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INTERNATIONAL BUSINESS TRAVEL: AN ENGINE OF INNOVATION?

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ABSTRACT

While it is well known that managers prefer in-person meetings for negotiating deals and selling their products, 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. Business travel is shown to have a signi…cant e¤ect up and beyond technology transfer through the channels of international trade and foreign direct investment. On average, a 10% increase in business travel leads to an increase in patenting by about 0.2%, and inward business travel is about one fourth as potent for innovation as domestic R&D spending. We show that the technological knowledge of each business traveler matters by estimating a higher impact for travelers that originate in U.S. states with substantial innovation, such as California. This study provides initial evidence that international air travel may be an important channel through which cross-country income di¤erences can be reduced.

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1 Introduction

Throughout history the international flows of skills embodied in people had major effects on innovation and growth across countries. A case in point is the year 1789. Despite the fact that England at the time had banned the international movement of skilled craftsmen to ensure that its technology would not spread elsewhere, a certain Samuel Slater disguised himself and succeeded to slip out on a ship to the United States. There, he built the first water-powered textile mill and became known as the father of the American Industrial Revolution. Today, in contrast, blueprints can be transferred electronically within seconds over the Internet. Does this mean that skills embodied in people play no role anymore for innovation? In this paper we provide evidence on this question by studying the impact of international business travel on innovation.

Business trips bring local entrepreneurs into personal contact with foreigners and their technology. This may stimulate innovation locally because technology is incremental in nature, with knowledge of prior art helping to generate new technology. Technological knowledge tends to also be tacit—it is difficult to fully characterize.[1] The face-to-face communication with foreign business travelers could thus be crucial for transferring technology, ahead of methods such as telephone calls or video-conferencing. Consistent with that, surveys typically find that business executives prefer face-to-face meetings over phone or web-based communication (Forbes 2009, Harvard Business Review 2009). Nevertheless, to date we know quite little on these issue. This paper's goal is to fill this gap.

[1] 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.

We employ a new dataset to examine the impact of business travelers from the United States on patenting in 34 countries, both rich and poor, over more than a decade (the years 1993 to 2003). One challenge we face is that business travelers might arrive in a country for systematic, non-random reasons, which would bias our findings. Our analysis addresses endogeneity concerns by contrasting the behavior of business travelers with that of friends and family travel. Central is the idea that while business travel might be affected by changes in economic return to traveling (e.g., changes in the business climate), family travel is not. In our analysis, we find that business travel has a positive impact on that country's rate of innovation. Quantitatively, a 10% increase in business travelers raises patenting on average by about 0.2%, and in a typical case business travel from the United States accounts for about 10% of the total difference in patenting across countries. Moreover, we find evidence that the impact of business travel on patenting is increasing in the technological knowledge carried by each particular traveler.

Trade in services today is very important for many countries, and still we know very little about service trade.[2] With our study of air travel we broaden existing perspectives that tend to focus on trade in goods to shed light on the role played by service trade. Moreover, in contrast to the small but growing literature on the role of business travel in facilitating international goods trade (Poole 2010, Cristea 2011), our analysis links business travel to innovation while accounting not only for changes in goods trade but also in foreign direct investment (FDI). From a policy perspective, this paper highlights the potential gains from services liberalization, such as the Open Skies Agreement, in terms of innovation and growth.[3]

[2] For example, services exports are close to 40% of goods exports in the United States. News release of the U.S. Bureau of Economic Analysis, May 11, 2011.

[3] The Open Skies Agreement seeks to liberalize air travel to and from the United States, see http://www.state.gov/e/eeb/tra/ata/. This paper is also relevant for multilateral service liberalizations; see

The diffusion of knowledge 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). Specifically, some recent research assumes that knowledge is entirely embodied in people (Burstein and Monge-Naranjo 2009) so that international travel is crucial for knowledge diffusion. Empirically, it is an open question whether effective knowledge transfer is possible by simply providing (non-rival) blueprints or whether knowledge embodied in people is needed, and if the latter, whether people need to meet in person or not. Our contribution to this literature is to provide initial evidence on it.

The importance of personal contacts for international technology transfer has been analyzed in empirical work in a number of papers. Common ethnicity may lower the cost of transferring knowledge from one country to another (Kerr 2008).[4] Moreover, movements of scientists themselves can be a conduit of international knowledge flows (Oettl and Agrawal 2008, Kim, Lee, and Marschke 2006). Our research is complementary to this body of work. In contrast to the usually fairly small samples of previous work, this paper studies knowledge transfer through face-to-face meetings in more than 100,000 of business trips, as well as providing causal evidence by addressing the potential endogeneity of business travel.

A number of authors have considered air travel as a conduit for technology transfer, with mixed results. Gambardella, Mariani, and Torrisi (2009) find that, controlling for other factors, air passengers are not significantly related to productivity differences across European regions. In contrast, Andersen and Dalgaard (2011) employ information from the World Tourism Organiza-

WTO (2006) which discusses key multilateral issues.

[4]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).

tion to show that the number of air travelers can explain cross-country productivity differences.[5] We improve on this literature by employing better data on air travel. Even if it were the case that tourists–which are the bulk of the air travelers in the typical existing study– are important for international knowledge diffusion, since data on tourism to date are not comparable across countries empirical work based on them is unlikely to yield robust results. In contrast, our air traveler measure is consistent because it comes from one survey. Moreover, we can separate business travelers from tourists and other travelers. This is useful because one would expect business travelers to matter more for technology diffusion than tourists and other travelers.[6]

Our research also employs an unusually detailed measure of innovation. In particular, we know the identity and countries of residence of all patentees in the sample. Thus we can ask whether business travel from a country that is the home country of one of the patent owners is more potent in its effect on innovation than business travel in general (we do not know whether the business traveler was in fact the patentee). In contrast, most existing studies focus on productivity as the measure of innovation. That has certain advantages, chief perhaps that economic effects are easily quantified. At the same time, productivity measures tend to confound several factors that have different implications, something we avoid in this study by working with patent data.[7]

The remainder of the paper is as follows. The next section motivates the analysis in terms of theory and also it discusses the key empirical issues. The following section 3 introduces the main

[5] Related work includes Le (2008) and Dowrick and Tani (2011).

[6] The data is described in section 3 below.

[7] 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 also Keller (2004) for more discussion.

features of the data as well as their sources, with more details on the construction of the data set given in the Appendix. Section 4 presents the estimation results and quantifies the implied effect of business travel on innovation. A number of concluding observations are collected in section 5.

2 International business travel and innovation: a framework for analysis

Our goal is to assess the impact of international business travel on the rate of innovation across countries. To do so, this section provides a theoretical motivation and also discusses a number of key choices we make in terms of data, identification, and estimation technique.

As a point of departure in terms of theory, it is useful to think of a model in which technological knowledge diffuses abroad through business travel and other channels. Keller and Yeaple (2012) analyze firms that decide whether to produce intermediate goods for their 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 foreign country managers, which is subject to communication frictions because technological knowledge is tacit.

This model posits a trade-off of technology transfer in embodied form through trade and through direct communication associated with FDI production. A role for business travel in enhancing technology transfer naturally arises when home country managers can travel to the host country. Face-to-face time enhances technology transfer at the same time that it might lead to learning on the part of unaffiliated host country agents (perhaps through labor turnover).[8] This learning is what may raise the host country's rate of patenting.

In terms of empirics the goal is to estimate the relationship between the rate of innovation and inward business travelers from abroad. We measure innovation using data on patenting at the level of 37 industries in 34 countries.[9] Our business travel information is on outward business travel from the United States and covers mostly U.S. citizens. We do not know whether a particular traveler is involved with innovation in the country he or she is flying to, but we do know the U.S. state (and county) of where the traveler is originating from. This will allow us to contrast the impact of business travelers from states such as California, where knowledge levels and patenting rates are relatively high, with states such as Nebraska, where they are generally lower.

Next we turn to identification. Let P_c denote the number of patents of country c, and $\tilde{B}_c$ its number of inward business travelers. In estimating the impact of business travelers on patenting several issues will have to be addressed. First, to account for the fact that the number of patents is affected by many factors, such as the size of country c, we include a set of variables Z_c that reduces concerns arising from omitted variables. Second, our approach eliminates the influence of unobserved factors at the country-, industry-, and year-level by including the corresponding fixed effects.

[8] The incentive of knowledge owners will typically be to prevent leakage of the knowledge to others. This by itself may be a reason for reducing the number of face-to-face meetings, except in cases where the technology transfer is intended as in the case of joint ventures.

[9] The industry dimension is important because industries vary greatly in terms of patenting activity. A list of the industries is given in Appendix Table A1.

This leaves the possibility that $\tilde{B}_c$ is endogenous due to time-varying factors (for example, changes in a country's tax code boost patenting and also trigger more inward business travel). This would leave $\tilde{B}_c$ correlated with the error of the regression and yield inconsistent estimates. In this paper two methods are employed to address such concerns. The first method adds on the right-hand side of the equation a control function (CF) such that $\tilde{B}_c$ may be endogenous without the CF but it is exogenous once the CF is included, and hence, the coefficient on $\tilde{B}_c$ with CF is consistent. Control function approaches have been widely used in empirical work recently, for example in the estimation of production functions (see Olley and Pakes 1996 and related extensions). The second method we employ is instrumental variable (IV) estimation, specifically the approach developed in Mullahy (1997). Both the control function and the IV strategies employed here are well-established methods and covered in standard econometrics textbooks such as Wooldridge (2002).

While the two estimation strategies differ in general, they are related in that for either to work certain exclusion restrictions must be satisfied. For the IV strategy this means the instrument must be valid. In our case, we will mainly rely on friends & family travel as an instrument for business travel. The exclusion restriction is that friends & family travel does not affect patenting in a country.[10] Analogous to the requirement that the instrument is valid in the IV strategy, the CF approach requires that the CF itself is appropriate. In our case the control function will typically be the residual from a regression of business travel on friends & family travel. Then, the exclusion restriction is, similar to the IV case, that friends & family travel is not a determinant of patenting, conditional on all covariates. Because friends & family travel is

[10] The full condition is that friends & family travel does not affect patenting *and* that it is not correlated with any determinants of patenting; see Wooldridge (2002, Ch. 19.5.1).

determined by factors that are quite different from business travel, and moreover, these factors typically do not change from year to year, we consider it to be very likely that our approach towards possible endogeneity is successful. We will return to this issue below.

This section is concluded by discussing the regression techniques employed below. The fact that our dependent variable y, the number of patents, is non-negative and has no upper bound suggests to use count data models which rely on the exponential function, $E(y|x) = \exp(\mathbf{x}\boldsymbol{\beta})$. Within this class the assumption that y given x has a Poisson distribution has been most common given the efficiency properties of its maximum likelihood estimators.[11] At the same time, making the Poisson distributional assumption has been criticized because it implies restrictions on the conditional moments of y, in particular $Var(y|x) = E(y|x)$, that are typically rejected in the data (also here). However, it is well-known that a Poisson quasi-maximum likelihood estimator (QMLE) is fully robust to distributional misspecification in the sense that it obtains consistent coefficient estimates of $\boldsymbol{\beta}$ for the conditional mean, $E(y|x) = \exp(\mathbf{x}\boldsymbol{\beta})$, irrespective of whether the Poisson distributional assumption was correct or not. In this paper a QMLE approach is employed throughout. We present results for two alternative distributional assumptions, (1) that y is distributed Poisson given $\mathbf{x}$, and (2) that y is distributed Negative Binomial given $\mathbf{x}$. While both estimators yield consistent estimates, the specific distributional assumption determines how the variance-covariance matrix is calculated. As we will show below, the results using either assumption are generally very similar.

The following section gives an overview of the data that will be employed.

[11] See Wooldridge (2002, Ch. 19).

3 Data

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 year.[12] 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).[13] 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 year 1993 to 2003.[14]

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

[12] 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.

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

[14] 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.

one in 50 of all foreign patent applications in the United States during the sample period had foreign and U.S. coinventors.

It is well-known that a principal determinant of a country's innovation its R&D expenditures. We have obtained this data from OECD Statistics.[15] We also include another measure of innovation, namely the patent applications by residents of each country (source: World Intellectual Property Organization).[16] These variables control for innovative cycles in each country that are general in the sense that they are not specifically related to inward business travel from the United States. In addition, including domestic resident 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.

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, a branch of the U.S. Department of Commerce. This survey provides information on travel from the United States to foreign countries for U.S. residents 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 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 year 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

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

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

(a measure of technological prowess) at the level of the U.S. states and industries. Our business traveler variable, B_{cit}, is defined as follows:

$$B_{cit} = P_{it} \times \sum_{s \epsilon S} \frac{P_{sit}}{GSP_{st}} \times \ \tilde{B}_{sct}, \forall i, t, \tag{1}$$

where the variable P_{sit} is the patent stock of U.S. state s in industry i of year t, GSP_{st} is the state's gross product, P_{it} is the patent stock of U.S. industry i in year t, and $\tilde{B}_{sct}$ is the raw (unweighted) number of business travelers from state s to foreign country c in year t. The weight on the unweighted business travelers in equation (1), $\frac{P_{sit}}{GSP_{st}}$, incorporates two ideas. First, travelers who originate from a state s that has more patents relative to the size of the state's economy receive greater weight than travelers that come from a state s' with fewer patents. We choose this formulation because if the patent stock of state s is higher than of state s', it is plausible that business travelers from s carry on average more knowledge than those from s'. Second, the weight $\frac{P_{sit}}{GSP_{st}}$ is also increasing in the patent stock of state s in a particular industry i. This picks up any particular strength of state s in a certain industry i compared to the strength of state s in the average industry.[17] 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.

[17] There are alternative approaches to the weights $\frac{P_{sit}}{GSP_{st}}$ proposed here. To pick up the differential knowledge across travelers, for example, one could introduce variables for different states, such as California versus Nebraska, separately. While this approach can be useful (see Keller 2002, Acharya and Keller 2009), it can also be difficult to estimate multiple additional parameters, which is one reason for why we adopt the weighted sum in equation (1). Note that equation (1) also scales by the total U.S. patent stock by industry, P_{it}, proxying for the U.S. knowledge in that industry *and* year (up and beyond general effects picked up by industry and time fixed effects).

Analogously to the weighted number of business travelers from the United States according to equation (1), we also compute the numbers of travelers who visit friends & family, are traveling for religious reasons, are retired, or are homemakers. These variables will be employed below in form of control functions as discussed below.

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). We want 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 and U.S. imports from each of the sample countries. Both outward FDI from the U.S. and inward FDI to the U.S. are included as controls as well. Outward FDI from the U.S. is captured by the total sales of U.S. majority-owned multinational affiliates in each of the sample countries, while inward FDI to the U.S. by the total sales of nonbank U.S. affiliates of foreign multinational firms. These data come from the U.S. Bureau of Economic Analysis.

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 34 countries that are included in this analysis is given in Table A3 of the Appendix. The following five rows in Table 1 present (in natural logarithms) U.S. resident travel data for business, visiting friends and family, and religious purposes, along with data on travelers that are retired and homemakers.[18] As can be seen from the table, the number of travelers for the purpose of business and visiting friends and family are close in magnitude, while the number of observations for religious travel, retired, and homemaker travel is smaller.

We now turn to the empirical analysis.

4 Empirical Analysis

In this section we present the empirical approach in detail, and we also show the results. The estimation equation that will be employed is

$$E\left[P_{cit}|B_{cit}\right] = \exp\left[\alpha \ln B_{cit} + \beta \ln X_{cit} + \mu_c + \mu_i + \mu_t + \varepsilon_{cit}\right], \tag{2}$$

where P_{cit}, the expected patent counts of a country c in industry i and year t, is a function of B_{cit}, the number of business travelers at that time between country c and the U.S., other determinants X_{cit} of country c's patenting in the U.S. (such as R&D expenditures), country-, industry- and year fixed effects (the μ's), and an error term, ε_{cit}. As noted above, we will use quasi- maximum likelihood estimation (QMLE) in form of both Poisson and Negative Binomial in our empirical analysis. We begin with simple Poisson QMLE and Negative Binomial regressions before moving to control function and IV approaches to deal with possible endogeneity.

The results of estimating equation (2) are shown in Table 2. In columns 1 to 7, the dependent variable is the foreign country's patent counts taken out at the U.S. patent office, while in columns 8 to 9 the dependent variable is the subset of foreign patents that have U.S. coinventors.

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

Columns 1-6 and 8 report estimates from the Poisson model, while columns 7 and 9 from the Negative Binomial model. Bootstrapped standard errors which allow for clustering at the country-year level are reported in parentheses, and for the business travel variable we also show the (bias-corrected) bootstrapped 95% confidence intervals.[19] Column 1 shows that there is a strong correlation between patenting and travel from the United States, which is not reduced with the inclusion of controls for size and level of development (column 2). 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. Importantly, the inclusion of these variables does not change the business travel coefficient by much. In column 4, we include R&D expenditures, which has the expected positive sign.

Recall that the left-hand side variable is a country's industry-level patenting in the United States. In column 5 the domestic patenting of the country's residents is added. This controls for technology and other shocks that lead to changes in a country's overall patenting. We see that resident patenting is strongly correlated with the country's patenting in the United States, a plausible result that holds throughout our analysis. In column 6, U.S. imports and inward FDI are added, which does not change the estimated effect of business travel on U.S. patenting. With the inclusion of all control variables, the business travel coefficient is estimated at around 2%. Domestic R&D expenditures and resident patent applications are associated with higher patenting in the United States. In column 7 the estimates from the Negative Binomial model are employed. The coefficient of business travel is estimated slightly higher now, at around 3%.[20]

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

[20] From the confidence intervals given in Table 2 we know that the business variable is significanct at a 5% level

We now turn to a preliminary analysis of the economic magnitude implied by these 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 0.2% higher number of patent applications in the United States. If we focus on foreign patents with U.S. coinventors, the coefficient estimate for business traveler is about 0.03-0.04, see columns 8 and 9, compared to 0.02 for all U.S. patents in column 6. The finding of a larger coefficient for U.S. business travelers when U.S. persons are coinventors is consistent with stronger international transfer through business travel for these technologies.

In the previous regressions the relationship between patenting and business travel may be affected by unobserved shocks which would lead to biased estimates because $E[B_{cit}, \varepsilon_{cit}] \neq 0$. In particular, we are concerned that $E[B_{cit}, \varepsilon_{cit}] > 0$ because this would lead to an upward bias in the business travel coefficient. We use both control function (CF) and instrumental variable (IV) approaches to deal with possible endogeneity of business travel.

Consider the CF approach first. The main idea 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.[21] The control function that we propose is the residual of a regression of business travel on visiting friends & family travel. Consider the following ordinary least-squares regression:

$$\ln B_{cit} = \gamma_c + \gamma_i + \gamma_t + \gamma_1 \ln V_{cit} + \gamma_2 X_{cit} + \omega_{cit}, \tag{3}$$

where V_{cit} is the number of travelers that visit friends & family between the U.S. and country

or less in all specifications of Table 2.

[21] See Blundell and Powell (2003) for an overview and general results of the CF approach, and Wooldridge (2002, Ch. 19) for a textbook treatment.

c in year t and industry i. Note that the estimated residual $\hat{\omega}_{cit}$ of this regression will tend to be high whenever business travel is high relative to friends & family travel, conditional on all covariates.[22] This would be the case if the travel destination has received tax breaks or other positive shocks that make it a more attractive place to do business. Because these are the kinds of circumstances that are primary concerns to us, this residual $\hat{\omega}_{cit}$ will serve as our control function.

Another issue is that the CF needs to be based on something that is related to business travel.[23] For example, a new direct air connection from the United States to a specific foreign country will typically increase both business travel and family & friends travel. In Figure 1, we show the 10-year differences for friends & family versus business travel in our data. There is clearly a strong correlation, and this also exists for shorter periods of time.

[FIGURE 1 ABOUT HERE]

The thus constructed CF $\hat{\omega}_{cit}$ is added to equation (2) to yield our estimating equation for the CF approach:

$$E\left[P_{cit}|B_{cit},\hat{\omega}_{cit}\right] = \exp\left[\alpha \ln B_{cit} + \beta \ln X_{cit} + \mu_c + \mu_i + \mu_t + \theta\hat{\omega}_{cit} + \varepsilon_{cit}\right]. \tag{4}$$

This allows to consistently estimate the impact of business travel on patenting because the CF essentially filters out the factors that might cause $E[B_{cit}, \varepsilon_{cit}] \neq 0$ in equation (2). Identification in this approach comes from changes in business travel conditional on changes in profitability,

[22] The definition of this traveler category in the SIAT survey is: "Visit Friends/Relatives".
[23] This requirement is analogous to a strong first stage correlation in the typical two-state least squares IV estimation.

technological capability, and all other factors that are captured by shifts in the business versus friends & family traveler relationship. In addition, the endogeneity of B_{cit} can be formally tested by looking at the parameter estimate of $\hat{\theta}$ on the control function (see Wooldridge 2002, Ch. 19). In our case, if the control function enters equation (4) significantly, the test implies that business travel is endogenous, whereas if the control function does not enter significantly the exogeneity of business travel cannot be rejected.

As noted above, the main identification assumption is that visiting friends & family travel does not transfer technology. Of course, friends & family travel to foreign countries conveys information about the U.S. and its economy, but this general effect will be covered largely by the fixed effects. Beyond that there is little reason to believe that friends & family travel responds to short-term, time-varying shocks in the business climate and the like, as the primary motive of visiting friends and family is to maintain personal relations.

Table 3 shows the results from a number of control function regressions (equation 3 above). Column 1 corresponds to visiting friends & family travel as the only control variable, while columns 2, 3, 4 and 5 successively include additional control variables. They are the number of persons traveling who are retired (column 2), the number of persons who travel for religious reasons (columns 3 and 5), and the number of travelers that are homemakers (4 and 5). These additional travelers, whether classified by purpose, as in the case of religion, or by occupation, as in the case of homemakers and retirees, share with visitors of family & friends that it is reasonable to assume that they are not importantly involved in the transfer of technological knowledge. As seen from Table 3, the number of each type of traveler is positively correlated with business travel. The most important predictor is visiting friends & family travel, probably because it is relatively common, see the summary statistics in Table 1. The coefficient on friends & family travel is highly significant at around 0.8, and the regressions have an R-squared upwards of 0.92. These results suggest that the control function will not lack power.

The second approach to deal with the potential endogeneity in the business travel variable is the Poisson GMM IV approach due to Mullahy (1997). The instrument that we use for the business travel variable is visiting friends & family travel. The IV approach requires that the friends & family travel instrument is both (1) powerful and (2) valid. Regarding the former, it is evident from Figure 1 as well as from Table 3 that the instrument is strongly correlated with business trave. The validity of a single instrument cannot be directly tested. At the same time, consistent with the validity of the exclusion assumption, friends & family travel is not significantly correlated with patenting when it is added to equation (2). However, this cannot be taken as a formal test.

Table 4 shows the results of the control function and IV approaches. The control functions $\hat{\omega}$ constructed from the residuals of the first and fifth column of Table 3 are included in the Poisson and Negative Binomial regressions.[24] The first column repeats the results from Table 2, column 6 with a coefficient of 2.2% for the business traveler variable. If endogeneity generates an upward bias in this coefficient, upon inclusion of the control function one expects that the coefficient on business travel will decrease, and that the coefficient on $\hat{\omega}$ itself is positive. We find that the coefficient on the business travel variable falls little, from 2.2% in column 1 to 2.1%. The control function point estimates are positive, around 0.55%, but not significant. In column 4, we report results from the Poisson IV estimation. The coefficient on business travel

[24] The other control functions based on Table 3 give similar results.

is similar, at 2.4%, although somewhat less precisely estimated.

We also present results from the QMLE estimator with CF and the negative binomial distributional assumption, see column 5. As in the case of the IV Poisson estimation (column 4), this yields coefficients on Population and GDP per capita which are larger than with the Poisson CF approach, see columns 2 and 3. However, all estimation methods agree that the coefficient on business travel is, with a range of 2.1% to 2.5%, not far from the estimate on business travel under the assumption of exogeneity, at 2.1% (column 1).

Taken together, these results imply that the evidence for endogeneity of business travel is limited. Yes, the control function is positive in columns 2, 3, and 5, but it is never significant at standard levels, and based on this test we cannot reject exogeneity of business travel. Further, a Hausman-type test for endogeneity based on column 1 (under the assumption of exogeneity) and column 5 (IV, under the assumption of endogeneity) does find some evidence for differences of estimated coefficients, and hence endogeneity–at the same time, the coefficient of primary interest–on business travel–is almost the same under either the exogeneity or the endogeneity assumption. In the end, given that our primary concern is consistency of the estimation we might prefer the CF/IV estimates which are consistent whether or not business travel is endogenous. However, based on our formal tests there is no reason to reject the exogeneity assumption.

Turning to the results for the subset of foreign patent applications in the United States with U.S. coinventors 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 3.8% to 3.3% and the control function itself is positive but not significant (columns 6 and 7). In column 8, the Poisson IV procedure estimates the impact of business travel on patenting to be higher, at 8.2%. The relatively large number of zeros in the dependent variable for U.S. joint patents appears to make it computationally difficult to exploit the moment conditions that this estimator relies on, and we are inclined to discount this higher coefficient estimate. Overall, the results of Table 4 show that inward business travel from the U.S. gives a significant boost to foreign countries' patenting, and this effect is stronger in the case of patents with U.S. coinventors.

What are the economic magnitudes that our estimates yield? Take Poland and Romania, two Eastern European countries of roughly similar size. It turns out that during the sample period covered by the survey there were on average almost 6 business travelers per industry and year going to Romania, and about 16 going to Poland. At the same time, the mean patenting rate in Romania was 1.12 while it was 1.31 in Poland. We can use our estimates from Table 4 to gauge the importance of international business travel from the U.S. in accounting for this difference of 0.19 in mean patenting. The coefficient on business travel is 0.021 (column 2, Table 4). This brings the predicted patenting premium for Poland over Romania attributable to the higher number of U.S. business travelers to about 0.02 (equal to $\exp[0.021 \times \ln(1.31)] - \exp[0.021 \times \ln(1.12)]$), or about 11% (0.02/0.19) of the total difference in patenting between Poland and Romania. The contribution of travel from *all* countries, as opposed to just from the U.S., 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 the impact of domestic R&D expenditures. Using the marginal effects based on our Table 4 regression estimates, we find that business travel has about one quarter of the size of the impact of domestic R&D on patenting. Overall, these results indicate that international business travel explains a moderately large portion of differences in the rate of patenting across countries.

These results come from a large sample of industries which exhibit a lot of variation in terms of patenting activity. In the context of international technology diffusion, the question is whether learning effects are predominantly associated with the sectors in which there is a lot of technology creation, as opposed to with all sectors. To see this we examine whether the estimated relationship between business travel and innovation holds equally for high versus low patenting industries.[25] The results are shown in Table 5, columns 1 to 6. Column 1 repeats for convenience the estimates from Table 2, column 6, while in columns 2 and 3 in addition to business travel an interaction of business travel with a high patenting dummy (based on either median or mean) is included. It is apparent that the coefficient on business travel is greater in high patenting industries than in the average industry (coefficient of 0.029 to 0.049, compared to 0.022 in column 1). At the same time, for low-patenting industries the business travel estimate is close to zero.

In columns 3 to 6 of Table 5 we show analogous results using the control function approach with the Poisson assumption, where column 4 repeats the earlier results assuming that the impact of business travelers on international knowledge diffusion is constant across industries (from Table 4, column 2). Given the interaction of business travelers with the high-patenting dummy, there are now two control functions, one from the regression on business travel on friends & family travel, as before, and one from the regression of the business travel-high patenting interaction on the friends & family travel-high patenting interaction. The interaction CF results

[25] In order to form high versus low patenting industries, we take into account changes in the composition across countries when creating median and mean patent counts by industry. The high patenting dummy is equal to 1 if patent counts for a given country c in year t and industry i is higher than median/mean.

of columns 5 and 6 confirms the results without CF in columns 2 and 3 in that business travel affects patenting mainly in high-patenting industries. This result is along earlier findings that foreign direct investment triggers technology spillovers for domestic firms primarily in high-technology industries (Keller and Yeaple 2009).

Finally, we show results from another specification check in Table 5 on the far right. So far our business traveler variable was adjusted for differences in the knowledge carried by each traveler by using information on whether their U.S. state of departure is a high- or low-patenting origin (see equation 1 above). Another approach would simply sum over all business travelers irrespective of from which U.S. state they come. Results for this unweighted business traveler variable are shown in columns 7 (without CF) and 8 (with CF) of Table 5. We see that the point estimates for business traveler are about one half of what they were before (see columns 1 and 4 of Table 5), and moreover the unweighted business traveler coefficients are not significant at standard levels. We conclude that accounting for technological knowledge heterogeneity is very important in studying international technology diffusion.

We have also conducted a number of other robustness checks, including lagging the patent variable so as to further reduce the possibility that patent applications in the U.S. simply mirror domestic patent applications, as well as lagging the business traveler variable to allow for the possibility that it might take some time until business travel from the U.S. translates into domestic innovation. Overall these analyses have shown that the impact from U.S. business travel on foreign countries' rates of innovation we estimate is robust.

We now turn to a concluding discussion.

5 Conclusions

The basic premise of the paper is that face-to-face meetings might be particularly important for the transfer of technology because the latter 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 by looking at business travel from the United States to thirty-four 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 case for about 10% of the total difference in patenting rates, and its contribution is about one quarter of the impact 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 might affect innovation. In particular, given that entry requirements often reduce the number of business travelers that come to a country, 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.

While our results suggest that short-term international labor movements could be an important way through which cross-country income differences can be reduced, more work needs to be done. A particularly promising direction of future work may be to include more geographic detail, perhaps isolating key states, such as California. It would also 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 or substitutability between cross-border travel, trade, and FDI that needs to be addressed by future work.

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6 Appendix

This section gives the details on the sources and construction of our the 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 year for each patent, patents are aggregated by foreign country and technological subcategory for each year 1993-2003 to obtain patent counts by foreign countries and industries for each year 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 year 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 year during 1993-2003. Similarly, patent counts are aggregated to a given industry for each year 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 year 1993-2003.

Our main variable of interest is B_{sct}, the number of business travelers from state s to foreign country c in year t. We calculated the number of travelers who are visiting friends and family, 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-industry 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 (1). The final travel variables are in natural logarithms, with one added to each value. Furthermore, in this analysis we only consider positive numbers of business travelers.

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 and imports by country and year 1993-2003 are collected from U.S. Census Bureau (www.usatradeonline.gov). U.S. FDI by destination countries and years 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). FDI to U.S. by countries and years is captured by the total sales of nonbank U.S. affiliates of foreign multinational firms and comes from 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 domestic patent applications (by first named inventor) by 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. The final dataset is an unbalanced sample for 34 countries and 37 industries for the years 1993-2003.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
US Patenting				
US patent counts	101.319	322.750	0	3748
Joint US patent counts	2.070	5.761	0	77
US Resident Travel				
Business travel	1.506	1.480	0	8.923
Visit friends & family travel	1.421	1.489	0	8.792
Religious travel	0.077	0.335	0	4.217
Retired travel	0.980	1.237	0	7.115
Homemaker travel	0.571	0.968	0	7.241
Other Variables				
Population	10.133	1.519	5.619	14.062
Real GDP per capita	9.745	0.566	7.599	10.783
US exports	22.809	1.297	18.544	25.436
US FDI	24.071	1.561	16.300	26.734
R&D expenditures	22.654	1.342	18.821	25.385
Resident patent applications	8.295	1.932	3.714	12.859
US imports	23.031	1.430	18.947	25.710
FDI to US	20.890	2.489	11.513	24.594

Note: Number of observations for all variables is 5,202. All variables, except US patent counts and Joint US patent counts, are in natural logarithms. Real GDP per capita, US exports, US FDI, R&D expenditures, US imports and FDI to US are in dollars. US FDI is total sales of majority owned multinational firms. FDI to US is total sales of nonbank US affilities of foreign multinational firms.

Table 2: Business Traveler Exogenous

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Poisson	Poisson	Poisson	Poisson	Poisson	Poisson	Negative Binomial	Poisson	Negative Binomial
Dependent variable				US patents				Joint US patents	
Business travel	0.022*	0.022*	0.022*	0.021*	0.022*	0.022*	0.028*	0.038*	0.034*
	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.012)	(0.016)	(0.014)
	[0.2%, 4.1%]	[0.2%, 4.1%]	[0.2%, 4.0%]	[0.2%, 3.8%]	[0.3%, 3.8%]	[0.3%, 3.8%]	[0.2%, 5.2%]	[2.0%, 6.4%]	[-0.9%, 6.4%]
Population		5.055**	4.005**	1.166	0.856	0.893	1.984**	0.913	1.610
		(0.972)	(0.930)	(1.138)	(1.144)	(1.228)	(0.687)	(1.435)	(1.299)
GDP per capita		0.750*	0.602	0.226	0.184	0.245	1.139**	0.802	1.318+
		(0.357)	(0.552)	(0.582)	(0.582)	(0.673)	(0.375)	(0.692)	(0.714)
US exports			0.018	-0.119	-0.184	-0.159	-0.078	0.035	0.015
			(0.205)	(0.206)	(0.203)	(0.243)	(0.112)	(0.216)	(0.183)
US FDI			0.238+	0.089	0.033	0.055	-0.007	-0.359*	-0.332+
			(0.124)	(0.132)	(0.129)	(0.133)	(0.082)	(0.170)	(0.195)
R&D expenditures				1.131**	0.835**	0.831**	0.552**	0.242	0.074
				(0.317)	(0.312)	(0.296)	(0.135)	(0.386)	(0.321)
Resident patent applications					0.534**	0.502**	0.484**	0.684**	0.723**
					(0.121)	(0.132)	(0.076)	(0.215)	(0.215)
US imports						-0.093	-0.225	0.367	0.384
						(0.206)	(0.150)	(0.262)	(0.252)
FDI to US						0.071	-0.106*	-0.009	-0.017
						(0.100)	(0.051)	(0.125)	(0.178)
Observations	5,202	5,202	5,202	5,202	5,202	5,202	5,202	5,202	5,202
Log-likelihood	-67,416	-66,644	-66,483	-65,954	-65,552	-65,541	-18,767	-5,942	-5,492

Notes: All specifications include country, year and industry fixed effects. Bootstrapped standard errors allow for clustering by country-year and are shown in parenthesis; + p<0.10, * p<0.05, ** p< 0.01. Bootstrapped bias-corrected 95% confidence intervals for the business travel variable are reported in brackets.

Table 3: Control Function Regressions

	(1)	(2)	(3)	(4)	(5)
Dependent variable			Business travel		
Visit friends & family travel	0.871**	0.811**	0.808**	0.772**	0.771**
	(0.008)	(0.014)	(0.014)	(0.016)	(0.016)
Retired travel		0.082**	0.077**	0.065**	0.062**
		(0.015)	(0.015)	(0.015)	(0.015)
Religious travel			0.070**		0.050**
			(0.019)		(0.019)
Homemaker travel				0.093**	0.090**
				(0.015)	(0.015)
Population	-0.661+	-0.646+	-0.649+	-0.680+	-0.681+
	(0.387)	(0.387)	(0.386)	(0.388)	(0.387)
GDP per capita	-0.176	-0.169	-0.176	-0.172	-0.177
	(0.190)	(0.189)	(0.189)	(0.188)	(0.188)
US exports	0.010	0.017	0.017	0.007	0.008
	(0.059)	(0.059)	(0.059)	(0.059)	(0.059)
US FDI	0.004	-0.001	0.003	-0.001	0.002
	(0.037)	(0.037)	(0.037)	(0.036)	(0.036)
R&D expenditures	-0.007	0.003	0.009	-0.005	-0.001
	(0.078)	(0.077)	(0.077)	(0.076)	(0.076)
Resident patent applications	0.158**	0.159**	0.157**	0.161**	0.159**
	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
US imports	0.092	0.088	0.089	0.092+	0.093+
	(0.056)	(0.056)	(0.056)	(0.055)	(0.055)
FDI to US	-0.032	-0.032	-0.030	-0.031	-0.030
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Observations	5,202	5,202	5,202	5,202	5,202
R-squared	0.922	0.923	0.923	0.924	0.924

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

Table 4: Patent Counts with Control Function and Instrumental Variable Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Poisson	Poisson CF	Poisson CF	Poisson IV	Neg Bin CF	Poisson	Poisson CF	Poisson IV
Dependent variable			US patents				US joint patents	
Business travel	0.022*	0.021*	0.021*	0.024+	0.025*	0.038*	0.033+	0.082+
	(0.010)	(0.010)	(0.010)	(0.015)	(0.012)	(0.016)	(0.018)	(0.043)
	[0.3%,3.8%]	[0.8%,3.9%]	[0.7%,4.2%]	[-0.6%,5.7%]	[0.7%, 4.4%]	[2.0%, 6.4%]	[0.9%, 5.9%]	[8.1%, 16.2%]
Population	0.893	0.898	0.898	2.793**	1.989**	0.913	0.936	0.407
	(1.228)	(1.244)	(1.235)	(0.969)	(0.684)	(1.435)	(1.447)	(0.968)
GDP per capita	0.245	0.251	0.251	1.437**	1.140**	0.802	0.819	0.668
	(0.673)	(0.679)	(0.678)	(0.463)	(0.373)	(0.692)	(0.719)	(1.948)
US exports	-0.159	-0.160	-0.160	-0.117	-0.079	0.035	0.026	-0.289
	(0.243)	(0.242)	(0.243)	(0.240)	(0.112)	(0.216)	(0.217)	(0.512)
US FDI	0.055	0.054	0.054	-0.238	-0.005	-0.359*	-0.358*	-1.602*
	(0.133)	(0.132)	(0.132)	(0.154)	(0.082)	(0.170)	(0.171)	(0.673)
R&D expenditures	0.831**	0.832**	0.832**	0.657**	0.549**	0.242	0.235	1.924**
	(0.296)	(0.295)	(0.293)	(0.215)	(0.136)	(0.386)	(0.382)	(0.604)
Resident patent applications	0.502**	0.502**	0.502**	0.604**	0.486**	0.684**	0.685**	1.424*
	(0.132)	(0.132)	(0.132)	(0.121)	(0.076)	(0.215)	(0.213)	(0.558)
US imports	-0.093	-0.095	-0.094	-0.168	-0.225	0.367	0.367	2.108*
	(0.206)	(0.207)	(0.207)	(0.174)	(0.151)	(0.262)	(0.264)	(0.903)
FDI to US	0.071	0.070	0.070	-0.208**	-0.106*	-0.009	-0.012	-0.709**
	(0.100)	(0.099)	(0.099)	(0.070)	(0.051)	(0.125)	(0.124)	(0.234)
Control function		0.005	0.006		0.018		0.028	
		(0.035)	(0.035)		(0.024)		(0.053)	
Instrument/Control function		FF	FF, Rl, Rt, Hm	FF	FF		FF	FF
Observations	5,202	5,202	5,202	5,202	5,202	5,202	5,202	5,202
Log-likelihood	-65,541	-65,540	-65,540	n/a	-18,767	-5,942	-5,942	n/a

Notes: All specifications include country, year and industry fixed effects. Bootstrapped standard errors allow for clustering by country-year and are shown in parenthesis; + p<0.10, * p<0.05, ** p< 0.01. Bootstrapped bias-corrected 95% confidence intervals for the business travel variable are reported in brackets. Types of travel variables for instrument/control function: FF- visit friends & family , Rl- religious, Rt-retired, Hm-homemaker.

Table 5: Specification Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable				US patents				
Business travel	0.022*	0.001	-0.014	0.021*	0.006	-0.014		
	(0.010)	(0.012)	(0.011)	(0.010)	(0.012)	(0.013)		
	[0.3%, 3.8%]	[-1.6%, 2.8%]	[-3.1%, 0.6%]	[0.8%, 3.9%]	[-0.3%, 4.1%]	[-3.5%, 1%]		
Business travel* High patents (median)		0.029**			0.024**			
		(0.010)			(0.009)			
		[1.3%, 4.4%]			[0.4%, 4.1%]			
Business travel* High patents (mean)			0.049**			0.046**		
			(0.009)			(0.009)		
			[3.4%, 6.8%]			[3.4%, 5.9%]		
Business travel (unweighted)							0.010	0.011
							(0.012)	(0.013)
							[-1.1%, 3.6%]	[-0.3%, 3.9%]
Population	0.893	0.978	1.251	0.898	0.953	1.255	0.841	0.838
	(1.228)	(1.242)	(1.248)	(1.244)	(1.268)	(1.284)	(1.259)	(1.270)
GDP per capita	0.245	0.275	0.241	0.251	0.300	0.272	0.217	0.214
	(0.673)	(0.667)	(0.647)	(0.679)	(0.663)	(0.647)	(0.680)	(0.681)
US exports	-0.159	-0.186	-0.194	-0.160	-0.183	-0.195	-0.151	-0.151
	(0.243)	(0.243)	(0.244)	(0.242)	(0.240)	(0.241)	(0.243)	(0.243)
US FDI	0.055	0.037	0.049	0.054	0.015	0.037	0.057	0.057
	(0.133)	(0.133)	(0.133)	(0.132)	(0.137)	(0.135)	(0.133)	(0.133)
R&D expenditures	0.831**	0.882**	0.843**	0.832**	0.890**	0.849**	0.840**	0.840**
	(0.296)	(0.285)	(0.285)	(0.295)	(0.284)	(0.287)	(0.294)	(0.293)
Resident patent applications	0.502**	0.478**	0.460**	0.502**	0.483**	0.460**	0.504**	0.504**
	(0.132)	(0.129)	(0.128)	(0.132)	(0.130)	(0.130)	(0.131)	(0.132)
US imports	-0.093	-0.064	-0.026	-0.095	-0.056	-0.025	-0.087	-0.087
	(0.206)	(0.197)	(0.192)	(0.207)	(0.202)	(0.197)	(0.202)	(0.203)
FDI to US	0.071	0.058	0.059	0.070	0.055	0.055	0.068	0.068
	(0.100)	(0.099)	(0.095)	(0.099)	(0.098)	(0.093)	(0.100)	(0.100)
Control function				0.005	-0.026	0.001		-0.002
				(0.035)	(0.050)	(0.050)		(0.033)
Control function: interaction					0.077	0.041		
					(0.056)	(0.052)		
Observations	5,202	5,202	5,202	5,202	5,202	5,202	5,202	5,202
Log-likelihood	-65,541	-65,087	-64,421	-65,540	-65,015	-64,385	-65,770	-65,769

Notes: Poisson QMLE Regressions. All specifications include country, year and industry fixed effects. Bootstrapped standard errors allow for clustering by country-year and are shown in parenthesis; + p<0.10, * p<0.05, ** p< 0.01. Bootstrapped bias-corrected 95% confidence intervals for the business travel variable are reported in brackets. Control function in columns (4)-(6) and column (8) is based on visit friends & family travel.

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 Sample

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

Table A3B: Countries in Sample

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

Figure 1

10-year Differences of Business and Friends & Family travel , 1993-2003