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INTERNATIONAL BUSINESS TRAVEL AND TECHNOLOGY SOURCING

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ABSTRACT

Access to new foreign technology is often central to countries' development strategies. However, we know very little about the quantitative impact of technology sourcing. In this paper, we study the role of outward international business travel for technology sourcing and innovation by examining whether patenting in European regions is affected by the number of business travelers heading to the United States. Using European regional patent data for the years 1996 to 2010 from Eurostat and information on incoming business travelers from the U.S. Department of Commerce's Survey of International Air Travelers, we find that controlling for a region's R&D spending and size, innovation is increasing in the number of business travelers of the region to the United States. Technology sourcing through in-person business travel is not only statistically but economically significant, accounting, for example, for 20% of the higher patenting in Germany's Greater Stuttgart area, compared to Portugal's Algarve region.

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1 Introduction

Acquisition of new foreign technology is often central to countries' development strategies. A case in point is South Korea, one of the so-called East Asian miracle countries (World Bank 1993), which encouraged its students, scientists, and engineers to go abroad to acquire leading-edge technology that upon their return would improve domestic technology. In the mid-1970s, the fraction of South Korea's post-secondary student population studying abroad was six times what it was for Argentina, for example (Westphal, Kim, and Dahlman 1984).[1] Despite the prominence of such activities in accounts of successful catch-up and development, we know very little empirically about the importance of technology sourcing. In this paper, we examine the role of outward international business travel for technology sourcing and innovation.

This paper asks whether patenting in European regions is affected by the extent to which its business travelers head to the United States, a country that is widely considered to be close to the world's technology frontier. Because technology is first and foremost knowledge–a blueprint– it might seem that business travel is unnecessary since blueprints, as a form of disembodied knowledge, can easily be emailed for use abroad. And yet, researchers studying technology diffusion emphasize that technological knowledge contains non-codifiable elements that make it 'tacit' (silent), and that face-to-face meetings are an effective way in which such knowledge is transferred (Polanyi 1966; see discussion in Keller 2004).

Employing European regional patent data level for the years 1996 to 2010 from Eurostat and information on US business travelers from the U.S. Department of Commerce's Survey of International Air Travelers (SIAT), we find that controlling for a region's R&D spending and size, innovation increases with the number of outward business travelers from a given region to the United States. Because our data provides information not only on the European traveler's city of residence but also US destination county, we can account for differences in the knowledge content gained from business trips by accounting for R&D differences across US regions. For example, a business trip to Silicon Valley is expected to provide more knowledge than a trip to a typical town in the American Midwest, and more generally we exploit the idea that travel to high-R&D locations improves patenting by more than travel to locations with less R&D. The relationship between outward business travel and patenting is not only statistically but also economically significant. For example, technology sourcing through business travel to the US accounts for about 20% of the higher patenting in the Greater Stuttgart area, compared to Portugal's Algarve region.

This paper contributes to a large and growing literature on international technology diffusion

[1] The fact that some of those heading abroad eventually choose to not return matters quantitatively, but it does not negate the point in principle.

(Keller 2010 is a survey). While trade based on exogenously given productivity differences can be seen as a form of international technology diffusion, the substantially higher performance of outward-oriented economies compared to inward-oriented economies is hard to explain without accounting for the flows of tacit knowledge between economic agents who take part in international transactions.[2]

The literature so far has focused on international trade and foreign direct investment to explain why outward-oriented economies perform better compared to inward-oriented economies. In particular, we know that economies benefit if their import composition is tilted towards technologically innovative trade partners (Keller 2000, 2002a), and that firms gain in productivity by engaging in export activity (learning-by-exporting; van Biesebroeck 2005, De Loecker 2007). Quantitatively important technology learning spillovers from inward FDI have been documented for countries as diverse as China, the United States, and Lithuania (Jiang, Keller, Qiu, and Ridley 2019, Keller and Yeaple 2009, and Javorcik 2004, respectively). Our paper provies an additional explanation, the flows of tacit knowledge that are associated with business travel.

Some authors examine the relationship between international business travel and these channels of technology diffusion, in particular FDI. For example, Foley and Kerr (2013) note that international business travel may help to explain why a higher share of inventors from a certain ethnicity lead to an expansion of multinational employment in the region where this ethnicity is prevalent.[3] A smaller literature has examined the role for international business travel in the diffusion of technology. Hovhannisyan and Keller (2015) show that US business travelers generate positive learning externalities in the countries to which they fly to. By studying travelers from Europe who travel to the United States, this paper focuses on technology sourcing.[4] Technology sourcing related to multinational activity has been analyzed by Almeida (1996) and Branstetter (2002), and the research most closely related to ours may be Griffith, Harrison, and van Reenen (2006) who show that UK firms tap into leading-edge knowledge by locating R&D activities into the United States. To the best of our knowledge, ours is the first paper that estimates the importance of business travel for international technology sourcing.

The remainder of this paper is as follows. Section 2 provides information on the sources and main patterns of the data, with more details on data construction given in the Appendix. The following section 3 introduces our statistical model and discusses the sources of identification. All estimation results are given in section 4. We present a number of concluding thoughts in section 5.

[2]See Keller, Lampe, and Shiue (2019) for more discussion.

[3]See also Fageda (2017) who shows that increased availability of nonstop flights increases the amount of FDI in the corresponding region.

[4]See also Piva, Tani, and Vivarelli (2018) who estimate the combined sectoral impact of inward and outward business travel on productivity across countries.

2 Data and Summary Statistics

This section describes our main data sources and provides initial evidence by examining key patterns in the data.

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 of European countries' residents to the United States during the years 1993 to 2003 (see the Appendix for details). The data has information on the travelers' European city of residence, U.S. destination county and the purpose of the travel (business or other). We aggregate this data to business travelers from a given European city to a given U.S. state. Further, we match European cities to regions based on documentation from the Eurostat at the NUTS 2 level. Figure 1 shows the NUTS 2 regions of Europe (2010 classification) constructed from the Eurostat Statistical Atlas.

We have consistently coded the travel data taking account of changes in the European regional classification; see the Appendix for a detailed description.

Table 1 shows some basic patterns of outward business travel from European regions to the United States. It is clear from Table 1 that there is substantial variation in business travel originating from various European regions. There are also important size (gravity) effects; Lombardia (ranked 5th) , for example, with Milan, has a larger population than Sardinia (Sardegna), which is ranked among the regions with the lowest number of originating business travelers. The top regions from which business travelers come to the U.S. are London, Île de France (including Paris), and Oberbayern (which contains Munich).

Table 2 presents information on patterns of European business travel to each U.S. state. Note that size plays a role here as well (California, New York, and Florida are all big states).

In addition to size, the destination of European travelers appears to be also determined by other considerations. Despite its relatively small size, the District of Columbia, for example, hosts a relatively high number of R&D plants, and regions in which a lot of R&D is performed should matter more for technology sourcing than regions where little R&D is done. In order to account for differences in local technological capacity in the United States we employ R&D data by the U.S. National Science Foundation to construct R&D stocks of each state.[5]

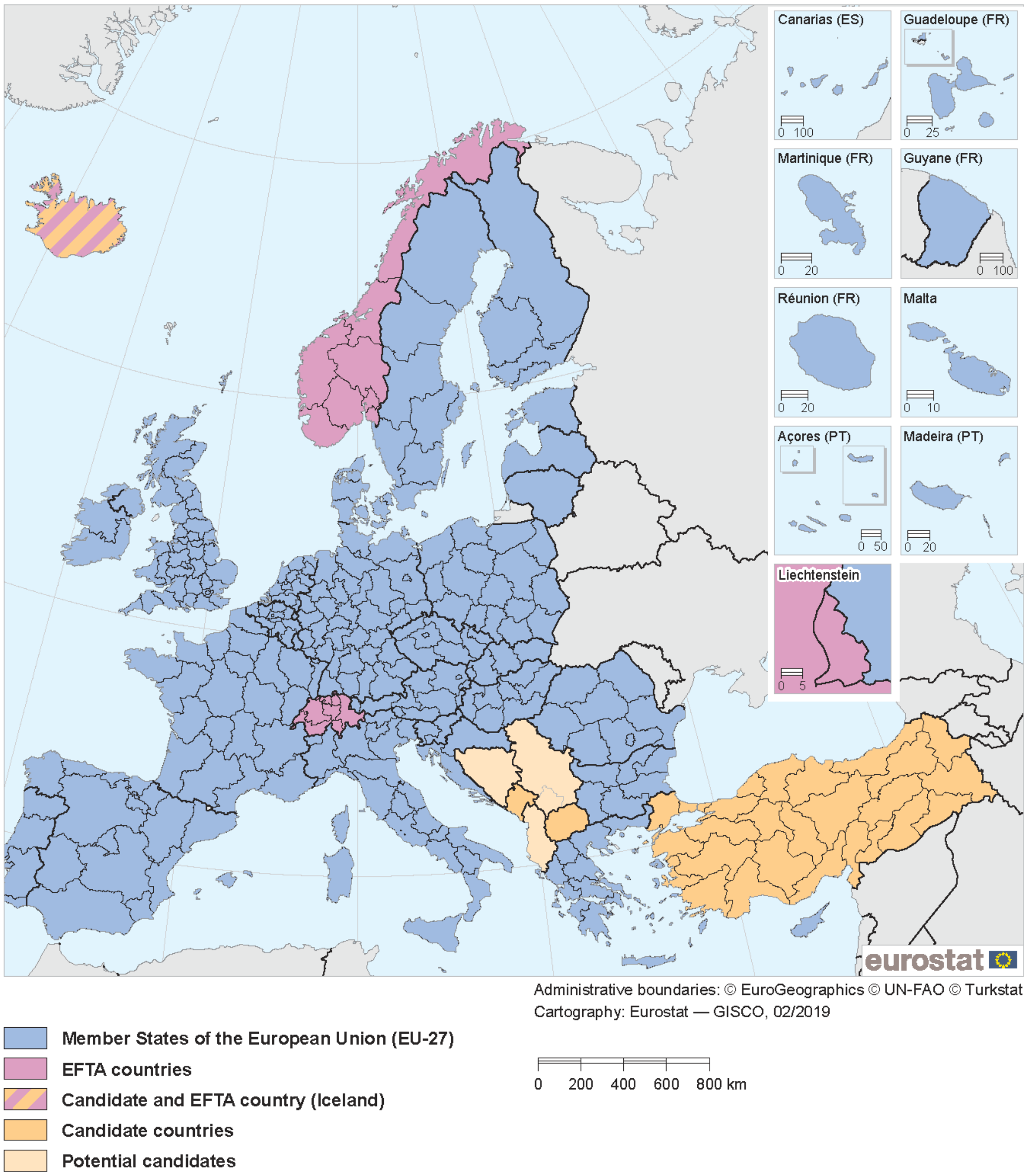
Table 3 shows information on R&D stocks across U.S. states in our sample.

Our technology sourcing variable for European region r in year t, $BizTravSource_{rt}$, is defined as follows:

[5]We follow Keller (2002a) and others in constructing R&D stocks using the perpetual inventory method; see the Appendix for details.

Figure 1: NUTS 2 Regions of Europe

NUTS 2 regions in the Member States of the European Union (EU-27) according to NUTS 2010, with corresponding statistical regions in EFTA countries, candidate countries and potential candidates



Note: Regions in the Member States of the European Union (EU-27) according to **NUTS 2010**. Statistical regions in EFTA countries, candidate countries and potential candidates according to latest available bilateral agreement. The designation of Kosovo is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo Declaration of Independence.
Iceland hold the status of a candidate country from 2009 – 2013.

Source: Eurostat, constructed with the Statistical Atlas tool.

Table 1: Business Travel from European Regions

Region Code	Region Name	Country	Average No. of Business Travelers
		Top 10 regions	
UKI	London	United Kingdom	528.00
FR10	Île de France	France	318.33
DE21	Oberbayern	Germany	180.67
DE71	Darmstadt	Germany	169.33
ITC4	Lombardia	Italy	167.00
SE11	Stockholm	Sweden	164.33
FI1B	Helsinki-Uusimaa	Finland	132.67
DK01	Hovedstaden	Denmark	132.33
AT13	Wien	Austria	127.67
ITI4	Lazio	Italy	125.33
		Bottom 10 regions	
FR21	Champagne-Ardenne (NUTS 2013)	France	0.33
ES22	Comunidad Foral de Navarra	Spain	0.33
HR03	Jadranska Hrvatska	Croatia	0.33
CZ03	Jihozápad	Czech Republic	0.33
ITI3	Marche	Italy	0.33
RO21	Nord-Est	Romania	0.33
RO11	Nord-Vest	Romania	0.33
BE32	Prov. Hainaut	Belgium	0.33
ITG2	Sardegna	Italy	0.33
BG33	Severoiztochen	Bulgaria	0.33

Notes: The table presents 1993-1995 average number of business travelers to the U.S. from a given European region.

Table 2: Business Travel to U.S. States

US State	Average Business Travel
Top 10 States	
California	851.00
New York	737.67
Florida	382.67
Illinois	296.00
District of Columbia	242.33
Massachusetts	218.67
Texas	216.00
Pennsylvania	137.67
Georgia	117.00
Washington	106.67
Bottom 10 States	
Idaho	9.00
Vermont	8.67
Alaska	6.33
West Virginia	6.33
Mississippi	5.33
Arkansas	4.67
Montana	4.67
Wyoming	4.67
North Dakota	2.33
South Dakota	1.67

Notes: The table presents 1993-1995 average number of business travelers from Europe to a given U.S. state.

Table 3: R&D Stocks by U.S. State

US State	Average R&D Stock
Top 10 States	
California	438592.40
Michigan	219919.40
New Jersey	164311.90
New York	150265.60
Massachusetts	115838.40
Texas	104518.10
Pennsylvania	95464.12
Illinois	92915.80
Washington	82840.97
Ohio	75043.61
Bottom 10 States	
Arkansas	2634.34
Louisiana	2455.46
Nebraska	2122.78
Mississippi	1426.38
Hawaii	875.10
North Dakota	850.25
Montana	763.72
Alaska	470.41
South Dakota	463.02
Wyoming	386.76

Notes: The table presents 1996-2010 average R&D stock of U.S. states (in constant $). We use 5% of depreciation rate to estimate the R&D stocks; New Mexico stock had negative R&D growth, stock not shown.

$$BizTravSource_{rt} = \sum_{s \epsilon S} B_{rs} \times RD_{st}, \forall r, t, \quad (1)$$

where RD_{st} is the R&D stock of U.S. state s in year t. Following Griffith, Harrison, and van Reenen (2006), in order to reduce endogeneity concerns we employ pre-sample weights in the construction of $BizTravSource_{rt}$: B_{rs} is defined as the average number of business travelers between European region r and U.S. state s over the years 1993 to 1995. The weighting with B_{rs} in this expression incorporates the idea that travelers flying to a state s where more R&D is performed may have a greater impact on European innovation than travelers that journey to a state s' where less R&D is performed because the former has more technology than the latter.

Innovation The dependent variable in our analysis is constructed from patent applications to the European Patent Office (EPO) of a given NUTS 2 region in the years 1996 to 2010 as recorded by the Eurostat. This data comes from the regional statistics database of Eurostat which provides data on patent applications by year and NUTS 2 region.[6] We focus on applications to the EPO since we are interested in understanding the impact of knowledge transfer on domestic innovation in European regions. Furthermore, by restricting the analysis to EPO patent applications we ensure that the innovations will pass the same quality standard and are comparable. The top ten and bottom ten European patenting regions are presented in Table 4, showing that there is a large amount of variation in regional patenting. In the regression analysis below we will focus on each region's share in all of Europe's patenting.

Other variables In addition to technology sourcing, a region's level of innovation may depend on the region's own level of R&D spending, and perhaps also on R&D at the country level, perhaps due to different innovation cycles at the country level. Therefore we control for regional (NUTS 2) and country level R&D (source: Eurostat, regional statistics database). The size and development level of each region may matter, among others, for its domestic technology absorptive capacity, and consequently we include data on GDP for each region. The data on GDP for each NUTS 2 region for the years 1996 to 2010 is from Cambridge Econometrics European Regional Database.

Summary statistics of the data are presented in Table 5. After combining the various sources of data, our baseline sample has 2,185 observations from 22 countries and 254 NUTS 2 regions. The countries included in the analysis are Austria, Belgium, Bulgaria, Czech Republic, Germany, Denmark, Greece, Spain, Finland, France, Croatia, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovakia, and United Kingdom. We have an unbalanced data set, due especially to missing R&D data; the influence of this will be examined below. The first

[6]We use the date of patent application compared to the grant date to ensure that the differences in processing times would not be a factor.

Table 4: Patenting in European Regions

Region Code	Region Name	Country	Average Patenting
		Top 10 regions	
FR10	Île de France	France	2934.51
DE11	Stuttgart	Germany	2429.28
DE21	Oberbayern	Germany	2379.15
NL41	Noord-Brabant	Netherlands	1652.08
DEA1	Düsseldorf	Germany	1445.32
DE71	Darmstadt	Germany	1444.44
FR71	Rhône-Alpes (NUTS 2013)	France	1330.39
DEA2	Köln	Germany	1287.44
ITC4	Lombardia	Italy	1286.57
DE12	Karlsruhe	Germany	1271.83
		Bottom 10 regions	
PT15	Algarve	Portugal	1.57
PL34	Podlaskie (NUTS 2013)	Poland	1.46
PL62	Warminsko-Mazurskie	Poland	1.32
RO22	Sud-Est	Romania	1.16
BG31	Severozapaden	Bulgaria	1.02
EL42	Notio Aigaio	Greece	1.00
BG34	Yugoiztochen	Bulgaria	0.81
RO31	Sud - Muntenia	Romania	0.76
PT20	Região Autónoma dos Açores	Portugal	0.75
PT30	Região Autónoma da Madeira	Portugal	0.64

Notes: The table presents 1996-2010 average patenting of European regions at the EPO.

Table 5: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Share of patenting (in %)	0.335	0.694	0.000	5.942
R&D-Weighted US Bus. Traveler	9.414	6.532	0.000	18.390
R&D (Region)	5.521	1.677	0.156	9.775
GDP (Region)	3.333	1.041	-0.293	6.331
R&D (Country)	8.904	1.625	4.230	11.113

Notes: Number of observations for all variables is 2,185. Share of patenting is each region's share of patenting in percent. R&D- Weighted US Bus. Traveler is U.S. business travel from each region weighted by the US destination state's R&D stock. Regional R&D, regional GDP and country R&D are in natural logarithms. Regional GDP is in billions of euro, while regional and country R&D are in millions of euro.

row of Table 5 shows each region's share of all European patents. On average, a region has a share of 0.3% of all European patenting, with some regions accounting for a substantially higher fraction.

The next three rows in Table 5 show descriptive statistics (in natural logarithms) on measures of regional R&D expenditures and regional GDP, as well as country level measure of R&D expenditures for each country where each region is located. The figures confirm that there is a substantial amount of heterogeneity across these regions.

The next section introduces our estimation framework.

3 Statistical Model

Our empirical specification is given by the following estimation equation

$$share\_pat_{rt} = \beta_1 BizTravSource_{rt} + \beta_2 RD_{rt} + \beta' \mathbf{X} + \omega_r + \tau_t + \varepsilon_{rt}, \tag{2}$$

where the dependent variable is $share\_pat_{rt}$ is the share of European region r in all European patenting of year t, and $BizTravSource_{rt}$ is the US state R&D-weighted sum of outward business travelers to the US from region r in year t defined in equation (1) above. Simply put, we seek to explain the composition of European patenting across regions by the composition of outward business travel to the United States.[7]

Another variable that may influence innovation is each region's own R&D effort, RD_{rt}, defined as region r's R&D stock in year t. The vector $\mathbf{X}$ includes region r's GDP in year t as a size control

[7]In the absence of differences in bilateral travel patterns to the US, $BizTravSource_{rt}$ would simply be equal to the sum of US state R&D, which would not be identified separately from time fixed effects.

and, in some regressions, other variables which may exert an influence on patenting.

As noted earlier, the business travel variable $BizTravSource_{rt}$ is constructed using pre-sample data for 1993-95 to reduce endogeneity concerns. We also include time fixed effect, τ_t, that captures common shocks, as well as regional fixed effects at the NUTS 2 level, ω_r; the latter addresses unobserved and observed time-invariant heterogeneity across regions. We assume that the error term ε_{rt} is well behaved and estimate the equation with OLS, allowing for dependence by employing clustered standard errors.

The inclusion of regional fixed effects in equation (2) means that identification comes solely from time-variation within each region. The coefficient of primary interest β_1 will be positive, providing evidence for technology sourcing through outward business travel, if regions whose outward US business travel grows or shifts towards more high-tech destinations typically account for a larger share of European patenting. European travel patterns to destinations other than the US may affect patenting; furthermore, based on existing evidence one would expect that regional trade and FDI patterns may matter as well. Due to the unavailability of suitable data, here we cannot explicitly address these points, and we assume that the influence of these factors are captured at least in part by regional R&D and GDP. Note that country-level changes of non-business travel factors will be addressed in the robustness analysis below by including country-by-year fixed effects; as we will see this does not much change the results.

4 Empirical Results

4.1 Main Results

Table 6 shows estimation results based on a number of different versions of equation (2) above. In order to show which determinants matter and which do less so, the baseline specification is developed step by step. We begin by including the business travel, technology sourcing variable only with a time trend; column (1) shows that the bilateral correlation between patent share and outward business travelers is positive and significant. Year fixed effects capture common shocks to these European regions, which may have become more common due to the introduction of a common currency, the Euro, in 1999. Replacing the trend with year fixed effects, we see that this does not have a major impact on this result (column (2)).

Regions located in different European countries are likely subject to shocks at the country level, such as national innovation policies. To capture these effects we introduce country fixed effects in column (3); the increase in R^2 indicates that country effects can account for some of the variation in patenting, however, the change in the point estimate for the sourcing variable is relatively small.

Next, we include each region's R&D, which is time-varying, together with regional fixed effects as controls for heterogeneity at the regional level (standard errors are now clustered at the region and year level, 254 regions and 15 years). The coefficient on regional R&D is positive, as expected, and the business traveler sourcing variable has now a coefficient of 4.6% (column (4)).

Accounting for changes in the size of the region, as measured by GDP, does not lead to major changes in our technology sourcing findings (column (5)). Furthermore, R&D at the country level has only a marginally positive coefficient (column (6)). Including country R&D reduces somewhat the size of the regional R&D coefficient, likely because of the positive correlation of the two. In contrast, the outward business travel coefficient increases somewhat to 5.1%, significant at standard levels.

Finally, a simple analysis of the economic magnitudes is provided by comparing standardized regression coefficients (or, beta coefficients), once each variable has been rescaled to have zero mean and a standard deviation of one. These coefficients are shown in column (7) in hard brackets. According to these results, outward business travel to the US is of great importance for the composition of European patenting. In particular, it is exceeding that of the region's own R&D spending (beta coefficients of 0.48 and 0.08, respectively). Of course, given the extent to which patenting and business travel is distributed across European regions the average effect does not necessarily apply to most regions. It is thus instructive to compare two particular European regions, for example the Stuttgart area in Germany and Portugal's Algarve region. Recall from Table 4 that in terms of patenting, the former is highly innovative compared to the latter. Based on our estimates in column (6), the higher sourcing benefit from US business travel for the Greater Stuttgart area accounts for almost 20% of the higher patenting in Stuttgart when compared to the Algarve region.

Overall, these results provide evidence that technology sourcing through business travel is an important channel of technology diffusion.

4.2 Robustness Checks

This section discusses a number of important robustness checks, see Table 7 for the results. The first column repeats the baseline finding from Table 1 (column (6)) for comparison. The next specification allows for arbitrary year-to-year changes in patenting at the country level by including country-by-year fixed effects. This leads to a moderate increase for the technology sourcing point estimate, and we conclude that our findings do not primarily reflect shocks at the country-year level.

Table 6: Basic Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable				Share of patenting			
R&D-Weighted	0.037**	0.036**	0.032**	0.046*	0.045**	0.051**	0.051**
US Bus. Traveler	(0.002)	(0.002)	(0.002)	(0.019)	(0.016)	(0.019)	(0.019)
							[0.478]
R&D (Region)				0.043**	0.038**	0.031**	0.031**
				(0.006)	(0.007)	(0.007)	(0.007)
							[0.075]
GDP (Region)					0.066*	0.041	0.041
					(0.027)	(0.030)	(0.034)
							[0.061]
R&D (Country)						0.024+	0.024+
						(0.013)	(0.013)
							[0.056]
Trend	Yes	No	No	No	No	No	No
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	No	No	No	No
Region FE	No	No	No	Yes	Yes	Yes	Yes
Observations	2,185	2,185	2,185	2,185	2,185	2,185	2,185
R-squared	0.129	0.142	0.300	0.988	0.988	0.988	0.988

Notes: Dependent variable is region's share of patenting, in percent. Estimation by least squares. All independent variables enter in logs. Bootstrapped standard errors in parentheses; robust in columns (1) to (3), two-way clustered on region and year in columns (4) to (7). ** p<0.01, * p<0.05, + p<0.1. Standardized coefficients in column (7) in square brackets.

Table 7: Robustness Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable				Share of patenting				
R&D-Weighted Business Traveler	0.051**	0.058+	0.056**	0.080**	0.059**	0.059**	0.062**	0.061**
	(0.018)	(0.034)	(0.015)	(0.018)	(0.020)	(0.016)	(0.018)	(0.019)
Business Travel* Late Period						-0.000	0.001	0.002+
						(0.001)	(0.001)	(0.001)
R&D (Region)	0.031**	0.032**	0.026**	0.054**	0.057**	0.031**	0.051**	0.070**
	(0.006)	(0.011)	(0.006)	(0.010)	(0.018)	(0.008)	(0.011)	(0.015)
R&D (Region)* Late Period							-0.017	-0.011
							(0.010)	(0.007)
GDP (Region)* Late Period							0.006	0.010
							(0.014)	(0.011)
R&D (Country)* Late Period							0.004	0.008*
							(0.003)	(0.004)
GDP (Region)	0.041	0.047	0.023	0.004	0.041	0.041		
	(0.036)	(0.092)	(0.026)	(0.036)	(0.051)	(0.035)		
GDP (Country)	0.024+	-0.007	0.020	0.013	0.016	0.023+		
	(0.013)	(0.064)	(0.013)	(0.019)	(0.028)	(0.013)		
Country*Year FE		Yes						
Excluding Germany			Yes					
11 Years of data per region				Yes				Yes
Business travel positive					Yes			
Observations	2,185	2,185	1,981	1,118	1,504	2,185	2,185	1,118
R-squared	0.019	0.084	0.017	0.039	0.988	0.019	0.022	0.045

Notes: Dependent variable is region's share of patenting, in percent. Estimation by least squares. All columns include region and year fixed effects. All independent variables enter in logs. Bootstrapped two-way clustered standard errors on region and year in all columns. ** p<0.01, * p<0.05, + p<0.1.

The next three specifications explore robustness of the results with respect to sample composition. First, Germany is Europe's biggest economy, and we have seen above that German regions account for a substantial portion of all patenting in Europe. Dropping German regions from the sample, however, does not lead to a major change in the technology sourcing coefficient (see column (3)). Furthermore, as noted above there is no patent and R&D data for some of the regions annually during our sample period. To understand the influence of the regions' entry and exit from the sample for the results we examine a more balanced sample with eleven or more observations per NUTS 2 region. As seen from column (4), the business traveler-sourcing coefficient is now higher, at about 8%. It is reassuring that we estimate a positive coefficient with the more balanced sample, because it suggests that the entry and exit from the sample mainly generates noise that is weakening the estimated relationship between US business travel and regional patenting.

In a final check on sample composition we focus on observations with strictly positive levels of technology sourcing. This sheds light on whether our findings are mostly driven by European regions from which business travelers to the US are originating, versus those regions where this is not the case. The results in column (5) indicate that this is not the case.

The following specifications examine whether the technology sourcing effect associated with outward business travel has become weaker or stronger over time. First, we introduce an interaction between $BizTravSource_{rt}$ and an indicator for years after 2002. As shown in column (6), this interaction is not significant at standard levels. This finding does not change when we introduce additional post-2002 interactions for regional R&D, regional GDP, and country-level R&D (column (7)). Finally, the last column in Table 7 shows that the finding of no major change in the relationship between technology sourcing through business travel over time largely holds as well for the sub-sample for which we have at least eleven observations per region. This suggests that technology sourcing through business travel is not an important reason why international technology diffusion has increased over time (as shown in Keller 2002b).

Overall, we find evidence for a statistically and economically significant relationship between business travel to the US and European patenting.

5 Conclusions

The results of this paper suggest for developing countries seeking to catch-up to foreign technology, that in-person meetings in the U.S. are essential to capture tacit knowledge. This paper goes hand-in-hand with Hovhannisyan and Keller (2015) that shows business travel by U.S. travelers carry the non-codified knowledge overseas as well. Together, the papers provide consistent support for the importance of face-to-face meetings for international technology diffusion.

Using European regional data of U.S.-bound business-travelers from 1993-1995 and regional patent data for 1996-2010, this paper finds evidence that patenting in a region rises as the number of business travelers to the U.S. increase, even after controlling for a set of other regional and country variables that could affect a region's innovation. These results remain robust after adding country-by-year fixed effects, dropping German regions from the sample, and after narrowing the sample to those countries for which we have, or close to, annual data.

The effects are also economically significant. Twenty percent of the difference in patenting between the Greater Stuttgart area --one of the regions with the highest average outward business travelers to the U.S.-- and the Algarve region in Portugal can be explained by Stuttgart's high level of in-person business conducted in the United States.

However, we caution the reader that our results are limited in a few ways by a lack of suitable data. First, the paper is missing non-US destination travel patterns which could systematically affect the results. Second, regional trade and FDI patterns may also have an effect on regional patenting. These unobserved variables will be captured in part by the included regional R&D and GDP variables however, it would be useful to re-examine our findings once suitable regional data on trade and FDI is available.

The evidence in this paper provides support for the notion that some technological knowledge can not be expressed in written form. This paper is also relevant to recent claims that China is "stealing technology" because the results suggest that merely having blueprints is not enough to implement technology effectively.[8] Rather, China's technological improvements --the evidence suggests--is coming from face-to-face interactions between US and Chinese engineers associated with FDI and other international transactions involving the meeting of domestic and foreign nationals.

[8] https://www.forbes.com/sites/charleswallace1/2019/01/30/intelligence-chiefs-back-trump-on-chinese-technology-theft/

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Appendix

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

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 European residents traveling to the United States in the period of 1993-1995. Although the data on 1993-2003 is available, we only use data for the pre-period 1993-1995 to reduce endogeneity concerns. Information on travel comes from an individual-level database which has information on traveler's European city of residence, main purpose of the trip, secondary purposes of the trip, main destination US counties, secondary destination US counties, and quarter and year of travel. Data is aggregated up to US destination states, and both main destination and secondary destination states are coded. Individual observations are expanded if a particular individual traveled to distinct destination states, 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 for business purposes are aggregated by European city of residence and destination US state. After matching European city of residence to NUTS 2 regions (see below), business travel data is constructed, B_{rs}, as the average number of business travelers between European region r and U.S. state s over the years 1993 to 1995.

Eurostat data and NUTS classification

European cities are matched to NUTS 3 2010 classification regions based on this source file:

https://ec.europa.eu/eurostat/documents/Ttypologies and local information corresponding to NUTS3.xls.

Further, NUTS 3 regions are aggregated up to NUTS 2 regions. Eurostat constantly revises the NUTS classication, however, data on regional patenting and R&D and country R&D from Eurostat were presented in either NUTS 2010 or 2013 classification. All inconsistencies were manually checked and corrected based on documentation from Eurostat available at

https://ec.europa.eu/eurostat/web/nuts/history.

US R&D stocks

R&D expenditures by U.S. states during years 1996 to 2007 were available from the NSF's Survey of Industrial Research and Development (SIRD), while data for the years 2008 to 2010 were obtained from NSF's Business Research and Development and Innovation Survey (BRDIS). In the years 1991 to 1997 data was collected only in odd years, therefore data on R&D for the year 1996 was linearly interpolated.

Using R&D expenditures data from 1996-2014, R&D capital stocks (S) which are defined as beginning of period stocks, were constructed from R&D expenditures (R) based on the perpetual inventory model, $S_t = (1-\delta)S_{t-1} + R_{t-1}$, where δ is the depreciation or obsolescence rate, which is assumed to be 5 percent. The benchmark stock of R&D is calculated as $S_0 = R_0/(g+\delta)$, where g is the average annual logarithmic growth of R&D expenditures over this period, and R_0 is the first year in which data was available for all states. The data for R&D expenditures was available from 1991, however several states had missing observations during the years of 1991-1995, therefore 1996 is chosen as the first year. Finally, RD_{st}, is obtained as the R&D stock for each state s and each year t for the years 1996-2010, which is used for the construction of our technology sourcing variable.

Patent data

Patent applications to the European Patent Office (EPO) by priority year and NUTS classification in the period of 1996 to 2010 were obtained from the Eurostat's regional statistics database. Priority date corresponds to the first filing worldwide and is the closest to the invention date. Therefore priority date in the text is referred to as the application date. We use patent applications to the EPO by each NUTS 2 European region and application year for the years 1996 to 2010. Although Eurostat provides data by European NUTS regions for up to year 2012, we only use data up to 2010 as data on 2011 and 2012 data was incomplete. This is a common occurrence with patent data as the last several years in the patent datasets are prone to truncation issues.

According to Eurostat documentation, regional patent data is assigned based on inventor's place of residence. This approach allows measuring the inventive capacity of each region. For applications with multiple inventors, the patent is divided equally among all of the inventors resulting in fractional counting and thus avoiding double counting. Finally, the dependent variable in our analysis $share\_pat_{rt}$ is constructed as the share of each European NUTS 2 region r in all European patenting of year t.