International Business Travel: An Engine of Innovation?*

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Abstract

While business surveys often find that managers prefer face-to-face communication for negotiating deals and selling their product, there is reason to believe that face-to-face meetings are particularly important for the transfer of technology, because technology is best explained and demonstrated in person. This paper examines the role of inward business travelers in raising a country's rate of innovation by looking at business travel from the United States to thirty-six other countries during the years 1993-2003. We find that international business travel has a significant effect up and beyond technology transfer through international trade and foreign direct investment. On average, a 10% increase in international business traveler arrivals leads to an increase in patenting by about 0.6%. There is also strong evidence that the impact on innovation depends on the quality of the technological knowledge carried by each business traveler. This study suggests that international air travel is an important channel through which cross-country income differences can be reduced. A number of policy issues that are raised by our analysis of short-term cross-border labor movements are discussed.

Keywords: International technology transfer, face-to-face communication, tacit knowledge, cross-border labor movements, patenting

JEL: F20, O33, J61

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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 to slip 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 intermediate 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.[1]

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 will help. Technology also tends to be tacit–it is difficult to fully characterize–, and it is well-known that face-to-face communication is more effective than other forms for transferring technology.[2] Nevertheless we know very little on the impact of cross-border worker flows on innovation. In this paper, we employ a new dataset to examine the impact of business travelers from the United States on patenting in 36 countries and the period of 1993 to 2003. Our main finding is that business travel raises a country's rate of innovation, with a 10% increase in business travel increasing patenting on average by about 0.6%.

[1] The focus will be on short-term labor movements. In Slater's time, short-term movements were mostly ruled out due to high travel costs.

[2] Polanyi (1958) discusses this 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.

The importance of personal contacts for international technology transfer has been noted in Kerr (2008) who shows that larger ethnic research communities in the United States constitute networks that are capable of raising productivity in the foreign countries with mainly that ethnicity.[3] Movements of scientists themselves can be a conduit of international knowledge flows (Oettl and Agrawal 2008, Kim, Lee, and Marschke 2006), consistent with the finding that R&D managers access externally-located technology partly through hiring of researchers from the outside (Cohen, Nelson, and Walsh 2002). In contrast, we focus on the impact of business visits using information on international air travel patterns. These are short-term movements that are observed at a relatively high frequency–there are more than 100,000 international business trips in our data–which is used to identify the causal effect of cross-border movements.

Air travel has been considered as a channel for technology transfer in a number of papers. Andersen and Dalgaard (2009) find that the number of air travelers relative to the population is a strong predictor for cross-country productivity differences, though a concern is that the underlying data may not be sufficiently harmonized across countries. In a recent analysis of European regions, the number of airplane passengers is not significantly related to productivity differences once other determinants are controlled for (Gambardella, Mariani, and Torrisi 2009). An important issue is that business travelers are often recorded together with leisure travelers, including tourists, which is a limitation because the impact of international travel on technology transfer presumably rests with the former and not the latter. In our data business and leisure travelers are separated.[4]

[3] Related is also the work by Rauch (2001), Singh (2005), Agrawal, Cockburn, and McHale (2006), and Agrawal, Kapur, and McHale (2008).

[4] In addition, below we will also employ information on the traveler's occupation.

The focus of Dowrick and Tani (2009) to explain total factor productivity (TFP) differences by business travel is on the one hand attractive because it is well-known that most income differences are due to TFP differences (Hall and Jones 1999, Caselli 2005).[5] On the other hand, TFP is only an indirect measure of technology; in fact, it might be argued that TFP captures also the social capital or the quality of institutions across countries. This study focuses on a more direct outcome of international technology transfer, namely domestic innovation in terms of patenting activity.

The focus on business travel expands on what is known about the channels of international technology transfer more generally. Among the most commonly channels cited in the literature are international trade and foreign direct investment (FDI), and it is an important feature of our analysis that we are able to estimate the contribution of cross-border movements of labor relative to trade and FDI.[6] Finally, to the best of our knowledge this study is the first that incorporates some heterogeneity in terms of the knowledge held by the business travelers, which as we show below is crucial to quantify the benefits from cross-border workers flows on the domestic rate of innovation.

The remainder of the paper is as follows. The next section gives an overview of the empirical analysis that will be conducted, and we will also highlight important aspects of the method of estimation. Section 3 describes the data that will be used, with more details given in the

[5] See also Le (2008) who studies the relation between TFP and foreign R&D in the tradition of the international R&D spillover literature (Coe and Helpman 1995, Keller 1998), using the share of foreign-born population as weights.

[6] See Keller (2002) on imports, De Loecker (2007) on exports, and Keller and Yeaple (2009) on FDI for example; Keller (2009) surveys the literature. Employing the same traveler survey as we do here, Poole (2009) has recently concluded that business travel spurs international trade between countries; this is another reason for why it is important to control for trade in our context.

Appendix. All empirical results are presented in section 4, while section 5 contains a concluding discussion of our findings.

2 An empirical model of innovation through cross-border movements

In this paper we are interested in estimating the impact of international business travel on differences in the rate of innovation across countries. Innovation is measured in terms of the number of the countries' patent counts.[7] In terms of business travel, our analysis is more limited because such data is not widely available. We examine outward business travel of U.S. residents–which are predominantly U.S. citizens–to other countries. The focus on one source country of all travelers imposes a certain amount of homogeneity in terms of technology for the analysis. Moreover, the fact that this country is the United States is helpful because as one of the world's most advanced countries the U.S. is suitable in a study of technology transfer to our countries.

Our approach is quite simple. We hypothesize that patenting in a particular country c, P_c is some unknown function Ψ of inward business travelers from the United States, B_c, plus other observed and unobserved determinants, Z_c :

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

where Θ is a vector of unknown parameters. There are a number of generic problems with

[7] The usage of patent data is well-established in empirical studies of innovation. See Griliches (1990) for a discussion of the key issues.

estimating consistent parameters, including endogeneity, that will be addressed below. Another issue is more specific to our analysis: the number of patents, P_c, is a non-negative count variable. Consequently least-squares techniques, which assume unbounded support, are not appropriate. Instead the analysis will rely on estimates from 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, with the main difference compared to a Poisson regression being that the negative binomial model does not assume equality between the mean and the variance.[8]

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

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 as recorded by the United States Patent and Trademark Office (USPTO). 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 data base, which has information on country of residence for each of possibly several inventors per patent, as well as the application month and year.[9] In the case of multiple inventors, we assign a fraction of $1/n$ to each inventors

[8] Cameron and Trivedi (1998) discuss count data models more generally; see also the arguments in favor of Poisson-like regression models in Santos Silva and Tenreyo (2008).

[9] In terms of timing, we focus on the date of application as opposed to the date of when the patent is granted, so that differences in the processing time of patents do not play a role.

country of residence, where n is the number of inventors for each patent. The main dependent variable in the empirical analysis is the sum of these patent shares aggregated by foreign country for each quarter during the period 1993 to 2003.[10]

We have also employed the USPTO individual inventor database to track foreign patents applied for in the United States that have a U.S. coinventor. These patents are of particular interest because it is relatively likely that the U.S. travel is related to the foreign patent since the traveler could in fact be the U.S. coinventor on that patent. For this reason, we believe that the relationship between inward business travel and domestic innovation might be strengthened. Using the same methodology for these patents as above, we find that on average about one in forty of all foreign patent applications in the United States during our sample period had foreign and U.S. coinventors on the patent.

In addition to any impact from the cross-border movements of labor, a principal determinant of a country's rate of innovation are its R&D expenditures. We have obtained this data from OECD Statistics[11]. 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).[12] These measures 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.[13]

[10] For more information on patent data construction, please see the Appendix.

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

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

[13] In addition, including all resident patents on the right hand side controls for a '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 data The information on international air travel in this paper comes from the Survey of International Air Travelers (SIAT) which is conducted by the United States Office of Travel and Tourism Industries.[14] This survey provides information on travel from the United States to foreign countries for U.S. residents and each quarter during the years 1993 to 2003.[15] The air travel 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 the U.S. to a given foreign country for each quarter during the years 1993 to 2003.

While we do not have information on the technological knowledge of each individual traveler, we account for differences across business travelers in this respect by incorporating information on patent stocks (a measure of technological prowess) at the level of the U.S. states. Our weighted business traveler variable B_{cqt} becomes

$$B_{cqt} = \sum_{s \epsilon S} \frac{P_{sqt}}{GSP_{sqt}} \times \tilde{B}_{scqt}, \tag{2}$$

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, and $\tilde{B}_{sqt}$ is the (unweighted) number of business travelers from state s to foreign country c in quarter q of year t. Equation (2) captures the idea that U.S. travelers

[14] The Office of Travel and Tourism Industries is part of the International Trade Administration, U.S. Department of Commerce.

[15] Our focus on travel into foreign countries is parallel to the great majority of studies of technology transfer through trade and FDI, since those focus on imports and inward FDI. At the same time, the SIAT data also has information on travel from foreign countries into the United States, with which we are planning to study whether there is evidence for technology sourcing through travel (e.g., see Griffith, Harrison, and van Reenen 2006 on technology sourcing through FDI).

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.[16] The patent figures by state 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 level patent statistics are shown 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, or are retired or homemakers. These variables will be employed in our empirical analysis below as well.

Other variables The size and level of development of a country is going to affect its level of patents 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). It is also important to control for other channels of international technology transfer, where international trade and foreign direct investment (FDI) are most important. The regressions include U.S. exports to each of the sample countries, as well as the total sales of U.S. majority-owned multinational firms in each of the sample countries. Additional country-level control variables that we will consider are for the pre-sample period: the cumulative patent stock of each country for the years 1975-1992 and 1982-1992 (source: USPTO data).

Summary statistics of the data are presented in Table 1. The first two rows show some

[16] It is worth noting that travelers from the U.S. might also bring valuable information that is not narrowly defined of technological nature, such as about potential profitability and demand conditions for a particular product in the United States. This consideration reinforces the choice of focusing on patent applications in the United States as our dependent variable.

descriptive statistics on fractional patent counts by foreign inventors and joint US/foreign patent counts. These data reveal that average involvement of foreign inventors in US patenting is around 40 times larger for patents in which at least one inventor was foreign compared to patents which have joint U.S./ foreign coinventors. Also, there is large variation in U.S. patenting by foreign countries as evidenced by the large 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. In Table 1, the next four rows present (in natural logarithms) U.S. resident travel data for business, religious, and visitor purposes, along with data on travelers that have the occupations "retired" and "homemaker". As can be seen from the table, the (natural logarithm) number of 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. The remainder of the table presents statistics for the other variables that are employed in this paper.

We now turn to the empirical results.

4 Empirical results

In this section we first introduce the estimation equation, before turning to a discussion of the major results. The estimation equation is given by

$$E\left[P_{cqt}|B_{cqt}, X_{cqt}, Z_{cqt}\right] = \exp\left[\alpha \ln B_{cqt} + \beta \ln X_{cqt} + \mu_c + \mu_q + \mu_t + \varepsilon_{cqt}\right] \tag{3}$$

where P_{cqt}, the expected patent counts of a country c in the United States in quarter q of year t, is a function of B_{cqt}, the number of business travelers at that time between country c and the U.S. (from equation 2), other determinants of country c's patenting in the U.S., X_{cqt} (such as R&D expenditures), country-, quarter-, and year fixed effects (the μ's), and an error term, ε_{cqt}. In our data, the mean value of patents exceeds its variance (overdispersion), and we found the negative binomial model to be preferred to the Poisson model.[17]

The initial results on the relation between innovation and U.S. business travel are shown in Table 2. In columns 1 to 6, the dependent variable is the foreign country's patent counts taken out at the U.S. patent office, while in column 7 the dependent variable is foreign patents that have U.S. coinventors. All regressions include year and quarter fixed effects. Robust standard errors which allow for clustering by country-year are reported in parentheses.[18] Column 1 shows that there is a strong correlation between patenting and travel from the United States, which however is partly due to size and level of development, as column 2 indicates: including GDP per capita and population reduces the coefficient on business travel from 1.2 to 0.2.

Next we include important controls for domestic technology investments as well as international technology transfer. R&D has a positive effect on patenting, and so do imports from the United States, which is consistent with trade-related technology transfer. A number of results are somewhat puzzling, such as the size (population) coefficient, which comes in negative. This suggests that there are still important country-level determinants that are missing from this

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

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

equation. The inclusion of these variables lowers the business travel coefficient, which falls from 0.2 to 0.07. In column 4, we include the country's overall patenting as additional variables, distinguishing resident from non-resident patenting. We see that resident patenting is more strongly correlated (though here not significant) with the country's patenting in the United States, a plausible result that holds throughout our analysis.

In column 5 we include information on the countries' patenting activity in the pre-sample period as an additional source of unobserved heterogeneity. As expected, the cumulative stock of pre-sample patents comes in positive, although the coefficient on population is still negative. It turns positive upon including country fixed effects as additional controls for unobserved heterogeneity (column 6), the specification shown above as equation 3). Including country fixed effects leads also to a substantial improvement in terms of fit, and the business travel coefficient is estimated at about 0.09 (significant at a 1% level). Domestic R&D expenditures and resident patent applications associated with higher patenting in the US, whereas US exports and US FDI are positive but not significant.

The size of the business travel coefficient suggests that a 10% increase in business travelers from the U.S. is associated with an about 1% 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 0.14, see column 7, compared to 0.09 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 on certain patents is consistent with stronger international transfer through travel for these technologies.

While endogeneity concerns are reduced through the inclusion of country variables as well as fixed effects on the right hand side, it is still possible that unobserved shocks affect the relationship between business travel and innovation, leading to biased estimates. In particular, we are concerned that $E[B_{cqt}, \varepsilon_{cqt}] > 0$, which would lead to an upward bias in the business travel coefficient. Our approach is to construct a control function variable, ω_{cqt}, such that when ω_{cqt} is included in the regression the correlation of business travel and the new regression error is essentially zero.[19] The control function that we propose is the residual of a regression of business travel on visitor travel for a given country, quarter and year. Consider the following least-squares regression:

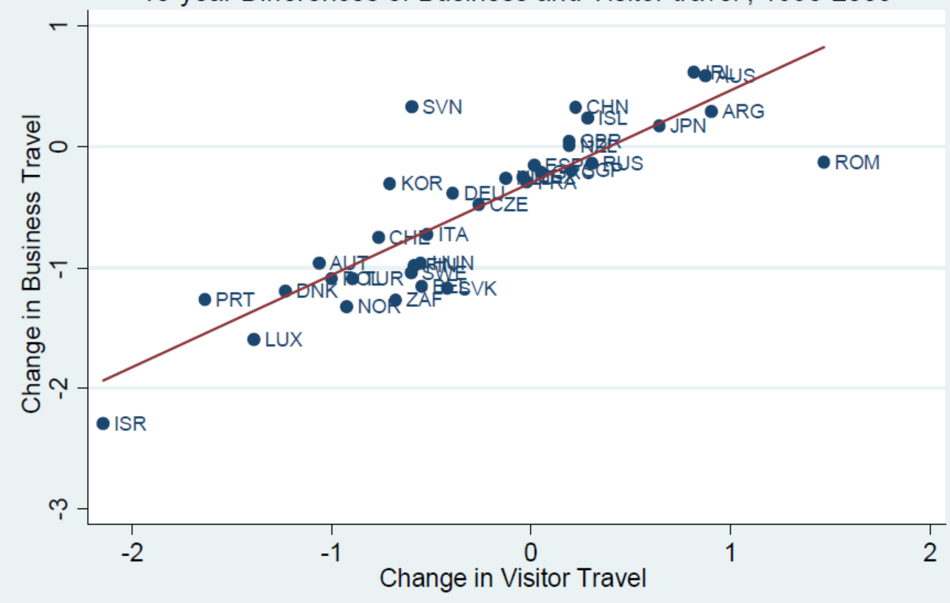
$$\ln B_{cqt} = \gamma_c + \gamma_q + \gamma_t + \gamma_1 \ln V_{cqt} + \gamma_2 X_{cqt} + \omega_{cqt}, \tag{4}$$

where V_{cqt} is the number of visitor travelers between the U.S. and country c in quarter q of year t. The residual $\hat{\omega}_{cqt}$ of this regression will tend to be high when business travel is high relative to visitor travel, conditional on all other covariates. As such this control function is well-suited to capture time-variant shocks that affect business conditions in country c, including shocks that at the same time raise the desirability of country c as a destination for U.S. business travelers and the propensity of country c to patent in the United States. For this control function approach to work, visitor travel must be strongly correlated with business travel, otherwise $\hat{\omega}_{cqt}$ will be mostly noise. In Figure 1, we show the 10-year differences for visitor versus business travel; the strong correlation, which also exists for shorter periods of time, is apparent.

[19] Control function approaches have recently 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.

Figure 1

10-year Differences of Business and Visitor travel , 1993-2003



Visitor travel is also a suitable control function variable because we do not expect that receiving visitors (defined as friends and relatives) from the United States affects a country's patenting, mainly because such visitors will generally not concern themselves with transferring technology from their home country.

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, and 4 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 involved in the transfer of technological knowledge. The results for these regressions indicate that all control variables (besided retired travel) are significantly correlated with business travel, for example because reductions in air fares have made travel for both business and religious purposes more attractive. The most important predictor is visitor travel, which is likely related to the fact that visitor travelers are more common than other travelers, see Table 1.

Table 4 shows the results when the control function, $\hat{\omega}_1$ to $\hat{\omega}_4$ for the four columns of Table 3, is included as a determinant of patenting in the United States. The first column repeats the baseline results from Table 2, column 6 with a coefficient of 8.6% for the business traveler variable. If endogeneity generates an upward bias in this coefficient, one expects that upon inclusion of the control function the coefficient on business travel will decrease relative to when the control function is not included, and that the coefficient on $\hat{\omega}$ itself is positive. Indeed, we find that the coefficient on the business travel variable falls, from 8.6% in column 1 to between 6% and 5.5% in columns 2 to 5, while at the same time it remains highly significant. The control function point estimates are between 5% and 6%, not significant at standard levels in columns 2 and 3, however significant at 10% in columns 4 and 5.[20] Turning to the results for 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 the same effects as it has for all patents: the business travel coefficient comes down from 0.14 to 0.12. Overall, these results indicate that there is a substantial effect of business travel on domestic innovation, with a coefficient of about 0.06 for all patenting and about 0.12 for patenting involving U.S. coinventors.

These results come from a large sample of countries in which some countries patent much

[20] This may in part be due to the clustering of the standard errors, which is a relatively conservative way to compute them.

more than other countries. In the following we examine whether the estimated relationship between business travel and innovation also holds for the major countries of the sample. The results are shown in Table 5. Column 1 repeats for convenience the baseline control function estimates for the whole sample (from Table 4, column 5), while in column 2 the sample is restricted to the countries which account for 99% of foreign patenting in the United States. This decreases the number of observations from 1164 to 804, restricting the sample to 23 countries.[21] For the limited set of countries, we estimate a somewhat stronger effect from trade relative to FDI, and a larger impact of resident patent applications, while at the same time the coefficient on business travel is quite similar (the point estimate changes from 5.9% to 6.8%). This is also the case if we restrict the sample so that it accounts for the bulk of business travel from the United States, see column 3 of Table 5.

On the right, we show the corresponding results for foreign patenting with U.S. coinventors. The size of the business travel coefficient and control function are similar to those in the full sample, while the control function estimates are not significant. The likely reason for the lower precision is the relatively small set of joint foreign/U.S. patents together with smaller number of countries in the sample (23, instead of 36). At the same time, the overall results are robust to concentrating on major countries in the world.

Next 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' patent stocks (recall equation 2 above). In Table 6 results from employing unweighted business travel variables are

[21] The set of countries which account for 99% of US foreign patenting is given in Table A1 of the Appendix; Taiwan is dropped from the regression as there is no information on R&D.

shown, in comparison to our baseline (weighted) business travel variable. Specifically, for all foreign patent applications in the U.S., the point estimate falls from 6% to essentially zero, and while the weighted travel variable is highly significant, the unweighted variable is not. In the case of the foreign patents with U.S. coinventors, on the right side of the table, we see that the unweighted business travel estimate is also very small, whereas the patent-stock weighted business travel has a coefficient of about 0.12.[22] From this we conclude that accounting for technological knowledge heterogeneity is very important in studying the impact of business travel on domestic innovation.

We have also conducted a number of additional 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 have no major effect on the estimated business traveler impact. 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. While the size of the lagged business estimate is smaller, it remains significant at standard levels. Overall our analysis indicates that the estimated impact from U.S. business travel on foreign countries' rates of innovation is very robust.

In the following section, we provide a concluding discussion.

[22] Similar results are obtained for any of the control function specifications shown in Tables 3 and 4.

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. 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-six other countries during the years 1993-2003. The results indicate that international business travel has a significant effect in addition to technology transfer through international trade and FDI, which are known to be important. Quantitatively, the impact of business travel on innovation is sizable: on average, a 10% increase in international business traveler arrivals leads to an increase in a country's patenting by about 0.6%. Moreover, there is strong evidence that the impact on innovation depends on the quality of the technological knowledge carried by each business traveler.

While these results suggest that short-term international labor movements may be an important way through which cross-country income differences can be reduced, more work needs to be done. One, it is important to expand the analysis to other samples and see whether the results continue to hold. Specifically, work on technology transfer through trade and FDI has emphasized that its strength may depend strongly on country and sectoral characteristics (see De Loecker 2007 and Keller and Yeaple 2009, respectively). While our results using U.S. state patent-weighted U.S. business traveler flows are consistent with that, including additional industry or geographic detail could be useful. Two, 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. Three, there are important questions on the degree of complementarity between cross-border travel, trade, and FDI that this paper has not addressed.

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 Gautier-Loiselle 2010, Stuen, Mobarak, and Maskus 2010). In contrast, our research informs policymakers by examining how strongly short-term cross-border movements affect innovation. For example, 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 better statistical information on international business travel, a key input for future work on this topic. Fortunately, there are some signs that international agencies are moving into this direction.[23]

[23] For example, 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

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6 Appendix

This data appendix explains the details on the sources and construction of our main variables.

Innovation US patent counts: The data on US patents issued from 1993-2003 comes from the United States Patent and Trademark Office (USPTO), Custom Data Extracts. Individual inventor database, which has address information (street, city, state, country of residence, etc) for each of multiple inventors per patent, is combined with bibliographical patent database, which has application month and year 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. Then using application month and year per patent, patents are aggregated by foreign country for each quarter during the period 1993-2003 to obtain patent counts by foreign countries for each quarter for years 1993-2003. Countries which ceased to exist during the sample period are excluded from the analysis (e.g. Czechoslovakia, Soviet Union, etc).

Joint US patent counts: To track patents which have a combination of foreign and US coinventors we also calculated foreign patent counts of only patents for which at least one US coinventor. For our sample period 1993-2003, there were 1,804,177 total patents, from which 51,744 (around 2.8%) were foreign with at least one US inventor. Using the same methodology as above, foreign patents with at least one US coinventor are obtained by aggregating by foreign country for each quarter during the period 1993-2003.

US patent stock by states: 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 US inventors, patent counts are aggregated to a given state for each quarter during the years

1993-2003.

Pre-sample patent variables: Pre-sample patent information on patents taken out at the USPTO is used to construct a country-specific patent stock built between 1975-1992, and 1982-1992. In addition, we constructed an indicator variable equal to one if a country had any positive patents during the years 1982-1992.

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, International Trade Administration, US Department of Commerce. SIAT is an on-going research program which collects statistical information on air travel patterns, volume and demographics on non-US residents traveling to the US and US residents traveling from the U.S (excluding Canada). SIAT has been conducted on a monthly basis starting from 1983 on randomly selected flights which have departed, or are about to depart, 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 US residents traveling from the United States to foreign countries in the period of 1993-2003. Outbound US resident travel data is an individual level database which has information on travelers' US 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. Purposes of the trip include business/professional, visit friends/relatives, religious/pilgrimages, and other. Occupations include homemaker, retired, and others. Main destination and secondary destination cities are both coded as destination countries. 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 US 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. In the same way, we calculate number of travelers who are visitors, are traveling for religious reasons, or are retired or homemakers. Subsequently, these aggregated travel variables are weighted by the ratio of US state patent stock to real state GDP (source: US department of Commerce, Bureau of Economic Analysis, BEA) to obtain country level travel variables. The final travel variables are in natural logarithms, with one added to each value. The impact of latter 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. US exports by country and year 1993-2003 are collected from U.S. Census Bureau (www.usatradeonline.gov). US FDI by destination countries and year 1993-2003 is proxied by the total sales of US majority-owned multinational firms and comes from US 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 collect data on OECD countries as well as some non-OECD member economies. 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 one 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 for years 1993-2003.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
US Patenting					
US patent counts	1584	474.96	1463.17	0	11377
Joint US patent counts	1584	11.77	21.61	0	144
US Resident Travel					
Business Travel	1584	3.73	1.41	0	6.92
Visitor Travel	1584	3.84	1.35	0	6.84
Religious Travel	1584	0.39	0.67	0	3.87
Retired Travel	1584	2.99	1.40	0	6.20
Homemaker Travel	1584	2.05	1.33	0	5.66
Other Variables					
Population	1584	9.64	1.62	5.57	14.07
Real GDP per capita	1584	9.66	0.58	7.60	10.84
US Exports	1584	21.89	1.72	17.34	25.44
US FDI	1440	23.51	1.66	16.30	26.73
R&D Expenditures	1356	22.00	1.49	18.22	25.38
Patent Applications, non-residents	1496	7.23	1.92	0	10.96
Patent Applications, residents	1496	7.37	2.13	0	12.86
Pre-Sample Patent Variables					
Cumulative US Patent Counts, 1982-1992	1584	6.75	2.67	0.69	12.27
Cumulative US Patent Counts, 1975-1992	1584	7.09	2.71	0.69	12.50

Note: 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							
Dependent variable	US patents						Joint US patents
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Business travel	1.176** (0.045)	0.199** (0.051)	0.068+ (0.036)	0.016 (0.037)	0.050+ (0.026)	0.086** (0.020)	0.138** (0.047)
Population		1.062** (0.043)	-0.646** (0.088)	-0.750** (0.086)	-0.639** (0.064)	2.376** (0.510)	1.442+ (0.831)
Real GDP per capita		3.655** (0.116)	0.401* (0.204)	0.238 (0.184)	-0.003 (0.137)	0.440+ (0.259)	0.627* (0.297)
US exports			0.287** (0.038)	0.268** (0.041)	0.254** (0.029)	0.034 (0.090)	0.578** (0.098)
US FDI			-0.144** (0.044)	-0.076+ (0.044)	-0.145** (0.038)	0.068 (0.065)	-0.157+ (0.086)
R&D Expenditures			1.579** (0.082)	1.509** (0.118)	1.114** (0.074)	0.698** (0.099)	0.277+ (0.142)
Patent applications, non-residents				0.036 (0.033)	0.041+ (0.021)	-0.012 (0.029)	-0.017 (0.037)
Patent applications, residents				0.104 (0.082)	0.120* (0.054)	0.139** (0.024)	0.212** (0.071)
Patent stock, presample					0.244** (0.025)		
Country effects	No	No	No	No	No	Yes	Yes
Log-likelihood	-9161	-8495	-6146	-5796	-5488	-4973	-2457
Number of observations	1584	1584	1216	1164	1164	1164	1164

Notes: Negative binomial regressions. All specifications include year and quarter 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				
Dependent variable	Business travel			
	(1)	(2)	(3)	(4)
Visitor travel	0.581** (0.034)	0.565** (0.039)	0.560** (0.038)	0.520** (0.043)
Retired travel		0.018 (0.019)	0.017 (0.019)	0.008 (0.018)
Religious travel			0.046** (0.017)	0.040* (0.017)
Homemaker travel				0.065* (0.027)
Population	-0.584 (0.681)	-0.543 (0.670)	-0.505 (0.676)	-0.558 (0.674)
Real GDP per capita	0.406 (0.291)	0.416 (0.289)	0.399 (0.282)	0.371 (0.280)
US exports	-0.044 (0.084)	-0.046 (0.085)	-0.037 (0.087)	-0.050 (0.088)
US FDI	0.073 (0.060)	0.071 (0.059)	0.076 (0.058)	0.070 (0.060)
R&D Expenditures	-0.030 (0.118)	-0.026 (0.115)	-0.010 (0.114)	0.001 (0.112)
Patent applications, non-residents	0.010 (0.027)	0.010 (0.027)	0.006 (0.025)	0.008 (0.026)
Patent applications, residents	0.049** (0.017)	0.050** (0.017)	0.051** (0.017)	0.050** (0.017)
Number of observations	1164	1164	1164	1164
R-squared	0.625	0.626	0.628	0.632

Notes: All specifications include country as well as year and quarter fixed effects. Number of countries included: 36. Robust standard errors in parentheses, + p< 0.10, *p<0.05, ** p<0.01

Table 4: Patent Counts with Control Function

Dependent variable	US patents					Joint US patents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Business travel	0.086** (0.020)	0.061* (0.029)	0.060* (0.029)	0.055+ (0.029)	0.059* (0.028)	0.138** (0.047)	0.123* (0.059)
Population	2.376** (0.510)	2.376** (0.512)	2.377** (0.512)	2.379** (0.513)	2.379** (0.512)	1.442+ (0.831)	1.441+ (0.830)
Real GDP per capita	0.440+ (0.259)	0.470+ (0.259)	0.471+ (0.259)	0.479+ (0.259)	0.473+ (0.259)	0.627* (0.297)	0.644* (0.295)
US exports	0.034 (0.090)	0.020 (0.092)	0.019 (0.092)	0.017 (0.092)	0.018 (0.092)	0.578** (0.098)	0.566** (0.105)
US FDI	0.068 (0.065)	0.073 (0.066)	0.073 (0.066)	0.074 (0.065)	0.073 (0.066)	-0.157+ (0.086)	-0.153+ (0.087)
R&D Expenditures	0.698** (0.099)	0.692** (0.099)	0.692** (0.099)	0.690** (0.099)	0.691** (0.099)	0.277+ (0.142)	0.274+ (0.141)
Patent applications, non-residents	-0.012 (0.029)	-0.011 (0.029)	-0.011 (0.029)	-0.011 (0.029)	-0.011 (0.029)	-0.017 (0.037)	-0.017 (0.036)
Patent applications, residents	0.139** (0.024)	0.142** (0.023)	0.142** (0.023)	0.142** (0.023)	0.142** (0.023)	0.212** (0.071)	0.212** (0.071)
Residual from first-stage		0.049 (0.034)	0.052 (0.034)	0.063+ (0.034)	0.055+ (0.033)		0.033 (0.063)
Control Function		*Vz*	*Vz, Rt*	*Vz, Rl, Rt*	*Vz, Rl, Rt, Hm*		*Vz, Rl, Rt, Hm*
Log-likelihood	-4973	-4972	-4972	-4971	-4972	-2457	-2457
Number of observations	1164	1164	1164	1164	1164	1164	1164

Notes: Negative binomial regressions. All specifications include country as well as year and quarter 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.

Table 5: Patent Counts of Major Countries

Dependent variable	US patents			Joint US patents		
	(1)	(2)	(3)	(4)	(5)	(6)
Business travel	0.059*	0.068*	0.065*	0.123*	0.127*	0.114*
	(0.028)	(0.027)	(0.028)	(0.059)	(0.058)	(0.057)
Population	2.379**	1.969**	2.381**	1.441+	1.054	1.192
	(0.512)	(0.499)	(0.555)	(0.830)	(0.803)	(0.813)
Real GDP per capita	0.473+	0.366	0.312	0.644*	0.649*	0.659*
	(0.259)	(0.261)	(0.266)	(0.295)	(0.294)	(0.292)
US exports	0.018	0.151	0.077	0.566**	0.597**	0.552**
	(0.092)	(0.097)	(0.099)	(0.105)	(0.104)	(0.102)
US FDI	0.073	0.033	0.096	-0.153+	-0.198*	-0.173*
	(0.066)	(0.072)	(0.076)	(0.087)	(0.086)	(0.086)
R&D Expenditures	0.691**	0.789**	0.716**	0.274+	0.335*	0.307*
	(0.099)	(0.103)	(0.110)	(0.141)	(0.142)	(0.143)
Patent applications, non-residents	-0.011	0.054*	-0.005	-0.017	-0.002	-0.013
	(0.029)	(0.025)	(0.035)	(0.036)	(0.037)	(0.036)
Patent applications, residents	0.142**	0.152**	0.139**	0.212**	0.239**	0.237**
	(0.023)	(0.030)	(0.022)	(0.071)	(0.082)	(0.079)
Residual from first-stage	0.055+	0.067*	0.069*	0.033	0.050	0.061
	(0.033)	(0.034)	(0.033)	(0.063)	(0.060)	(0.059)
Countries, 99% US total patenting		X			X	
Countries, 90% total business travel			X			X
Log-likelihood	-4972	-4110	-4462	-2457	-2133	-2280
Number of observations	1164	804	944	1164	804	944

Notes: Negative binomial regressions. All specifications include country as well as year and quarter 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 in all columns is visitor, religious, retired and homemaker travel.

Table 6: Results with Unweighted Travel

Dependent variable	US patents					Joint US patents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Business travel	0.036+ (0.019)	0.006 (0.028)	0.006 (0.028)	-0.001 (0.028)	0.003 (0.028)	0.029 (0.034)	0.004 (0.048)
Population	2.348** (0.534)	2.352** (0.539)	2.353** (0.539)	2.356** (0.539)	2.356** (0.539)	1.168 (0.842)	1.168 (0.840)
Real GDP per capita	0.516* (0.256)	0.556* (0.257)	0.556* (0.257)	0.566* (0.256)	0.561* (0.256)	0.759** (0.278)	0.793** (0.274)
US exports	0.004 (0.089)	-0.011 (0.091)	-0.011 (0.091)	-0.013 (0.090)	-0.012 (0.090)	0.500** (0.094)	0.482** (0.099)
US FDI	0.075 (0.066)	0.081 (0.066)	0.081 (0.066)	0.081 (0.066)	0.081 (0.066)	-0.126 (0.084)	-0.121 (0.085)
R&D Expenditures	0.680** (0.101)	0.671** (0.100)	0.671** (0.100)	0.669** (0.100)	0.670** (0.101)	0.228 (0.142)	0.222 (0.141)
Patent applications, non-residents	-0.008 (0.031)	-0.008 (0.032)	-0.008 (0.032)	-0.007 (0.032)	-0.007 (0.032)	-0.008 (0.037)	-0.006 (0.036)
Patent applications, residents	0.144** (0.025)	0.147** (0.024)	0.147** (0.024)	0.147** (0.024)	0.147** (0.024)	0.249** (0.077)	0.250** (0.077)
Residual from first-stage		0.060+ (0.036)	0.060+ (0.036)	0.073* (0.036)	0.067+ (0.036)		0.055 (0.063)
Control Function		*Vz*	*Vz, Rt*	*Vz, Rl, Rt*	*Vz, Rl, Rt, Hm*		*Vz, Rl, Rt, Hm*
Log-likelihood	-4987	-4985	-4985	-4985	-4985	-2469	-2468
Number of observations	1164	1164	1164	1164	1164	1164	1164

Notes: Negative binomial regressions. All specifications include country as well as year and quarter 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.

Table A1: Top 99% patenting countries in the US			
Country Name	Sum of US patents , 1993-2003	**Country Name**	Sum of US patents , 1993-2003
Japan	371221	**Austria**	5921
Germany	117610	**Denmark**	5208
Taiwan	47570	**Spain**	3215
France	43888	**Singapore**	3167
United Kingdom	42804	**China**	2945
South Korea	41103	**India**	2850
Italy	18689	**Norway**	2770
Sweden	16235	**Hong Kong**	2433
Switzerland	15417	**Russia**	2324
Netherlands	14848	**Ireland**	1510
Israel	10848	**New Zealand**	1415
Australia	9741	**South Africa**	1386
Finland	8997	**Brazil**	1169
Belgium	7724		

Notes: Taiwan, Brazil and India are excluded from the analysis due to unavailability of R&D data. This table does not include Canadian patents in the US, as Survey for International Air Travelers does not provide travel information for Canada.

Table A2: 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 A3A: Countries in 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 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	