming to a U.S. state s from country

[57] Hovhannisyan and Keller (2011) use SIAT data on U.S. residents traveling from the United States to foreign countries.

c in every quarter from 1993 to 2003.

According to the equation (3), business travelers coming to a certain U.S. state are weighted by that state's patent to GSP ratio, and aggregated over states. Data on patent stock by U.S. states is calculated based on custom extracts of United States Patents and Trademark Office (USPTO) files, while data on GSP by year is extracted from the Bureau of Economic Analysis (BEA). After performing weighting, we have total number of (weighted) business travelers coming to the U.S. from foreign countries in every quarter from 1993 to 2003.

The innovation measure used in this paper is domestic patenting by residents of foreign countries between the years 1993 to 2003. It is obtained from the World Intellectual Property Organization (Source: WIPO Statistics Database). It measures patent applications by first-named resident inventors in the home country. For example, this dataset captures patent applications filed by residents of Japan at the Japan Patent Office. This is a yearly-level dataset with varied country coverage.

The size and development level of a country affects its business travel. Therefore, data on a country's population and real GDP per capita are used as controls. They are extracted from the Penn World Tables, version 6.2. It is important to account for other avenues of international technology transfer such as international trade and FDI, as mentioned above. Imports from the United States and exports to the United States by each country from 1993 to 2003 is extracted from the U.S. Census Bureau (www.tradedataonline.gov). U.S. FDI in foreign countries is measured by total sales of majority-owned foreign affiliates of U.S. firms and is taken from the U.S. Bureau of Economic Analysis (BEA).[58]

[58]FDI in the U.S. is only available for a limited set of countries with a lot of missing observations. Therefore,

The final sample is an unbalanced quarterly sample for 84 countries for the years 1993-2003. The list of countries can be found in Appendix Table A2. Summary statistics of the main variables are presented in Table 1. Patent applications are quite dispersed, with the variance exceeding the mean. Patents is a count variable, thus Poisson and negative binomial regressions are appropriate estimation methods. Since there is evidence of over-dispersion, a negative binomial estimation method is more suitable. Only non-zero business travel to the U.S. is considered, since this analysis is not applicable to the case of patenting in the absence of travel. The top countries engaged in business travel to the United States are Japan, Taiwan, Germany, the United Kingdom and Australia. The list of top countries engaged in business travel to the U.S. is presented in Appendix Table A4.

Some initial evidence on the link between patenting and business travel is presented in Figures 1 and 2. We can see that there is a positive country-level relationship between patents-to-GDP ratio and business travel to the United States. In Figure 2, where the major outliers South Korea and Japan are omitted, an even more significant positive relationship is apparent. The empirical strategy will control for country and year fixed effects, so general differences between countries and years will be accounted for in the analysis. Additionally, a set of controls will be employed to account for factors that vary within a country over time.

The next section presents the empirical results.

3.4 Results

The objective of the empirical analysis is to estimate a relationship between business travel to the U.S. and innovation. The results of initial estimation of the equation (2) are presented in

it was not used in the analysis.

Table 2. As mentioned above, the estimation method involves negative binomial regressions. All columns include country and year fixed effects. Robust standard errors which allow for clustering by country-year are shown in parentheses. In the first column, business travel to the U.S. is estimated to be positive and significant, implying that there is a strong positive association between business travel to the U.S. by a country and that country's domestic patenting.

In column 2 of Table 2, controls for population and real GDP per capita are added to account for the fact that residents of large and rich countries will travel more. As expected, this decreases the coefficient on business travel from 0.032 to 0.027 while it remains highly significant. Next, imports from the U.S. and exports to the U.S. are added as additional conduits of technology transfer. For example, if a country has a vast trading relationship with the U.S., there would be a higher need for business travel. Furthermore, Poole (2010) and Cristea (2011) find positive relationship between trade and travel; thus, it is important to control for trade with the U.S. In columns 3 and 4, imports and exports to the U.S. are negative and not significantly estimated, however the coefficient on business travel is virtually unchanged.

U.S. FDI is added to column 5 of Table 2 as an additional control. If the U.S. invested a lot in a country, this might give rise to both business travel from the affiliate to the headquarters in the U.S., as well as increased domestic patenting. Including U.S. FDI does not change the estimated coefficient on business travel, while FDI is positive but not significantly estimated. Including all controls, the relationship between business travel and patenting is around 0.026 and significant. Population and real GDP per capita are estimated to be positive and significant, while the coefficients on trade and FDI are not significantly estimated.

The results in Table 2 give some initial guidance on the hypothesis of technology sourcing through international business travel. However, even after controlling for country and year fixed effects and including a set of controls, there are still endogeneity concerns. It is possible that factors that increase business travel also impact patenting. The best approach is to find exogenous variation in business travel to the U.S. that is not correlated with innovation in these countries. As mentioned above, the exogenous variation to business travel to the United States that will be used is variation occurring post-September 11, 2001 and subsequent changes in U.S. visa policy towards Visa Waiver Program (VWP) and non-VWP countries. As shown in Figure 3, 9/11 impacted VWP and non-VWP countries differently. In general, travel from VWP countries is larger than from non-VWP countries due to the strength of economic and political ties with the United States. Additionally, visa restrictions and other barriers to travel tend to impede travel flow. But VWP countries travel to the U.S. decreased possibly because of increased security measures and increased global instability. As Figure 3 illustrates, travel from VWP countries to the U.S. decreased more than from non-VWP countries. This evidence is consistent with findings by Poole (2010) and Neiman and Swagel (2009).[59]

The first stage regressions of the estimation of equation (4) is shown in Table 3. It is estimated by Ordinary Least Squares (OLS). In column 1 business travel to the U.S. is regressed on a dummy of September 11, 2001. The resulting coefficient on September 11 is negative as expected, but not significant. In column 2, a dummy for Visa Waiver Program countries in quarter q of year t is added. The coefficient on VWP is positive and

[59] Neiman and Swagel (2009) explain this decrease as a result of the fact that travelers from countries that did not require a visa experienced more hassles in general security, and as a result of general 'fear of flying'.

significant, while the coefficient on September 11 remains negative. To account for differential impact of September 11 on travel from countries that required a visa and those that did not, the interaction of VWP and September 11 is added in column 3. The coefficient on the interaction is negative and significant, confirming our earlier conjecture presented in Figure 3. The estimates of column 3 of Table 3 are chosen as the main first stage specification.

In Table 4 estimates from the second stage estimation are presented. For convenience the first column repeats the benchmark specification of Table 2 column 5. In the second column, domestic patenting is regressed on estimated business travel from the first stage of column 3 of Table 3 using negative binomial regression. The estimated coefficient increases significantly from 0.026 to 0.3 and is highly significant. This implies that by taking into account travel restrictions resulting from global conflict and visa requirements that influence travel to the United States, the estimates of business travel on innovation are even stronger. In the third column, the residual from the first stage is also included, which is positive and significant. This should reduce the bias associated with the calculation of clustered country-year standard errors due to the two-stage procedure. The coefficient on business travel in columns 2 and 3 is very close, around 0.3. In column 4, Poisson Instrumental Variables (IV) approach is used, where the instruments are Sept11, Visa Waiver Program and their interaction as in columns 2 and 3. The results are virtually identical, with an estimated business travel coefficient of approximately 0.3.

What are the magnitudes of the estimated coefficients? A 10 percent increase in a country's business travel to the U.S. increases that country's domestic patenting by 0.3 percent. Using the two-stage approach the estimates become even stronger: a 10 percent increase in business travel to the U.S. increases patenting by 3 percent.

Robustness checks are performed in Table 5. For convenience, the first column repeats the benchmark estimates of Table 2 column 5. In the second column, unweighted business travel to the U.S. is employed. It is smaller in magnitude and not significantly estimated, pointing to the importance of weighting business travel. Business travel to a high technology U.S. state matters more for the subsequent transfer of technological knowledge to the home country than travel to a low-technology U.S. state. In the third column of Table 3 estimates from IV Poisson of Table 4 column 4 are included for convenience. To evaluate the sensitivity of the estimates, patenting in the U.S. is used as an alternative innovation measure in the right part of table 5. Columns 4, 5, and 6 replicate the specifications of the previous columns with patenting in the U.S. as the dependent variable. Comparing columns 1 and 4, we can see that estimates of outward business travel on innovation are similar in the case of both patenting measures. In fact, the estimates in the case of patenting in the U.S. are somewhat higher, from 0.026 to 0.04. This might have to do with the fact that patenting in the U.S. is collected quarterly, and that all significant innovations are patented both domestically and in the U.S. Unweighted business travel is used in column 5, and the coefficient is much smaller and not significantly estimated. When considering IV regressions from travel and visa restrictions, the estimates of business travel in column 6 and column 3 are essentially the same, showing that the results of using domestic patenting are robust to another innovation measure.

The next section presents a concluding discussion.

3.5 Conclusions

Technological transfer from developed to developing countries is important for the latter's economic growth and convergence. This paper has studied international technology transfer through short-term cross-border labor flows. Travel across borders enables face-to-face communication, which is particularly important for the transfer of technology since it tends to be tacit and hard to codify. Business travelers who come to a high-technology country like the United States can source technological knowledge there, bring it back to their home country and encourage domestic innovation. Using data on 84 countries' business travel to the United States between 1993 and 2003, this paper finds that outward business travel is positively associated with a country's innovation as measured by domestic patent applications. The magnitude of the coefficient is considerable: a 10 percent increase in outward business travel increases domestic patenting by 3 percent.

This paper has a number of policy implications. Particularly, this study highlights the costs of travel restrictions in terms of their impact on innovation. Reducing visa restrictions and other travel barriers can stimulate international technology transfer and innovation. Also, this analysis sheds light on the importance of the liberalization of international services. The substantial gains from the liberalization of air passenger travel after signing Open Skies Agreements have been discussed by Cristea and Hummels (2011). This study stresses the liberalization of travel in terms of innovation, which might have more long-term economic growth implications for countries.

The empirical analysis performed in this paper presents the first evidence on the importance of outward business travel for a country's innovation. Future research can extend this analysis by including other samples and countries. Also, data on international travel is not very systematic across countries and does not always distinguish the purpose of each trip. Thus, there is a need for higher-quality data on international travel.

3.6 Tables and Figures

Table 1: Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max
Domestic Patents	2231	11179.230	49871.310	0	384201
Business Travel to US	2231	3.299	1.542	0.053	8.114
Population	2231	9.881	1.556	5.609	14.068
Real GDP per capita	2231	9.251	0.827	6.556	10.843
Imports from US	2231	21.791	1.511	16.432	24.937
Exports to US	2231	22.013	1.610	15.392	25.750
US FDI	2231	22.726	1.989	13.816	26.734

The sample includes 84 countries, and 11 years (1993-2003). All variables besides domestic patents are in natural logarithms. US FDI is total sales of majority owned US affiliates.

Figure 1: Business Travel and Patenting

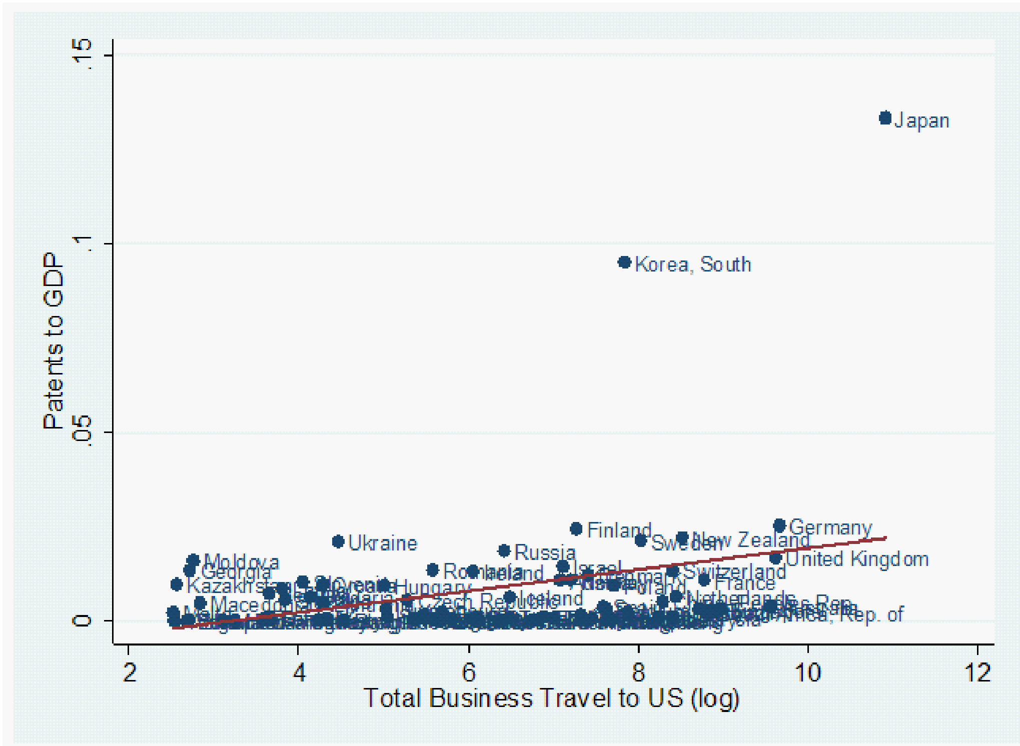

Figure 2: Business Travel and Patenting (omitting South Korea and Japan)

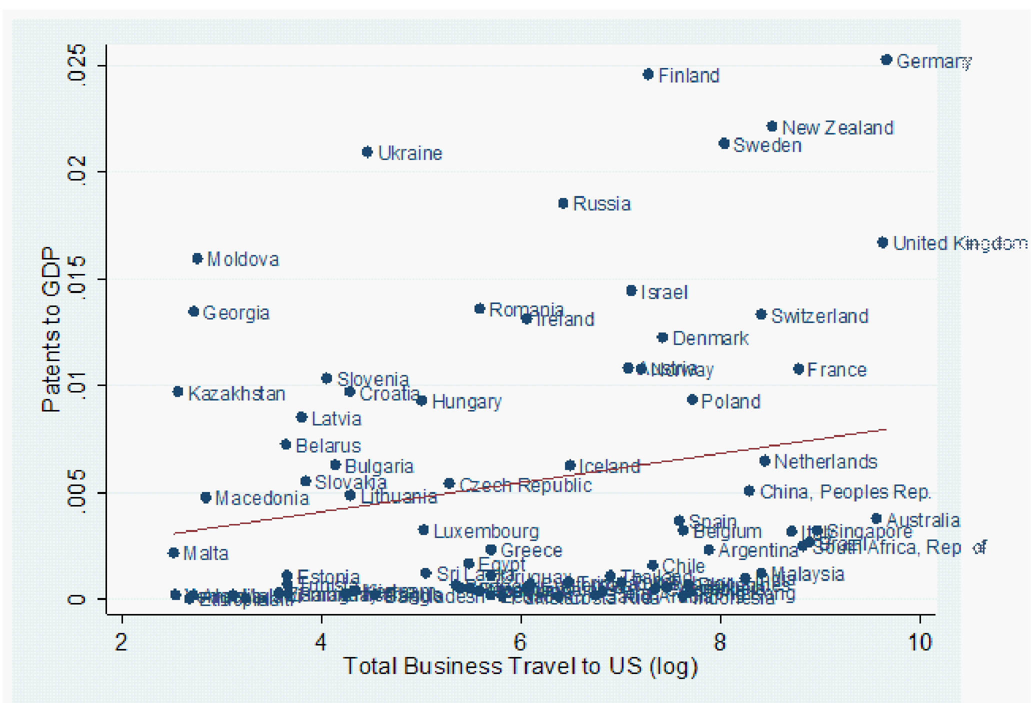

Table 2: Benchmark Specification

	(1)	(2)	(3)	(4)	(5)
Variables	Domestic Patenting				
Business Travel to US	0.032**	0.027**	0.027**	0.026**	0.026**
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Population		2.792***	2.803***	2.820***	2.669***
		(0.569)	(0.566)	(0.557)	(0.576)
Real GDP per capita		0.587**	0.650***	0.758***	0.624**
		(0.245)	(0.247)	(0.270)	(0.281)
Imports from US			-0.055	-0.040	-0.054
			(0.075)	(0.076)	(0.074)
Exports to US				-0.094	-0.103
				(0.085)	(0.084)
US FDI					0.070
					(0.049)
Observations	2231	2231	2231	2231	2231
Log-likelihood	-14525	-14457	-14455	-14452	-14449

Notes: All specifications include country and year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Figure 3: Business Travel- VWP and non-VWP Countries

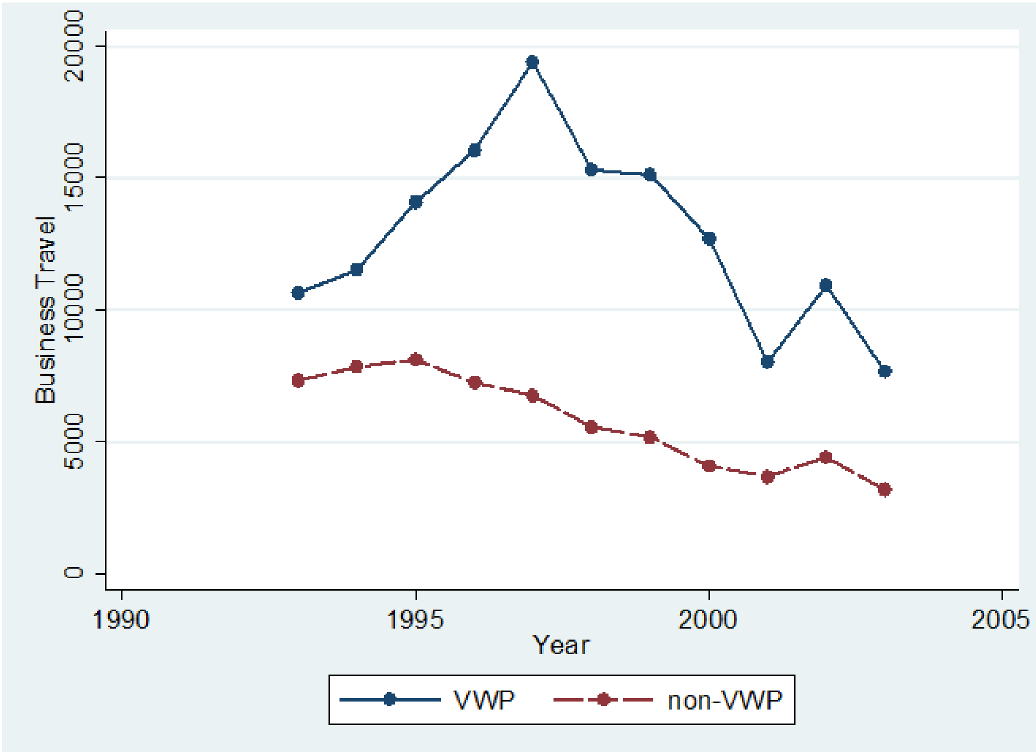

Table 3: First Stage Regressions

	(1)	(2)	(3)
Variables		Business Travel to US	
September 11	-0.057	-0.061	0.023
	(0.081)	(0.080)	(0.087)
Visa Waiver Program		0.496***	0.562***
		(0.088)	(0.091)
Visa Waiver Program * Sept 11			-0.207***
			(0.070)
Population	0.903	0.648	0.191
	(0.626)	(0.619)	(0.641)
Real GDP per capita	0.502	0.398	0.409
	(0.315)	(0.313)	(0.312)
Imports from US	0.056	0.051	0.038
	(0.090)	(0.090)	(0.090)
Exports to US	-0.209**	-0.214**	-0.224***
	(0.087)	(0.086)	(0.086)
US FDI	0.014	0.028	0.010
	(0.067)	(0.066)	(0.067)
Observations	2231	2231	2231
R-squared	0.833	0.835	0.836

Notes: All specifications include country and year fixed effects. Robust standard errors are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Two Stage Least Squares Regressions

	Negative Binomial	2-stage Negative Binomial	2-stage Negative Binomial	IV Poisson
	(1)	(2)	(3)	(4)
Variables	Domestic Patenting			
Business Travel to US	0.026**			
	(0.013)			
Estimated Business Travel to US		0.300***	0.301***	0.303***
		(0.080)	(0.080)	(0.074)
Residual from the First-stage			0.021*	
			(0.013)	
Population	2.669***	2.395***	2.386***	2.265***
	(0.576)	(0.584)	(0.584)	(0.436)
Real GDP per capita	0.624**	0.479*	0.475*	0.531***
	(0.281)	(0.281)	(0.282)	(0.200)
Imports from US	-0.054	-0.069	-0.068	-0.084
	(0.074)	(0.074)	(0.073)	(0.053)
Exports to US	-0.103	-0.049	-0.049	-0.049
	(0.084)	(0.084)	(0.084)	(0.064)
US FDI	0.070	0.065	0.065	0.070*
	(0.049)	(0.049)	(0.049)	(0.037)
Observations	2231	2231	2231	2231
Log-likelihood	-14449	-14443	-14440	-14440

Notes: All specifications include country and year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis in columns (1), (2) and (3). *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Robustness Checks

	Negative Binomial	Negative Binomial	IV Poisson	Negative Binomial	Negative Binomial	IV Poisson
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Domestic Patenting			Patenting in the US		
Weighted Business Travel to US	0.026**		0.303***	0.040***		0.292**
	(0.013)		(0.074)	(0.015)		(0.140)
Unweighted Business Travel to US		0.022			0.012	
		(0.013)			(0.015)	
Population	2.669***	2.677***	2.265***	4.963***	5.093***	4.030***
	(0.576)	(0.576)	(0.436)	(0.369)	(0.373)	(0.604)
Real GDP per capita	0.624**	0.627**	0.531***	1.819***	1.860***	1.557***
	(0.281)	(0.282)	(0.200)	(0.270)	(0.268)	(0.390)
Imports from US	-0.054	-0.054	-0.084	0.212***	0.203***	0.068
	(0.074)	(0.074)	(0.053)	(0.075)	(0.074)	(0.093)
Exports to US	-0.103	-0.103	-0.049	-0.248***	-0.259***	-0.120
	(0.084)	(0.085)	(0.064)	(0.081)	(0.080)	(0.120)
US FDI	0.070	0.070	0.070*	0.172***	0.168***	-0.006
	(0.049)	(0.049)	(0.037)	(0.063)	(0.064)	(0.073)
Observations	2231	2231	2231	2241	2241	2241
Log -likelihood	-14449	-14450		-7730	-7737	

Notes: All specifications include country and year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis in columns (1), (2),(4) and (5). *** p<0.01, ** p<0.05, * p<0.1.

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A Appendix (for Chapter 1)

Appendix 1: Countries in the Sample

Argentina	Italy
Australia	Japan
Austria	Korea: Republic of
Belgium	Malaysia
Brazil	Mexico
Chile	Netherlands
China	New Zealand
Colombia	Norway
Costa Rica	Peru
Czech Republic	Philippines
Denmark	Poland
Ecuador	Portugal
Egypt	Russia
Finland	Saudi Arabia
France	Singapore
Germany	South Africa
Greece	Spain
Honduras	Sweden
Hong Kong	Switzerland
Hungary	Taiwan
India	Turkey
Indonesia	United Kingdom
Ireland	Venezuela
Israel	

B Appendix (for Chapter 2)

B.1 Appendix Tables

Table A1: NBER Technological Subcategories

Subcategory	Description	Subcategory	Description
11	Chemical: Agriculture, Food &Textiles	**45**	Electrical & Electronics: Power Systems
12	Chemical: Coating	**46**	Electrical & Electronics: Semiconductor Devices
13	Chemical: Gas	**49**	Electrical & Electronics: Miscellaneous
14	Chemical: Organic Compounds	**51**	Mechanical: Mat. Proc & Handling
15	Chemical: Resins	**52**	Mechanical: Metal Working
19	Chemical: Miscellaneous	**53**	Mechanical: Motors & Engines, Parts
21	Computers & Communications: Communications	**54**	Mechanical: Optics
22	Computers & Communications : Computer Hardware & Software	**55**	Mechanical: Transportation
23	Computers & Communications : Computer Peripherals	**59**	Mechanical: Miscellaneous
24	Computers & Communications: Information Storage	**61**	Others: Agriculture, Husbandry &Food
25	Computers & Communications : Electronic business methods and software	**62**	Others: Amusement Devices
31	Drugs & Medicine: Drugs	**63**	Others: Apparel & Textile
32	Drugs & Medicine: Surgery & Med Inst.	**64**	Others: Earth Working & Wells
33	Drugs & Medicine: Genetics	**65**	Others: Furniture & House Fixtures
39	Drugs & Medicine: Miscellaneous	**66**	Others: Heating
41	Electrical & Electronics: Electrical Devices	**67**	Others: Pipes & Joints
42	Electrical & Electronics: Electrical Lighting	**68**	Others: Receptacles
43	Electrical & Electronics: Measuring & Testing	**69**	Others: Miscellaneous
44	Electrical & Electronics: Nuclear & X-rays		

Notes: This classification is based on NBER patent data project classification (classification 2006 excel file). Source: https://sites.google.com/site/patentdataproject/Home/downloads/patn-data-description

Table A2A: US Patenting by States, 1993-2003

State	Sum of patents by state, 1993-2003	State	Sum of patents by state, 1993-2003
Alabama	4277	**N. Carolina**	20142
Alaska	521	**Nebraska**	2290
Arizona	17271	**Nevada**	3692
Arkansas	1829	**New Hampshire**	6846
California	202830	**New Jersey**	41686
Colorado	21337	**New Mexico**	3833
Connecticut	20141	**New York**	68699
Delaware	4668	**North Dakota**	801
Florida	28949	**Ohio**	35574
Georgia	15294	**Oklahoma**	5893
Hawaii	905	**Oregon**	16015
Idaho	14952	**Pennsylvania**	37766
Illinois	40205	**Puerto Rico**	258
Indiana	15905	**Rhode Island**	3251
Iowa	7054	**S. Carolina**	6257
Kansas	4489	**S. Dakota**	801
Kentucky	4794	**Tennessee**	8860
Louisiana	5083	**Texas**	67284
Maine	1585	**Utah**	7876
Maryland	16128	**Vermont**	4209
Massachusetts	40813	**Virginia**	12678
Michigan	41655	**W. Virginia**	1608
Minnesota	30280	**Washington**	24422
Mississippi	1821	**Washington, DC**	733
Missouri	9600	**Wisconsin**	19188
Montana	1474	**Wyoming**	614

Table A2B: US Patenting by Industries, 1993-2003

Subcategory	Description	Sum of patents by industries, 1993-2003
11	Chemical: Agriculture, Food &Textiles	2404
12	Chemical: Coating	11814
13	Chemical: Gas	3597
14	Chemical: Organic Compounds	15801
15	Chemical: Resins	22499
19	Chemical: Miscellaneous	68308
21	Computers & Communications: Communications	80433
22	Computers & Communications : Computer Hardware & Software	74403
23	Computers & Communications : Computer Peripherals	22983
24	Computers & Communications: Information Storage	34557
25	Computers & Communications : Electronic business methods and software	16475
31	Drugs & Medicine: Drugs	67206
32	Drugs & Medicine: Surgery & Med Inst.	48587
33	Drugs & Medicine: Genetics	3927
39	Drugs & Medicine: Miscellaneous	9298
41	Electrical & Electronics: Electrical Devices	26673
42	Electrical & Electronics: Electrical Lighting	13495
43	Electrical & Electronics: Measuring & Testing	25291
44	Electrical & Electronics: Nuclear & X-rays	11057
45	Electrical & Electronics: Power Systems	29589
46	Electrical & Electronics: Semiconductor Devices	40253
49	Electrical & Electronics: Miscellaneous	18266
51	Mechanical: Mat. Proc & Handling	30835
52	Mechanical: Metal Working	16823
53	Mechanical: Motors & Engines, Parts	19412
54	Mechanical: Optics	11005
55	Mechanical: Transportation	24565
59	Mechanical: Miscellaneous	34426
61	Others: Agriculture, Husbandry &Food	16882
62	Others: Amusement Devices	12920
63	Others: Apparel & Textile	10156
64	Others: Earth Working & Wells	11417
65	Others: Furniture & House Fixtures	19629
66	Others: Heating	6220
67	Others: Pipes & Joints	5620
68	Others: Receptacles	15996
69	Others: Miscellaneous	72355

Table A3A: Countries in the Sample

Argentina	Luxembourg
Australia	Mexico
Austria	Netherlands
Belgium	New Zealand
China	Norway
Czech Republic	Poland
Denmark	Portugal
Finland	Romania
France	Russia
Germany	Singapore
Greece	Slovakia
Hungary	Slovenia
Iceland	South Africa
Ireland	Spain
Israel	Sweden
Italy	Switzerland
Japan	Turkey
Korea, South	United Kingdom

Table A3B: Countries in the Sample

OECD Countries		**Non-OECD countries**
Australia	Korea, South	Argentina
Austria	Luxembourg	China
Belgium	Mexico	Israel
Czech Republic	Netherlands	Romania
Denmark	New Zealand	Russia
Finland	Norway	Singapore
France	Poland	Slovenia
Germany	Portugal	South Africa
Greece	Slovakia	
Hungary	Spain	
Iceland	Sweden	
Ireland	Switzerland	
Italy	Turkey	
Japan	United Kingdom	

B.2 Data Appendix

This section gives the details on the sources and construction of our main variables.

Innovation U.S. patent counts: The data on U.S. patents issued from 1993-2003 comes from the United States Patent and Trademark Office (USPTO), Custom Data Extracts. The individual inventor database, which has address information (street, city, state, country of residence, etc) for each of multiple inventors per patent, is combined with the bibliographical patent database, which has application month and year, as well as original USPTO technological category for each patent. If a patent has multiple inventors, we assign a fraction of $1/n$ to each inventors country of residence, where n is the number of inventors. Using the original USPTO technological categories, each patent is assigned to one of 37 subcategories based on NBER patent classification (Hall et al. 2001). Then using application month and year for each patent, patents are aggregated by foreign country and technological subcategory for each quarter during the period 1993-2003 to obtain patent counts by foreign countries and industries for each quarter for years 1993-2003.

Joint U.S. patent counts: To identify patents which have a combination of foreign and U.S. coinventors we also calculated foreign patent counts of only patents for which there is at least one U.S. coinventor. Using the same methodology as above, foreign patents with at least one U.S. coinventor are obtained by aggregating by foreign country and industry for each quarter during the period 1993-2003.

U.S. patent stock by states and by industries: For the sample period 1993-2003, each patent with multiple inventors is assigned a fraction of $1/n$, where n is the number of inventors. Then keeping only U.S. inventors, patent counts are aggregated to a given state for each quarter during the years 1993-2003. Similarly, patent counts are aggregated to a given industry for each quarter during the years 1993-2003.

Travel The data on international air travel comes from the Survey of International Air Travelers (SIAT), which is conducted by the United States Office of Travel and Tourism Industries, a branch of the International Trade Administration, U.S. Department of Commerce. SIAT collects data on non-U.S. residents traveling to the U.S. and U.S. residents traveling from the U.S (excluding Canada). This survey has been carried out monthly starting from 1983 on randomly selected flights from the major U.S. international gateway airports for over 70 participating domestic and foreign airlines. Questionnaires in 12 languages are distributed onboard U.S. outbound flight to international destinations.

In this paper we use data on U.S. residents traveling from the United States to foreign countries in the period of 1993-2003. Outbound U.S. resident travel data is an individual level database which has information on travelers' U.S. county of residence, country of citizenship, main purpose of the trip, secondary purposes of the trip, main destination foreign cities, secondary destination foreign cities, occupation, quarter and year of travel. Trips can be made for the purpose of business, visiting friends and relatives, and religious, among others. Possible occupations include homemaker and retired, among others. Main destination and secondary destination cities are both coded. Individual observations are expanded if a particular individual traveled to distinct destination countries, treating each destination as a separate trip. If a particular traveler mentioned multiple purposes of the trip, each purpose is given equal weight. Further, expanded individual travel observations are aggregated by purpose of the trip and occupations by U.S. state and foreign country for each quarter during the years 1993-2003.

Our main variable of interest is B_{scqt}, the number of business travelers from state s to foreign country c in quarter q of year t. We calculated the number of travelers who are visitors, are traveling for religious reasons, or are retired or homemakers in the same way. These aggregated travel variables are weighted by the ratio of U.S. state patent stock to real state GDP and a given industry's strength in the U.S. (source: U.S. Department of Commerce, Bureau of Economic Analysis, BEA), see equation (2). The final travel variables are in natural logarithms, with one added to each value. The impact of adding one is small, as the results for the sample with strictly positive numbers of travelers are very similar.

Other variables Population size, real GDP per capita for each year 1993-2003 and country are obtained from Penn World Tables, version 6.2. U.S. exports by country and year 1993-2003 are collected from U.S. Census Bureau (www.usatradeonline.gov). U.S. FDI by destination countries and year 1993-2003 is proxied by the total sales of U.S. majority-owned multinational affiliates and comes from U.S. Bureau of Economic Analysis (BEA). Gross domestic expenditures on R&D expenditures (GERD) for each country in year 1993-2003 are obtained from OECD Statistics, which has data on OECD countries as well as some non-OECD member economies. Each country's total patent applications (by first named inventor) both by residents as well as non-residents of that country in 1993-2003 are from World Intellectual Property Organization (WIPO). All control variables employed in the analysis are in natural logarithms, with the exception of patent applications by residents and non-residents which are in natural logarithms but with one added to each value. The final sample is an unbalanced quarterly sample for 36 countries and 37 industries for the years 1993-2003.

C Appendix (for Chapter 3)

Table A1: Visa Waiver Program Countries during 1993-2003

	Country	Date of admittance	Date of cancelation
1	Andorra		
2	Argentina	Jul-96	Feb-02
3	Australia	Jul-96	
4	Austria		
5	Belgium		
6	Brunei		
7	Denmark		
8	Finland		
9	France		
10	Germany		
11	Iceland		
12	Ireland	Apr-95	
13	Italy		
14	Japan		
15	Liechtenstein		
16	Luxembourg		
17	Monaco		
18	Netherlands		
19	New Zealand		
20	Norway		
21	Portugal	Aug-99	
22	San Marino		
23	Singapore	Aug-99	
24	Slovenia	Sep-97	
25	Spain		
26	Sweden		
27	Switzerland		
28	United Kingdom		
29	Uruguay	Aug-99	Apr-03

Source: U.S. Department of Homeland Security, Yearbook of Immigration Statistics, 1993-2003. For Slovenia, actual entries began in 1998. Visa Waiver Pilot Program started in 1986. Unless mentioned otherwise, the countries were members of VWP since it began.

Table A2: Countries in the Sample

Algeria	Latvia
Argentina	Lithuania
Australia	Luxembourg
Austria	Macedonia
Bangladesh	Malawi
Belarus	Malaysia
Belgium	Malta
Brazil	Moldova
Bulgaria	Morocco
Chile	Netherlands
China	New Zealand
Colombia	Nicaragua
Costa Rica	Norway
Croatia	Pakistan
Czech Republic	Panama
Denmark	Paraguay
Ecuador	Peru
Egypt	Philippines
Estonia	Poland
Ethiopia	Portugal
Finland	Romania
France	Russia
Georgia	Saudi Arabia
Germany	Singapore
Greece	Slovakia
Guatemala	Slovenia
Haiti	South Africa
Honduras	Spain
Hong Kong	Sri Lanka
Hungary	Sweden
Iceland	Switzerland
India	Thailand
Indonesia	Trinidad & Tobago
Ireland	Tunisia
Israel	Turkey
Italy	Ukraine
Jamaica	United Kingdom
Japan	Uruguay
Kazakhstan	Venezuela
Kenya	Vietnam
Korea, South	Yemen
Kyrgyzstan	Zambia

Table A3: Countries in the Sample, Members of the Visa Waiver Program

Argentina	Luxembourg
Australia	Netherlands
Austria	New Zealand
Belgium	Norway
Denmark	Portugal
Finland	Singapore
France	Slovenia
Germany	Spain
Iceland	Sweden
Ireland	Switzerland
Italy	United Kingdom
Japan	Uruguay

Table A4: Top Countries with Business Travel to U.S.

Country	Sum of business travel, 1993-2003
Japan	54696
Taiwan	16228
Germany	15656
United Kingdom	15044
Australia	14162
Singapore	7800
Brazil	7218
South Africa	6758
France	6472
Italy	6067
New Zealand	4986
Netherlands	4634
Switzerland	4463
Malaysia	4455
China	3960
India	3807
Sweden	3067
Argentina	2641
Korea, South	2528
Poland	2236
Hong Kong	2194
Philippines	2154
Belgium	2044
Indonesia	2033
Spain	1960