The Effect of Communication Costs on Trade in Headquarter Services*

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Abstract

Communication is a real barrier to organizing international production as it hinders knowledge transmission. This paper provides evidence to suggest that a way in which multinational firms economize on costly information transfers is by using skilled foreign workers, since local talent can substitute for knowledge inputs from the headquarters. Combining U.S. data on headquarter service exports with information on communication costs and skill endowments by country, I find that while communication costs decrease the export of headquarter services to foreign affiliates, the effect becomes weaker in the average educational attainment of foreign workers. The sensitivity of headquarter service exports to communication barriers at low levels of skill endowment has important implications for the geography of multinational production, as well as for policies aimed at improving communication infrastructure.

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Keywords: headquarter services; services trade; intra-firm trade; communication costs; telecommunication; knowledge transfers

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1 Introduction

Developments in communication and transportation technologies are often cited as the catalyst for global production networks.[1] Increasingly, firms establish new facilities in foreign markets or relocate divisions of their production chain abroad. But as production networks expand across national borders, multinational corporations (MNC) must account for new costs arising from managing, coordinating and monitoring foreign operations. Information transmission costs represent such an example.

Recent evidence on the sensitivity of foreign investments to geographic distance suggests that MNCs respond to the cost of transferring intangible assets when making location decisions.[2] Yet less is known about the ways in which parent firms can minimize the cost of knowledge transfers to distant affiliates. How do MNCs organize foreign production operations in the presence of costly communication? One possibility is to transfer complex technologies embodied in intermediate inputs in order to avoid communicating them directly (Keller and Yeaple, 2013).[3]

In this paper, I examine empirically an alternative channel through which multinational firms economize on the cost of cross-border knowledge transfers: by hiring skilled workers to execute the assigned activities. A well-trained production team substantially reduces the interventions by the headquarters in the ordinary production problems of that foreign affiliate. The implicit tradeoff comes from the fact that high ability workers are relatively more expensive, so paying the skill premium becomes optimal only when the savings from monitoring efforts and cross-border communication outweigh the costs with skilled labor. The goal of this paper is to test this hypothesis and investigate the extent to which knowledge transfers within multinational firms respond to communication barriers in a way that is systematically related to foreign workers' ability level.

The insight that the availability of talent in the foreign market substitutes for the knowledge inputs provided by the headquarters, saving on frequent communication, has been emphasized in theoretical models of firm organization (Antras et al., 2006; Grossman, 2013). However, the empirical work in support of it is sparse. We know little about how communication barriers interact with the skill endowment of host countries in determining the production activity of multinational firms. The goal of this paper is to fill this gap in the literature.

To quantify the involvement of the headquarters in the production operations of foreign affiliates through the provision of knowledge inputs and other intangible assets, I use aggregate

[1] A key assumption in models of foreign direct investment (FDI) is that firms are able to transfer their technologies abroad. However, technology diffusion is costly. Its success depends on the effectiveness of information transmission (Arrow, 1969; Teece, 1977). So, developments in communication technologies have definitely facilitated the expansion of multinational firms (di Giovanni, 2005). Additional insights are provided by Hummels et al. (2001), who bring evidence on the significant growth in vertical production networks over the last few decades, prompting conjectures about the role of developments in transportation and communication technologies as likely explanations.

[2] Yeaple (2009) provides intriguing evidence on the decrease in total affiliate sales with distance from their U.S. headquarters. Keller and Yeaple (2013) and Irarrazabal et al. (2013) rationalize this by the increased cost at which headquarter knowledge and services are available for distant affiliates. Head and Ries (2008) cite monitoring costs as frictions that inhibit cross-border ownership over distance.

[3] Keller and Yeaple (2013) find that knowledge intensive inputs are more likely to be produced by parent firms and shipped to foreign affiliates to avoid the inefficiencies resulting from transferring know-how from person to person. This has direct implications for the type of activities relocated abroad, with routine tasks being more likely to be offshored relative to complex tasks (Oldensky, 2012; Liu et al., 2011).

data on related-party exports of services by parents of U.S. multinationals. Headquarter services are particularly appealing to analyze empirically. Services are the fastest growing component of world trade, accounting for 20% of international transactions by value, and multinational firms play a large role in their growth. For example, in the U.S., almost 40% of services trade happens within the boundaries of multinational firms (Bureau of Economic Analysis, 2010). However, in spite of this observed growth, services face significant trade barriers. As intangible, knowledge-intensive activities, the cost of information transmission represents a large barrier to their trade. So, understanding the extent to which foreign assets such as workers' skills represent a substitute for headquarter services is important because it sheds light on the strategies employed by MNCs to mitigate the impact of communication costs. It also raises important policy debates about the role of infrastructure spending aimed at reducing communication costs – particularly in the context of developing countries, where human capital accumulation is achieved at a relatively slower pace.

For the econometric analysis, I combine public data on service exports by parents of U.S. multinationals to their foreign affiliates, with information on international communication costs, and with data on the average educational attainment of the labor force in foreign countries. The resulting dataset covers 32 countries over the period 1993-2008. I estimate an econometric model of intra-firm services trade adapted from the knowledge-capital model of FDI (Markusen, 2002). I find that while difficulties in cross-border communication affect negatively the export of headquarter services by U.S. multinationals relative to the total U.S. exports of service, this reduction in the fraction of intra-firm service exports is attenuated by the average education level of the workforce in the host country. The opposing effect of the interaction term between communication and skill level points to the substitution between the knowledge held by the foreign workers and the knowledge inputs transferred from the firm headquarters. This evidence brings support to the insight that an efficient way to organize multinational production across locations linked by costly or inefficient communication networks is to hire talented workers who are able to carry out production activities with very little supervision. These findings are robust to controlling for typical determinants of FDI such as economic size and bilateral trade costs, policies of economic integration, or differences in corporate tax rates.

This study contributes to the international trade literature in several ways. First, it adds to the limited research analyzing the determinants of services trade. Although the recent growth in services trade has been unexpected by economists (Blinder, 2006), and has brought challenges to policy makers (Economic Report of the President, 2004)[4], services remain overlooked in the international trade literature.[5] This study mitigates this shortage by shedding light on some of the factors that affect trade in headquarter services.

Second, this paper adds to the recent empirical work examining the organization and growth

[4]Some of the challenges highlighted in the Presidential Report involve the "painful" employment transition from the shrinking manufacturing sector to the growing service sector, the policy efforts towards liberalizing services trade, and the assessment of the costs and benefits of growing offshore outsourcing.

[5]The quality and availability of data have limited the number of studies that investigate the impact of barriers to services trade. Freund and Weinhold (2004) were among the first to focus on the role of Internet in facilitating services trade. Using richer data, Head et al. (2009) identify large and significant effects of distance, language similarity or colonial ties on the volume of business services trade.

of multinational production in face of barriers to information transmission (Keller and Yeaple, 2013; Oldensky, 2012; Liu et al., 2011). The closest papers to this one are Antras et al. (2006, 2008), who model multinational production as resulting from the efficient organization of knowledge flows in the presence of heterogeneous workers. In their empirical work, Antras et al. (2008) provide first evidence that the positive effect of a country's skill endowment on inbound FDI flows decreases in the development of intra-national communication technology. This paper takes the theoretical foundations in Antras et al. (2006) and complements the empirical work in Antras et al. (2008) in several ways: 1) by focusing on intra-firm export of services rather than total FDI flows in order to capture more directly the extent of headquarters' involvement in the production operations of foreign affiliates; 2) by using measures of cross-border rather than intra-national communication barriers; and 3) by exploiting panel rather than cross-sectional data, which allows the use of fixed effects to control for unobservable country-specific factors. Ultimately, understanding how communication barriers affect the organization of production is important, since part of the success of global production networks stems from managing knowledge flows efficiently. The findings here could also provide policy makers in less skill endowed countries with the necessary tools to support developments in communication infrastructure as a way to increase foreign investments.

Lastly, this paper is related to the recent work on the role and determinants of intra-firm trade.[6] Of particular interest for this study is the work of Irarrazabal et al. (2013), who emphasize two conditions necessary to rationalize the decline of multinational activity over distance: 1) affiliate production relies on headquarter inputs, which implicitly generates intra-firm trade; and, 2) intra-firm trade is subject to geographic frictions. Rodriguez-Clare et al. (2012) also build a model of multinational production where intra-firm transfers of intangible assets occur with a loss in their efficiency.

The rest of the paper is structured as follows. The next section describes the theoretical set-up based on Antras et al. (2006), which motivates the interdependence between communication costs and average skill level of the foreign labor force in determining the exports of headquarter services. Section 3 presents the estimation strategy, while the data sources are provided in Section 4. Section 5 discusses the estimation results, including the robustness checks. Section 6 concludes.

2 Theoretical Hypothesis

The empirical analysis of this paper is motivated by Antras et al. (2006). In this section I will describe a key insight of their model in order to provide intuition for the hypothesis that I will examine in the data. The main aim is to guide the econometric exercises and the interpretation of the results (rather than derive hypotheses for a direct test of their theory).

In their framework, Antras et al. (2006) assume a world of heterogeneous agents who are endowed with knowledge, defined by their skill level z, and with one unit of time. Production requires both knowledge and physical inputs supplied through labor effort. An effective way to

[6] Empirical papers on the determinants of intra-firm trade include, among others, Bernard et al. (2010) and Corcos et al. (2013). Neither of these studies focus on communication costs.

generate economic activity in this environment of skill heterogeneity and time constraints is by organizing agents into teams formed by a manager of skill z_m and n production workers of skill z_p, with $z_p \leq z_m$. This way workers allocate their time towards producing goods, while the more talented manager uses her time to oversee and provide knowledge inputs to workers whenever they encounter problems that need to be resolved before production gets finalized.

By choice of units, the skill level of an agent reflects the fraction of tasks she can successfully accomplish out of all the tasks involved in the production of the final good. To be precise, a worker of skill z_p knows the solution to a fraction z_p of all the problems that may arise during the production process. For any unresolved problem, the worker can ask the manager for solutions. Knowledge transmission is costly in terms of manager's time. The manager communicates with a worker at cost h expressed in time units, with $0 < h < 1$. If the manager has a solution to the problems brought up, which happens for a fraction z_m of all possible problems, then the worker is able to continue and complete production. If the manager does not have an answer to the problems raised, which happens with probability 1-z_m, then production for that unit fails and labor efforts are wasted.

A key insight from this set-up is that the size of the production team handled by a manager is determined by the amount of time the manager devotes per worker and by the level of communication cost. Since a worker needs guidance for a fraction $(1 - z_p)$ of the problems encountered, and the unit cost of knowledge transmission expressed in units of time is h, then the time constraint faced by a manager leading a team of n workers can be written as:

$$h(1 - z_p)n = 1 \tag{1}$$

The appealing feature of equation (1) is the embedded tradeoff between the skill level of the production workers and the size of the production team at a given level of communication cost h. Skilled workers economize on the need for knowledge transfers, and more broadly on the need for coordination and monitoring, allowing the manager to expand her span of control. This insight is especially valuable when production takes place at large distances, case in which coordination and communication are more difficult.

Output results from combining the labor efforts supplied by the n workers with the managerial talent given by the knowledge level z_m. With the information received from the manager, each worker of skill z_p can now solve z_m fraction of problems, which defines her output per unit of time. Taking the skill level z_p as a measure of workers' productivity, one can interpret communication as a costly technology that augments labor productivity. The total production realized by a team of size n of z_p workers is then given by:

$$y(z_m, z_p) = z_m \cdot n(z_p) \tag{2}$$

Any profit obtained by the firm compensates the manager for her talent. Normalizing the price of the (homogenous) final good produced, and letting $w(z_p)$ denote the equilibrium wage for

workers of skill z_p, the manager's rent is given by:

$$R(z_m) = \big(z_m - w(z_p)\big)n(z_p) = \frac{z_m - w(z_p)}{h(1 - z_p)} \tag{3}$$

where the second equality is obtained after substituting for $n(z_p)$ using equation (1).

Equation (3) shows an important outcome of the model: the complementarity between the skill of the manager, z_m, and that of its production team, z_p. More able workers already know how to solve many of the production problems they encounter. They need intervention only in exceptional cases, which is when the manger's expertise gets solicited. Therefore, the manager's skill must be above that of its production workers, otherwise matching and team production become unnecessary.

Managers maximize the rent in equation (3) subject to their time constraint in equation (1). This leads to the following differential equation for worker wages:

$$w'(z_p) = \frac{z_m - w(z_p)}{1 - z_p} \tag{4}$$

Each agent of skill z maximizes income $\{R(z), w(z)\}$, and, in doing so, makes an occupational choice decision. Letting z^* denote the marginal skill level of the agent who is indifferent between becoming a worker or a manager, then z^* solves the equation $\mathrm{R}(z^*) = \mathrm{w}(z^*)$.

In equilibrium, the labor market must clear and all workers in the economy must be matched to managers. Letting *m(z)* define the ability of the manager of a worker with skill level z, the labor market clearing condition can be written as:

$$\int_0^{z_p} g(z)dz = \int_{m(0)}^{m(z_p)} n(m^{-1}(z))g(z)dz, \qquad \text{for all} \quad z_p \leq z^* \tag{5}$$

where the left hand side of the equation measures the supply of production workers, while the right hand side captures the demand for production workers coming from the available managers. Deriving this condition with respect to z_p, one can solve the resulting differential equation to get the equilibrium assignment function *m(z)*.[7]

Antras et al. (2006) provide a complete characterization of the model equilibrium, which is defined by an assignment function of workers z to managers $m(z)$ (i.e., team formation process), an occupational choice decision characterized by z^*, a wage function $w(z)$ and a managerial rent function R(z). In the interest of brevity, and given the empirical focus of this paper, I omit the characterization of the equilibrium and refer the interested readers to their paper. Though an important point worth emphasizing here is that, in equilibrium, both the assignment function $m(z)$, and the wage function $w(z)$ depend on the level of communication costs h and on the distribution of skills. To see that, notice that the demand for workers in equation (5) is derived from the number of workers per production team integrated over the range of managers' skills. However, the level

[7]The two boundary conditions necessary for solving the equation follow directly from the positive sorting condition and are given by: $m(0) = z^*$, and $m(z^*) = 1$. In addition, continuity in the assignment function must be ensured, so that the wage function is differentiable over all skill levels $z < z^*$.

of communication costs has a direct influence on the size of the production team (equation (1)). Once the assignment function $m(z)$ becomes a function of h and of the parameters of the skill distribution, it follows from equation (4) that the wage function $w(z)$ will also depend on these parameters.

When communication costs are large, hiring more skilled workers is an alternative managers may consider as a way to alleviate the burden of costly information transmission. However, managers' sensitivity to changes in communication costs also depends on the availability of skilled workers in the economy. At a low average skill level, costly information transmission is more of a concern as workers are not very productive on their own without managers' intervention. Denoting by α the average skill level in the economy, it can be shown that $\frac{\delta m(z)}{\delta h} < 0$ (for values of z below a certain threshold), and that $\frac{\delta m(z)}{\delta h \delta \alpha} > 0$.[8] It is this insight of the model that I will investigate in the empirical part of the paper. The goal is to understand the extent to which the availability of skilled labor in the foreign market can act as a substitute for knowledge inputs from the headquarters when information transmission is costly.

An empirical complication comes from the use of aggregate data. This requires paying additional attention to the implications of the scale effects of FDI for the model predictions regarding skill composition. I defer that discussion to the empirical strategy section.

2.1 Offshoring and Multinational Production

The production problem just described can be embedded in a two country framework, where one of the countries, e.g., the North, is endowed with relatively more skilled labor than the other country, e.g., the South. In this context, managers can form teams with agents from the same country (i.e, domestic teams), or from the foreign country (i.e, cross-border teams). As shown in Antras et al. (2006), offshoring arises in this setting as a result of cross-border team formation. The positive sorting of managers and workers illustrated by equation (3) ensures that the best managers match with the most skilled production workers available anywhere in the world.[9] As there are more managers in the North and each manager seeks to attract the more skilled foreign workers before hiring the less skilled domestic workers, in equilibrium there is always going to be cross-border team production.[10] The output produced by the international production teams captures the size of the multinational activity, while the value of the knowledge inputs provided by the headquarters

[8] In Antras et al. (2006), equation (4) on page 41 provides the solution to the assignment function: $m(z) = z^* + hz(1 - \frac{1}{2}z)$, with the cutoff skill level $z^* = \frac{1+h-\sqrt{1+h^2+2h(1-\alpha)}}{h}$. After some algebra, it can be shown that $\frac{\delta m(z)}{\delta h} < 0$ for low values of z, and that $\frac{\delta m(z)}{\delta h \delta \alpha} > 0$.

[9] A simplifying assumption in Antras et al. (2006) is that the communication cost h is the same for domestic and international teams, which explains why managers seek to attract the best workers irrespective of the location. This may seem restrictive given the paper's empirical focus. However, since the variation exploited in the data analysis is within country over time, to the extent that cross-border communication costs co-vary with intra-national infrastructure improvements, then this simplifying assumption is not inconsistent with the empirical analysis. Another aspect omitted from the theory but present in the data is the fact that in a multi-country world, the communication cost h also differs across destinations, raising the issue of foreign location decisions. However, since many factors outside the model are first-order determinants of location choices across destinations, in the empirical analysis I take the presence of U.S. multinationals across countries as given, and only focus on how communication costs and foreign skill levels contribute in explaining the extent of headquarters' involvement in affiliates' activities.

[10] This is true as long as there are cross-country differences in the distribution of skill.

(i.e., headquarter services) represents a measure of offshoring, as defined from the perspective of the Southern country.

The interest of this paper is to examine how the communication cost affects the cross-border team formation, and more exactly, how its interaction with the average skill level in the foreign country influences the value of service offshoring and the size of multinational production. More exactly, building on Antras et al. (2006, 2008), the goal for the empirical analysis is to investigate the following hypothesis:

Offshoring and multinational production fall in communication costs. However the rate at which offshoring and multinational production decrease is slower the higher the average skill level of workers in the foreign country.

The intuition behind this hypothesis can be explained as follows. An increase in communication costs measured in units of time spent solving one worker problem has a direct negative impact on the number of workers a manager can handle, i.e., on the size n of the production team (see equation (1)). With fewer workers assigned per manager, the only way the labor market can clear in equilibrium is if there are more managers to form production teams with the unmatched workers. This raises the demand for managers in both countries and puts an upward pressure on the managerial rent that the marginal workers could earn, triggering a switch of the highest skilled workers into becoming managers. When the average skill level of the agents in the South is high, the equilibrium occupational cutoff separating workers from managers happens at a higher ability level.[11] So, the marginal workers who become managers are quite skilled (i.e., higher z), which implies that by the positive sorting rule (equation (3)), the new managers are able to attract more capable workers and establish larger production teams as compared to the case when the average skill level in the South is low. As a consequence, the initial supply of unmatched workers clears with fewer switches of workers into managers. The slower rate of occupational switching also implies smaller changes in the labor pool, e.g., a smaller reduction in the number and average skill level of the remaining workers. This means that the skill level and size of multinational production teams do not change as much due to the increase in communication cost, explaining the attenuation effect provided by the availability of foreign skilled workers on the negative impact of communication costs on multinational activity. Put differently, costly communication is not such a big deterrent to foreign investments when the foreign workers available for hire are skilled.

3 Empirical Specification

The goal is to investigate empirically the prediction that high cross-border communication costs affect multinational production negatively, and that the magnitude of this elasticity varies in a systematic way with the average skill level of the foreign labor force.

[11] In Antras et al. (2006), each agent maximizes income and in doing so makes an occupational choice decision. So, there is a marginal skill level z^* corresponding to the agent who is indifferent between becoming a worker or a manager, which solves the equation $\mathrm{R}(z^*) = \mathrm{w}(z^*)$. The skill level z^* defines the equilibrium occupational cutoff.

Given the theory-motivated focus on cross-border team production, the outcome variable to be examined should capture the involvement of the headquarters in the production activities of foreign affiliates. This is because the knowledge provided by the top managers is the input primarily affected by changes in communication costs or by changes in the average skill of the foreign labor force. Thus, I use information on the volume of intra-firm exports of headquarter services undertaken by U.S. multinational firms.

The estimation strategy is based on the knowledge-capital model of the multinational enterprise (Markusen, 2002), a popular framework for examining FDI flows that combines traditional gravity variables with factor endowments and international policy indicators.[12] I normalize the value of headquarter service exports by the total volume of service exports so that any unobservable factors that affect bilateral services trade in the same way irrespective of the nature and transaction type of these services (i.e., intra-firm versus arm's length trade) get removed from the regression. By focusing on service trade *shares* rather than *levels*, I minimize the incidence of spurious correlation. In the end, I arrive at the following regression specification:

$$\begin{aligned}\ln\frac{HQServExport_{jt}}{TotalServExport_{jt}} = (\beta_1 + \beta_2 \ln Skill_{jt}) \times \ln CommunicCost_{jt} + \beta_3 \ln Skill_{jt} + \\ + \beta_4 \ln Pop_{jt} + \beta_5 lnPcGDP_{jt} + \beta_6 ln(K/L)_{jt} + \beta_7 TCost_{jt} + \\ + \beta_8 \ln MktPotent_{jt} + \beta_9 Policy_{jt} + \alpha_t + \epsilon_{jt}\end{aligned} \tag{6}$$

where j indexes the foreign trade partner, t indexes the years, and α_t denotes the year fixed effects.[13] The exporting country index is suppressed because of the use of U.S. exports data in the empirical analysis. The regression coefficients β capture the *net* effect of the explanatory variables on the export of headquarter services *relative* to the total export volume of services. Therefore, the sign, the magnitude and the statistical significance of β coefficients should not be confounded with a level effect on the exports of headquarter services.

HQServExport measures the value of intra-firm exports of "other private services" undertaken by parents of U.S. multinational firms to their foreign affiliates located in country j.[14] The knowl-

[12] It is useful to note that a log-additive version of Markusen (2002) knowledge capital model, estimated in its linear form by Carr et al. (2001) and Blonigen et al. (2003), boils down to the set of exogenous variables included as controls in the regression specification estimated in this paper. Three features of my data sample make the non-linearities in the knowledge-capital model be almost entirely captured by distinct, log-linear host country variables: 1). the estimation sample uses only U.S. outbound FDI data, so the U.S. is the parent country in all bilateral pairs; (2). the estimation strategy controls for year and country-pair fixed effects, which means that any non-log-linear parent-host variable gets identified only from country j specific deviations from U.S. trends; (3). in the limited set of countries that make the estimation sample (see Appendix Table A1), the U.S. is the largest and most skilled abundant country (see Appendix Figure A1), which means that any constructed variables combining parent and host country data are in effect monotonic transformations of the host country data.

[13] The empirical literature on the boundaries of the multinational firms uses the fraction of intra-firm trade in total trade as a measure of the extent of vertical integration (see, for example, Antras (2003) and Yeaple (2006) among others). In spite of the common dependent variable to be explained, the interest of my econometric analysis is quite distinct from the research questions pursued in this literature, which focus on the trade-off between outsourcing and vertical integration.

[14] The category "other private services" consists of all private services other than travel, passenger fares, other transportation, and royalties and license fees. The largest service activities represented in this category are "business, professional and technical" services. Due to confidentiality reasons, data on related-party trade is not available for either subcategory of other private services.

edge intensive nature of the services typically traded within the boundaries of the firm make them a good proxy for the amount of information transmission that takes place cross-border between agents in integrated production teams.

The variable of interest, *CommunicCost*, denotes the cost of international communication between the headquarter and the host country. In the empirical analysis I use telecommunication data – the telephone rates charged per minute of phone call to country j – to measure communication costs. In robustness exercises, I also use data on other modes of communication such as the Internet or face-to-face communication, as measured by air travel flows. The theory framework formalizes the mechanism through which the cost of information transmission affects negatively the size of the production team (i.e., span of control), decreasing the aggregate volume of communication between managers and foreign production workers, as well as the total output produced by the foreign affiliates. In terms of the regression model, this implies that $\beta_1 < 0$.[15] In addition to the model predictions, there may be other channels outside of this framework through which communication costs affect the volume of intra-firm services trade – directly or indirectly, though an impact on the level of FDI (see, for example, Defever, 2012; Gumpert, 2014). These alternative channels linking communication costs to intra-firm trade and FDI are also going to be captured by the estimate β_1.

The key variable for the purpose of this paper is the interaction term between educational attainment (*Skill*) and the cost of knowledge transmission (*CommunicCost*).[16] The theory predicts that high barriers in communication must suppress the export of headquarter services even more when no skilled workers are available in the foreign market to mitigate the need for substantial cross-border knowledge transmission. Thus, the interaction term $Skill \times CommunicCost$ identifies the extent to which the average skill level of the workers in a foreign country acts as a substitute for knowledge inputs from the headquarters, alleviating the burden of costly information transmission. Following this intuition, I expect $\beta_2 > 0$. This effect is going to be the main coefficient of interest in the estimation exercises. It is worth mentioning here that β_2 should not be interpreted as a direct test of Antras et al. (2006), but rather an empirical regularity consistent with their theory.[17]

In an alternative model specification, I also explore the use of quantitative measures rather than price-based measures of communication as a way to capture the easiness of cross-border information transmission. I use data on the volume of international telephone communication between the U.S. and foreign country j, in minutes, as well as data on Internet penetration and on international air passenger flows to capture other modes of cross-border communication. One reason I experiment with quantity measures is because, conditional on prices, demand levels may provide additional information about the non-monetary costs of communication. For example, demand

[15] This statement assumes that the total export of services is less knowledge intensive and thus less sensitive to communication frictions than headquarter services are.

[16] Educational attainment has been a standard proxy for skilled labor endowments because of the large country coverage of the dataset. See Yeaple (2003) or Blonigen et al. (2003) among others.

[17] The only way an alternative mechanism that relates communication costs to FDI is going to affect the estimate of β_2 is if this alternative mechanism operates in conjunction with the average skill level of workers in the foreign country. Otherwise, any hypothesis linking communication costs to FDI will be captured by the independent effect of *CommunicCost* on the export share of headquarter services. To my knowledge, no other trade theory besides Antras et al. (2006, 2008) provides a mechanism relating communication costs to the average skill level of workers in the foreign country in order to explain intra-firm trade and overall FDI.

levels could reflect information about the characteristics of communication networks, about the connectivity and quality of services in general.

A potential drawback in using quantity measures comes from the fact that causality is less transparent: while price changes are typically taken as exogenous shocks to the activity of firms (more on this in the estimation results section), changes in the communication flows are more likely to be endogenous. I address this issue when describing the communications data, but also when discussing the instrumental variables (2SLS) method proposed as estimation strategy.[18] In the end, I expect the volume of communication to perform well as an indicator of the *inverse* of the cost of communication, and expect the regression coefficients corresponding to β_1 and β_2 to be significant yet of opposite sign.

The remaining time-varying foreign country control variables include factors capturing market access and market potential, which are standard determinants of FDI. The economic size and income level of the host country, as measured by the population size (*Pop*) and real per-capita GDP (*PcGDP*), account for the attractiveness of the foreign market as location for horizontal FDI. The factor endowment of the host country, measured by the capital-to-labor ratio, controls for one of the key determinants of the boundaries of the firm, and thus of intra-firm trade. *TCost* denotes the bilateral trade costs, as measured by a set of time-varying economic indicators: the trade openness of the host country, the real exchange rate and the strength of ethnic networks (i.e., number of persons living in the U.S. and born in country *j*). *MktPotent* denotes the market potential of the foreign country *j*, constructed as the distance weighted average of all countries' GDP (except its own). When affiliate production is not entirely commissioned back to the parent firm, large markets ensure economies of scale in production, which are necessary to overcome the fixed costs of building new production facilities abroad. The inclusion of *MktPotent* in the regression model controls for the likelihood of choosing a particular market as preferred location for FDI. Finally, *Policy* stands for the level of corporate tax rate in the foreign country[19], as well as for a set of economic integration policies, such as free trade agreements (FTA), bilateral tax treaties (BTT) and bilateral investment treaties (BIT). The theoretical FDI literature and the subsequent empirical evidence support the prediction that trade barriers have a positive effect on FDI flows, as it makes exporting a less attractive strategy for market access. At the same time, trade barriers discourage FDI because of difficulties in importing goods produced by the vertically integrated foreign affiliates. However, less is known about the impact of trade costs on intra-firm service flows. To the extent that intra-firm exports of headquarter services complement foreign direct investments in manufacturing, then host country trade openness and FTAs should have a negative effect on service exports by the parent to its foreign affiliates, while BTTs and BITs should have a positive effect on investments.[20]

[18] It is useful to point out that in the estimation I use data on *total* communication flows between the U.S. and foreign country *j*, and not only business or trade-related communication flows. This implies that a major fraction of the overall communication flows are driven by personal consumption reasons. While this adds noise to my communication measure, it also ensures that changes in communication flows happen for reasons independent of intra-firm trade flows, and more accurately reflect changes in average prices.

[19] Corporate tax rates serve as control for tax avoidance practices of MNCs via transfer pricing. One of the common ways in which multinational firms shift profits to low tax countries is by manipulating the prices of intra-firm trade transactions (Cristea and Nguyen, 2014), including the price of intangible assets.

[20] See the evidence in Bergstrand and Egger (2007) and Blonigen et al. (2014) among others.

Before discussing the data and the estimation results, it is worth bringing up several points regarding the model specification. First, the estimated effect of communication on intra-firm service exports by skill level could reflect both scale and composition effects. When communication costs change, affecting the match between domestic managers and foreign production workers, the size of the production team changes as well, affecting the scale of production and, implicitly, the total amount of knowledge transfers. So, in interpreting the elasticity β_2 one should consider both mechanisms. To the extent that the gravity control variables included in the regression already explain a large fraction of the variation in FDI levels across countries, then it is possible that the labor composition effects are responsible for a considerable share of the estimated effect. However, there is reason to believe that both effects are at play in the data, in which case distinguishing between the skill composition and the scale effects is difficult given the level of data aggregation.[21]

A second caveat relates to the high correlation between the average skill level of a country's workforce and other country specific characteristics such as per-capita income or the level of development. This poses difficulties in extending the regression model to account for interaction terms between the cost of international communication and foreign country characteristics other than the skill level. Thus, it could be possible that the estimated coefficients of interest may be contaminated by such omitted interaction terms.

One last point worth considering is that the reduced-form empirical analysis tests bilateral predictions derived from Antras et al. (2006) using a multi-country dataset, even though their theory is a two-country model. In the data, production decisions are not determined only by country-pair characteristics such as communication costs, but also by arbitrage decisions across multiple foreign markets. To the extent that the country-specific effects and time-varying control variables (e.g., market potential) account for investment opportunities in third countries, then the estimated coefficients should not be affected by this transition from the two-country theory set-up to a multi-country data environment. However, in the event that the model specification does not properly account for cross-country arbitrage opportunities, this may affect the estimated coefficients.

4 Data Sources

There are three pieces of information that are essential for the econometric estimation: 1) data on the value of intra-firm knowledge transfers, 2) data on the average skill level of workers in the foreign market, and 3) information on cross-border communication costs. The data used in the empirical exercises is for the U.S. The limited data availability on intra-firm services trade reduces the estimation sample to 32 foreign countries observed over the period 1993-2008. The Appendix Table A1 lists all the countries in the sample.

A challenging variable to measure is the flow of cross-border knowledge transfers, broadly defined. The aim is to find an appropriate way to capture the interdependence between the activity

[21] In unreported results available upon request, I have estimated the regression in equation (6) using as dependent variable the total sales of majority-owned foreign affiliates (MOFAs). I find that the same pattern of results holds.

of foreign affiliates and the knowledge inputs provided by their parent firms in the U.S. My approach is to consider the intra-firm export of services from the headquarters to their foreign affiliates. I employ publicly available BEA data on aggregate related party trade in "other private services", of which the largest category are business services.[22]

Data on the average educational attainment by country and year come from the Barro and Lee (2010) dataset. I use information on the average years of education in the total population aged 25 years and above in order to measure the knowledge and skill level of the foreign labor force.[23] The original Barro--Lee data reports educational attainment variables at five-year intervals for a large number of countries. To get annual data, I follow the practice in the literature and apply a linear interpolation to generate values for in-between years (Blonigen et al., 2003).

Finally, I consider several measures of international communication reported by foreign destination country: the cost and volume of telephone calls, the volume of economy class air passenger traffic between the U.S. and a foreign destination, and the Internet penetration rate in a foreign country (measured by the number of Internet users per 100 people). The telecommunication data is collected from the U.S. Federal Communications Commission (FCC), Section 43.61. I use information on the average U.S. billed revenue per minute (for message telephone services), as well as information on the total volume of outbound calls in minutes. The source of international aviation data is the Department of Transportation (DOT), Databank 1B, which provides information on the number of travelers, average economy-class discount airfare, and average number of flight segments per origin - destination trip. Lastly, Internet data on penetration rates are available from the World Development Indicators database provided by the World Bank. Gathering data on there distinct modes of communication that differ significantly in the ease and efficacy of knowledge transmission has the benefit of mitigating uncertainties about the actual communication mix that is employed in coordinating distant operations.[24]

The control variables used in the estimation come from data sources that are standard in the trade literature. Population, real per-capita GDP, factor endowments (capital stock, active labor force), trade openness (defined as the sum of imports and exports divided by GDP), and real exchange rates (LCU per US dollar) are available from the Penn World Tables. Gravity variables on bilateral trade frictions are provided by CEPII. Information on the top corporate income tax rates is available from the *World Tax Database* maintained by the University of Michigan. The bilateral

[22] A classification of tradable services with corresponding shares in total U.S. service exports is presented in the Appendix Figure A2. The Appendix Figure A3 shows the average exports of other private services by country from U.S. multinational firms to their foreign affiliates over the sample period (values in logs).

[23] An alternative measure of skill abundance is the fraction of adult population with at least secondary education (Antras et al., 2008). Since the correlation coefficient between the two educational attainment measures is 0.91, I decided to report estimation results using only average years of schooling. The empirical analysis based on the alternative skill measure is available upon request.

[24] For example, Cristea (2011) finds that business travels are important in cross-border trade relations. This could be one explanation for why Head et al. (2009) find that service offshoring is sensitive to distance. In face of costly communication, Keller and Yeaple (2013) argue that multinational firms optimally chose to move abroad only those activities that can be easily codified and transferred at distance. This could indirectly suggest that telephone and electronic communication might be the more prevalent mode of communication in international transactions. To complicate matters more, Gaspar and Glaeser (1998) argue that telephone and face-to-face communication are complements in production rather than substitutes.

treaty information is compiled from various sources: the United Nations Conference on Trade and Development (UNCTAD) provides data on the bilateral investment treaties (BIT) signed between the U.S. and foreign countries; information regarding the countries with which the U.S. has signed free trade agreements is available from the CEPII gravity database as well as the WTO website; finally, data on bilateral tax treaties is provided by the Internal Revenue Service.

Further details on data sources and variable construction are provided in a supplementary web appendix. Table 1 reports the summary statistics of all the variables used in estimating the regression specification given by equation (6).

One potential concern about the model identification is the correlation between the explanatory variables, in particular between the changes over time in economic development (i.e., per-capita GDP), trade openness, ease of knowledge transfers and educational attainment. To address this concern, Table 2 reports the correlation coefficients between the left-hand side regression variables. To ensure that the correlation coefficients reflect the same (residual) variation as used for model identification, each variable is first demeaned from country and time specific effects. Glancing over the coefficients, one point worth mentioning is the low correlation between the bilateral communication variables and the average skill level across the countries in the sample (the only exception is Internet penetration). This is important because it suggests that the interaction term between communication and skill is not highly collinear with each individual variable, and thus can be precisely estimated.

5 Estimation Results

5.1 Share of Headquarter Service Exports

Table 3 reports the main estimation results using as measure of communication cost the international calling rate per minute of conversation to a foreign country. Column 1 reports the baseline specification that includes only the key FDI determinants suggested by the knowledge-capital model, expressed in log-linear form. Column 2 adds the interaction term between communication cost and the average skill level in the host country, which is my main variable of interest. The coefficients of the main variables of interest have the expected signs and are highly significant. In both specifications, costly communication with foreign workers impacts in a negative and significant way the share of exports in headquarter services. However, the negative effect of the high calling rates is mitigated by the average skill level of the foreign workforce. The higher the educational attainment of the foreign workforce, the smaller the effect of communication cost becomes. This effect is consistent with the hypothesis described in the theory section. One explanation for this result is that easy communication allows U.S. managers to better exploit their capabilities by teaming up with less skilled foreign workers, because such workers witness a much faster growth in labor productivity conditional on having easy access to managers' knowledge. On the other hand, for locations abundant in skilled labor, international telephone rates have a smaller or even insignificant effect on the share of intra-firm services trade.

A potential concern with the results reported in column 2 is omitted variable bias. It is

possible that the estimated effects are driven by unobservable factors that not only determine the export of headquarter services relative to total service exports, but are also correlated with both cross-border communication costs and with the average education level in the foreign country. For example, countries that have institutions of higher quality could have more educated workers on average. Similarly, countries that are better connected to global production networks could invest more in communication technologies. To a large extent, these observations should not be a major problem since the dependent variable was intentionally expressed as a share term so that factors that affect to the same extent intra-firm and arm's length service exports will automatically drop out of the regression. In fact, even when the impact of an unobservable variable is not identical on each form of trade, still it will only have a *net* effect on the fraction of headquarter services in total service exports, which significantly reduces the likelihood of omitted variable bias. Nevertheless, to remove any remaining concerns, column 3 adds a set of time-varying country-specific controls such as the strength of ethnic networks, the level of corporate taxes and of exchange rates, as well as several international policy indicators. While all the control variables have the expected sign with some of them being significant, adding them to the regression equation leaves the sign and econometric significance of the variables of interest unaffected.

To push the identification strategy a step further, column 4 adds to the model specification country fixed effects. To a large extent, the main differences across foreign locations are already accounted for by the country-specific controls such as population, income level, relative factor abundance or trade openness. Nevertheless, by adding the country fixed effects I ensure that the coefficients of interest are identified only from the time variation within each country pair. As expected, the results reported in column 4 do not change qualitatively. Although the magnitude of the estimates decreases, the sign and significance of the coefficients of interest do not change. I continue to find evidence that while communication costs affect negatively the share of headquarter services in total service exports, this negative effect gets mitigated by the skill level of the foreign workforce.

So far, calling rates have been taken as exogenous to the export share of headquarter services. Even though price levels represent equilibrium outcomes, communication is a service consumed both for business and for personal purposes. Moreover, multinational firms account for only a fraction of the business-driven demand for international telecommunication. So, while calling rates are most likely not exogenous to country-specific characteristics, they are probably taken as given by a subset of users.

Nevertheless, to avoid relying on conjectures, I exploit information on two exogenous shocks to calling rates and use them as excluded instruments. First, I construct a weighted average of the U.S. calling rates to neighboring countries, where the weights are the bilateral distances from the country whose prices are instrumented for to all the other countries in the sample (i.e., instrument for $Pcall_i$ using $\sum_{j \neq i} \frac{Pcall_j}{dist_{ij}}$). The motivation for this instrument comes from the strong network effects associated with major investments in telecommunication infrastructure. Second, I calculate the imbalance between U.S. outgoing and incoming phone-call minutes within a bilateral pair. This is because an important cost component of international calling prices are the settlement

rates, which are the negotiated rates at which the one country compensates the other for the excess minutes terminated over its domestic telecom network. Being an important call originating country, the U.S. may be able to negotiate lower settlement rates with its partners.

Column 5 of Table 3 provides the estimates obtained from instrumental variables methods. The 2SLS estimates have the expected sign and are almost the same in magnitude as the OLS counterparts in column 4. Also, the excluded instruments perform well. Consistent with expectations, they are correlated with the endogenous variables (as seen from the F-statistics reported at the bottom of the table), and they are orthogonal to the regression residual from the export share of headquarter services (as suggested by the low Hansen J statistic). Moreover, a Hausman test of endogeneity fails to reject the null hypothesis of exogenous calling rates, thus confirming initial claims.[25] Based on this evidence, throughout the rest of the paper, I will assume that multinational firms take calling rates as given.

The marginal effects of communication costs on the share of intra-firm exports of headquarter services are reported in the bottom part of Table 3. I evaluate the marginal effects at the sample mean for educational attainment, respectively at one standard deviation above or below the sample mean. Across all specifications, the estimates suggest that at an average skill level below the sample mean, lower communication costs have a positive and significant effect on the import of headquarter services by foreign affiliates. Figure 1 plots the marginal effect of calling rates on the export share of headquarter services using estimates from the fixed effects specification. The marginal effects are calculated over the range of values for the average skill level of the foreign workforce that is observed in the data sample. The direct effect of the interaction term between communication and skill level is evident from the positive slope of the fitted line of marginal effects.

To provide more intuition for the economic significance of the results, the estimates suggest that moving from the level of educational attainment in the Philippines, which corresponds to the 25th percentile of the skill distribution in the sample in 2006, to the level of educational attainment in Norway, which corresponds to the 75th percentile of the skill distribution, the impact of communication cost is reduced by 103%, and this induces an additional increase in the export share of headquarter services of 0.14 percentage points.

Overall, the results in Table 3 provide strong evidence for the hypothesis that the negative effect of communication costs on the share of service exports by U.S. parents to their foreign affiliates is related in a systematic way to the average skill level of the foreign labor force. Conditional on key country characteristics, high cross-border communication costs inhibit to a lesser degree the export of headquarter services (relative to total service exports) as long as the foreign country is abundant in skilled labor.

Next, I examine the sensitivity of previous findings to an alternative communication measure: the volume of international telephone calls (in minutes). The motivation for using a quantity measure rather than a price measure for the easiness of international communication comes from the fact that the overall cost of transmitting information at distance depends not only on monetary

[25]The Chi-squared statistic from the Durbin--Wu--Hausman endogeneity test for calling rates is 1.347, with an associated p-value of 0.51.

costs but also on non-monetary costs. For example, the time zone difference or the quality of the telecommunication infrastructure have a direct influence on the cost of cross-border communication.

In what follows, I re-estimate the regression specification in equation (6) using the minutes of international phone calls between the U.S. and the foreign country j as proxy for the (inverse of) communication costs. This approach raises one empirical challenge though. While calling rates have the advantage of being exogenous to intra-firm business service transactions, the volume of communication may not be. Growth in multinational production to a given foreign country j may result in a significant increase in the volume of telephone calls undertaken to that destination. Given this potential endogeneity, I instrument the volume of telephone calls using two exogenous instruments. The first instrument is the price per minute of international phone call to a destination country (i.e., the same variable exploited previously). The second instrument captures the non-monetary costs of communication, and consists of the time zone difference between the U.S. and the foreign country j interacted with a linear time trend (to avoid perfect multicollinearity with the country fixed effects). Each of the two instruments is interacted with the average skill level in the host country to generate corresponding exogenous instruments for the interaction term.

The validity of both variables as exogenous instruments depends on two conditions being met: 1) the cost of phone call conversations, proxied by the two instruments, must be highly correlated with the observed volume of telecom traffic; however, 2) these instruments must be uncorrelated with the residual from the regression explaining the export share of headquarter services. At first, the latter condition may seem more problematic to ensure. However, it is useful to emphasize again that the dependent variable in these models is the export of headquarter service *normalized* by the total exports of services. This aspect plays a crucial role in validating the excluded instruments, and in identifying the model coefficients. This is because a shock to a country's telecommunication infrastructure that affects both the price of phone calls and the volume of headquarter service exports, is possibly going to also affect the total volume of service exports. So, by focusing on the share of headquarter services in total service exports, many of the unobservable factors that may affect a country's telecommunication and trade flows simultaneously, are already controlled for, eliminating any correlation between the proposed instruments and the regression residual. The same line of argument applies equally well to the use of time zone differences as excluded instrument. While time zone differences may have a direct impact on service exports, they should affect not only the level of intra-firm trade in services but also the level of trade between unaffiliated parties. However, this level effect nets out once I construct the ratio of headquarter service exports to total service exports, leaving no correlation between the trade shares and time zone differences. In light of these arguments, I believe it is reasonable to claim that the proposed instruments are valid, and to expect them to perform well in the regression. Standard statistical tests will provide further evidence on the performance of the suggested instruments.

Table 4 reports the estimation results. For comparison purposes, column 1 shows the OLS estimates, and columns 2 to 4 report the coefficients from both stages of the instrumental variables estimation. All the coefficients of interest have the expected sign – which is opposite from what was found earlier when using calling rates – and are highly statistically significant. This finding

reinforces prior results.[26] The ease of communicating with foreign workers, as captured by high communication flows, has a significant and positive effect on the share of headquarter service exports. The same is true about the average educational attainment of foreign workers. More importantly for the question addressed in this paper, the coefficient on the interaction term suggests that the average skill level of the foreign workforce matters for determining the export share of headquarter services, particularly when telecommunication is limited and difficult to establish. In fact, the marginal benefit of skill decreases once information transmission becomes really easy. These findings are consistent with the previous results. To provide more intuition for the economic significance of the results, moving from the level of educational attainment in the Philippines (at the 25th percentile of the skill distribution in 2006), to the level of educational attainment in Norway (at the 75th percentile of the skill distribution in 2006), the beneficial effect of communication flows is reduced by 53%, and this induces an additional reduction in the export share of headquarter services of 0.15 percentage points.

Columns 3 and 4 report the first stage estimations for the volume of phone calls, respectively for the interaction term with the average skill level. The exogenous instruments perform well, as can be observed from the reported performance of the first stage regressions. The significance of the estimates and the high F-statistics reported at the bottom of the table suggest that the excluded instruments are highly correlated with the endogenous variables. Failure to reject the test for overidentifying restrictions at the conventional confidence level further indicates that the instruments are uncorrelated with the residuals from the export share of headquarter services.

Comparing the second stage coefficients from the instrumental variable estimation (column 2) with the corresponding OLS counterparts (column 1), it can be noticed that the 2SLS coefficients for communication and average skill level are smaller in magnitude. This direction of change is consistent with the hypothesis of a positive correlation between phone calls and headquarter service exports. But more importantly, the pattern of results is the same as found before: both the level of communication and the average educational attainment have a positive effect on the demand for headquarter services by foreign affiliates. However, the extent to which communication affects intra-firm services trade is negatively related to the skill level of the foreign labor force. The marginal effect of communication evaluated at different points of the sample distribution for the foreign skill level are reported at the bottom of Table 4. They also match the findings discussed previously for the case of telephone rates. All the other regression variables have the expected sign and their magnitudes do not change very much compared to OLS levels.

5.2 Alternative Measures of International Communication.

To verify the robustness of previous findings, I experiment with alternative measures of international communication flows. In particular, I use information on two different modes of communication:

[26] In unreported estimations, I have experimented with removing the calling rate as an instrument for the volume of phone calls, and replacing it with the variables used for instrumenting the calling rates (i.e., calls imbalances, weighed average of neighboring countries' calling rates). Confirming expectations, the results are very similar in sign, magnitude and significance level. They are available upon request.

face-to-face communication, proxied by international air passenger flows, and electronic communication, proxied by Internet penetration rates (i.e., Internet users per 100 people).

Table 5 reports the regression results. Since both communication indicators are quantitative measures and therefore suffer from the same endogeneity problems as in the case of international telephone calls, I provide regression results using OLS as well as 2SLS methods. Focusing on air travel estimates first, I instrument air travel flows using data on the average annual airfare, on the average number of flight segments needed to reach a foreign destination, and on fuel costs as proxied by the interaction between geographic distance and fuel prices. The first two variables are also interacted with the average skill level of a foreign country and used as excluded instruments for the interaction terms involving the endogenous communication measures. Column 1 reports the OLS estimates, followed by the 2SLS estimates in column 2. The first stage coefficients for the excluded instruments are reported in columns 3 and 4. The excluded instruments perform well as suggested by the first stage statistics available at the bottom of the table.

Overall, the results have the expected sign and magnitude, giving support to prior findings based on telecommunication data. Both the OLS and 2SLS estimates suggest that while air travel has a direct positive effect on the export share of headquarter services, the benefits of good communication are less valuable when the average skill level of foreign workers is high. To provide more intuition for the economic significance of the results, moving the level of educational attainment from the 25th percentile (e.g., the Philippines) to the 75th percentile (e.g., Norway) of the skill distribution in 2006, the trade share reducing effect of air travel is amplified by 88%, and this induces an additional reduction in the export share of headquarter services of 0.35 percentage points.

The same pattern of results is found in columns 5-8, which report the estimates based on Internet penetration rates at country level. Focusing on columns 5 and 6 for the OLS and second stage IV estimates, it is again the case that communication appears as an important determinant of headquarter service exports, along with the average educational attainment of the workforce in the foreign country. The interaction term between the two variables, i.e., the coefficient of interest, has the expected negative sign but the effect is weakly identified, becoming insignificant in the 2SLS estimation. The challenge in getting clean identification for these results can be attributed to two factors. One could be the relatively high correlation between Internet penetration and average skill level, as reported in Table 2. This leaves less independent variation to be used for identifying the interaction term. The second explanation could be that Internet penetration – by being a communication measure heavily influenced by the level of per-capita income and overall development in a foreign country – has a pretty limited set of qualifying instrumental variables. The excluded instrument used here to correct for the endogeneity of Internet penetration rates is the U.S. billed revenue per minute of international telephone calls. The first stage estimates are reported in column 7 for Internet penetration, and in column 8 for its interaction with the average skill level in the foreign country. The excluded instruments seem valid in that they are correlated with the endogenous variables they instrument for as evidenced by the F-statistics at the bottom of the table. Lacking more choices for excluded instruments, the regression model is exactly identified, preventing a test of overidentifying restrictions.

Nevertheless, using this evidence in combination with the results already presented, it seems that by either measure of international communication, the main message suggested by the estimates is the same: the ability of headquarters to communicate and get involved in the activity of foreign affiliates is important, particularly for developing countries that are scarce in skilled labor.

5.3 Service Exports to Unaffiliated Parties.

As a robustness exercise, I perform a falsification test to verify the consistency of the main results with the theoretical hypothesis.[27]

The premise of the empirical analysis is that the substitution effect between the knowledge inputs provided by the headquarters and the skill level of the foreign production team comes from the need to efficiently organize production and knowledge transmission *inside* multinational firms. So, by design, the framework applies only to activities carried within the boundaries of multinational firms. This means that I should not be able to find the same substitution pattern affecting the volume of exports of other private services taking place between unaffiliated parties.

To check this intuition, I estimate the same regression model as before but using this time the value of unaffiliated service exports as dependent variable. While communication barriers may affect the export of services to unrelated parties, it is not clear why this effect should vary systematically with the average skill level in the foreign country other than because of income effects, demand sophistication or industrial composition. However, all these determinants should be accounted for in the regression model by the country-specific control variables and by the country fixed effects.

Table 6 reports the estimation results from this falsification exercise. Panel A uses the *level* of service exports to unaffiliated parties as dependent variable, while Panel B uses the export *share* as dependent variable to facilitate a direct comparison to previous estimates. I use both telecommunication and air travel data to measure communication. For conciseness, I only report the coefficients for the variables of interest. Column 1 reports the OLS estimates obtained by using calling rates as a measure of communication costs. Column 2 reports the OLS estimates based on the volume of phone calls in minutes as proxy for communication costs, while column 3 reports the corresponding 2SLS estimates. For robustness, columns 4 and 5 report the OLS and 2SLS estimates using air travel data. Neither the direct effects of communication and skill endowment nor their interaction term are statistically significant (the only exceptions correspond to estimates with sign that is opposite than expected). This provides further support to the fact that the identified substitution effect between service exports and labor inputs is not mechanical, and only applies to cross-border service flows that are directly related to the internal organization of production in multinational corporations.

[27] One other robustness exercise that is omitted from the paper exploits the theoretical implication that the size of foreign affiliates (i.e., value of the cross-border production) increase as a result of lower communication costs. This is because U.S. managers can now train larger teams of foreign workers, thus increasing their span of control. An empirical question is whether this effect is more pronounced at low levels of educational attainment. In unreported results available upon request, I investigate the effect of communication on the total sales of majority-owned foreign affiliates and find support for this insight.

6 Conclusions

A premise for multinational production is the transferability of intangible assets over space. While developments in communication and transportation technologies are often credited for the rapid growth of multinational corporations, many surveys of top business executives consistently rank face-to-face meetings as the most effective channel for transmitting knowledge at distance (Economist Intelligence Unit, 2007). Factoring in the costs of moving people over space, this sheds light on remaining communication barriers hindering the transfer of intangible assets abroad.

When information transmission, coordination and monitoring are costly, yet critical for an efficient operation of cross-border production networks, an important question is how can corporations mitigate the impact of costly communication. The hypothesis examined empirically in this paper is whether a higher average skill level of the local workforce reduces the involvement by the firms' headquarters in the ordinary production problems of foreign affiliates, thus diminishing the extent of cross-border communication.

Using the theoretical framework in Antras et al. (2006) to motivate the testable hypothesis, I investigate whether the exports of headquarter services to affiliates in foreign countries respond to barriers in international communication in a way that is systematically related to the average skill level of the foreign workforce. Using data on intra-firm exports of 'other private services' by parents of U.S. multinationals, combined with measures of international communication and skill endowments by country, I bring evidence in support of a substitution effect between communication from the headquarters and the average skill level of foreign workers. Controlling for standard determinants of FDI, I find that when cross-border communication is easy, headquarter service exports are larger towards less skill abundant production locations because coordination and problem solving are achieved at relatively low cost, while the savings in terms of wage bill can be significant. However, when international communication costs are high, multinational firms shield their activity from the inefficiencies driven by reduced communication by directing their operations to locations abundant in highly educated workers, as a way to cut down on the number of interventions from the headquarters.

The results in this paper have important implications for understanding how multinational firms organize production so as to economize on costly or inefficient knowledge transfers. Increasingly, the links between establishments of the same enterprise become more invisible as the transfers of unfinished products get substituted by transfers of know-how and other intangible assets. The findings of this paper bring new insights into the determinants of intra-firm services trade, which feed nicely into recent research on the operations of horizontally or vertically integrated firms. Ultimately, these results provide information about the interplay between communication infrastructure and skill endowments that are useful to policy makers interested in attracting foreign investments. Policies aimed at reducing communication costs may be particularly useful in the case of less skilled developing countries, as human capital accumulation is presumably a far slower process than improvements in communication infrastructure.

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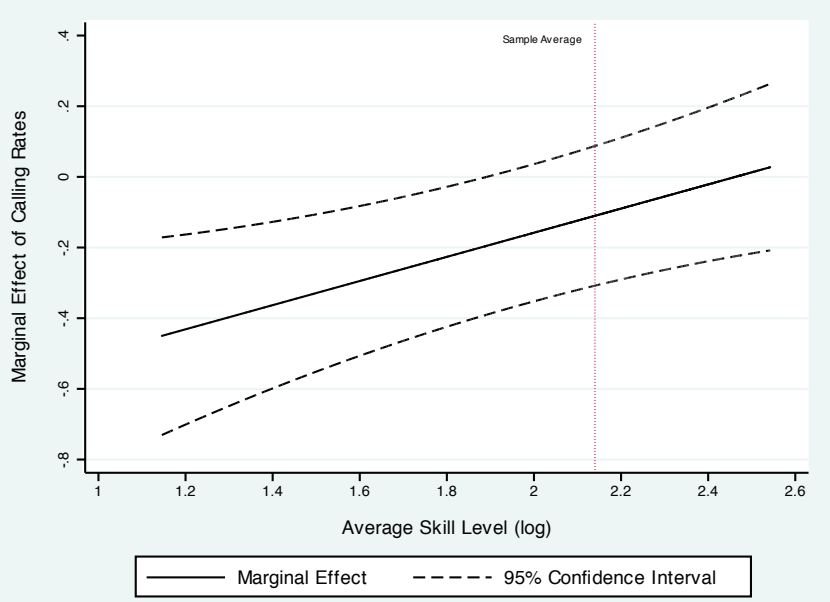
Figure 1: Marginal Effects of Communication Cost on the Export Share of Headquarter Services Evaluated at Different Skill Levels of the Foreign Workforce



Note: Marginal effects are calculated based on the estimates reported in Table 3 column 3. The vertical reference line is drawn at the sample mean for the average educational attainment variable, and it identifies the average marginal effect.

Table 1: Summary statistics

	No. Obs.	Mean	St. Dev.	Min	Max	CoV (%)[a]
Dependent Variables (in log form):						
Intra-firm Service Exports by U.S. Parents	462	5.595	1.521	0	8.934	76.8
Unaffiliated Service Exports	462	7.072	1.003	4.605	9.93	49.1
Share of Intra-firm Service Exports	462	-1.748	0.791	-6.439	-0.353	130.9
Sales by Majority-Owned Foreign Affiliates	462	10.514	1.349	6.109	13.361	53.1
Explanatory Variables (log form except if binary):						
Phone Calls (min)	462	19.71	1.198	17.024	23.411	5,226.5
Calling Rate ($/min)	462	-1.111	.966	-3.167	.633	64.5
Calls Imbalance (min)	462	9.119	5.865	1.151	19.985	72.30
Air Travel (passengers)	462	10.32	1.274	7.508	13.372	753.8
Air Fare ($)	462	6.599	.323	5.802	7.315	332.5
Flight Segments per Trip	462	.738	.203	.334	1.166	96.0
Internet Users (per 100 people)	442	1.878	2.414	-8.681	4.474	138.5
Average Skill Level	462	2.142	.298	1.146	2.542	95.1
Population	462	17.353	1.388	15.014	21.004	61.0
Real Per-capita GDP	462	9.682	.896	7.247	10.841	100.0
Capital-Labor Ratio	462	11.593	.848	8.934	12.679	281.8
Trade Openness	462	4.208	0.645	2.729	6.094	104.6
Market Potential	462	15.911	0.651	14.694	17.293	51.5
Exchange Rate	462	1.813	2.328	-3.437	9.301	3,006.6
Top Corporate Tax	462	3.362	.300	2.197	3.912	74.8
Bilateral Tax Treaty (BTT)	462	0.719	0.450	0	1	971.6
Bilateral Investment Treaty (BIT)	462	0.030	0.172	0	1	73.2
Free Trade Agreement (FTA)	462	0.115	0.319	0	1	43.7
Time Zone Difference	462	7.260	2.510	0.5	11	0.0

[a] CoV denotes the coefficient of variation, which is calculated based on variables' residual after removing the country and year fixed effects. For comparison, the reported CoV are normalized by the value for per-capita GDP, and expressed in percentages.

Table 2: Correlation Coefficients between De-meaned Variables

	Phone Calls	Calling Rate	Air Travel	Internet Users	Average Skill	Pop.	Per-cap. GDP	K/L Ratio	Trade Openness	Market Potential
Phone Calls	1.000									
Calling Rate	-0.420	1.000								
Air Travel	0.415	-0.087	1.000							
Internet Users	0.343	-0.365	0.261	1.000						
Average Skill	0.125	-0.147	0.151	0.510	1.000					
Population	0.303	-0.057	-0.154	0.234	0.055	1.000				
Pc GDP	0.303	-0.252	0.472	0.321	0.137	-0.019	1.000			
K/L Ratio	0.033	-0.257	0.167	0.444	0.264	-0.062	0.695	1.000		
Trade Openness	-0.025	-0.147	0.311	0.234	0.310	-0.336	0.439	0.351	1.000	
Market Potential	-0.089	-0.177	-0.383	0.069	0.065	0.244	0.071	0.255	-0.021	1.000
Corporate Tax	-0.061	-0.121	-0.025	0.046	-0.001	-0.134	-0.009	-0.029	0.015	0.031

Note: All variables are expressed in logs and correspond to the residual variation obtained after removing the country and year fixed effects.

Table 3: Effect of Communication Cost on the Export Share of Headquarter Services

Dependent Variable:	**Share of HQ Services in Total Service Exports**				
	OLS	**OLS**	**OLS**	**OLS**	**2SLS**
	(1)	(2)	(3)	(4)	(5)
Calling Rate	-0.602***	-1.410***	-1.192***	-0.841***	-0.874***
	[0.147]	[0.277]	[0.292]	[0.258]	[0.304]
Calling Rate × Skill Level		0.429**	0.353**	0.342***	0.332***
		[0.158]	[0.133]	[0.120]	[0.122]
Skill Level	-0.228	0.103	0.437	-1.239	-1.219**
	[0.519]	[0.575]	[0.448]	[1.009]	[0.600]
Population	0.187+	0.189+	0.438***	4.805***	4.812***
	[0.124]	[0.123]	[0.126]	[1.725]	[0.899]
Real per-capita GDP	0.496	0.563+	0.370	-0.036	-0.056
	[0.339]	[0.347]	[0.337]	[0.509]	[0.346]
K/L Ratio	0.176	0.128	0.357	0.152	0.144
	[0.308]	[0.313]	[0.337]	[0.389]	[0.259]
Trade Openness (Host)	0.547**	0.539**	0.871***	1.370***	1.364***
	[0.233]	[0.231]	[0.245]	[0.352]	[0.243]
Market Potential	-0.169	-0.159	-0.460*	-0.169	-0.208
	[0.288]	[0.284]	[0.252]	[0.707]	[0.437]
Distance	-0.112	-0.104	-0.246		
	[0.327]	[0.319]	[0.187]		
Contiguity	-0.483	-0.403	0.200		
	[0.636]	[0.645]	[0.645]		
Common Language	-0.055	-0.051	-0.051		
	[0.262]	[0.267]	[0.162]		
Common Colony	0.386+	0.383+	0.477**		
	[0.230]	[0.235]	[0.193]		
Real Exchange Rate			-0.039	0.030	0.027
			[0.039]	[0.113]	[0.069]
Top Corporate Tax			-0.635***	0.023	0.015
			[0.168]	[0.184]	[0.123]
BTT			0.567**	0.123	0.131
			[0.218]	[0.124]	[0.102]
BIT			0.282	0.039	0.030
			[0.284]	[0.121]	[0.140]
FTA			-0.624**	-0.452**	-0.449***
			[0.251]	[0.212]	[0.127]
Foreign Born Pop. × Year			-0.000***	0.004	0.004
			[0.000]	[0.005]	[0.003]
Country FE	NO	NO	NO	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	462	462	462	462	462
R-squared	0.477	0.501	0.634	0.403	0.403
First Stage Statistics:					
Partial F-stat: Calling Rate; Calling Rate×Skill					17.31; 24.84
Hansen J stat (p-val)					1.32 (0.25)
Marginal effect of calling rates (evaluated at various levels of skill):					
at 1 std. below mean		-0.620***	-0.540***	-0.211**	-0.261^{+}
		[0.137]	[0.130]	[0.100]	[0.163]
at sample mean		-0.492***	-0.435***	-0.110	-0.162
		[0.159]	[0.130]	[0.101]	[0.160]
at 1 std. above mean		-0.364*	-0.330**	-0.008	-0.063
		[0.190]	[0.143]	[0.113]	[0.164]

*** p<0.01, ** p<0.05, * p<0.1, + p<0.15. Robust standard errors in brackets

Note: The results correspond to the regression equation (6). The sample covers U.S. exports of "other private services" to 32 countries over 1993-2008. All continuous variables are expressed in logs. The dependent variable is calculated as the exports of services by parent firms to their foreign affiliates divided by the total exports of services. International communication is measured in cost terms as the calling rate per minute of phone call conversation. The skill level variable is defined as the average educational attainment of the foreign workforce. The remaining regression variables are standard for explaining bilateral trade or FDI flows. All estimates are obtained by OLS, except for the last column of 2SLS estimates. The calling rate and its interaction term are instrumented using as excluded instruments a distance-weighted average of other countries' calling rates, as well as the calls imbalance between U.S. outbound and inbound minutes of phone calls by country.

Table 4: Effect of Communication Flows on the Export Share of Headquarter Services

Dependent Variable:	**Share of HQ Services in Total Service Exports**			
	OLS	**2SLS**	**1st Stage**	
			Calls	*Calls* × *Skill*
	(1)	(2)	(3)	(4)
Phone Calls	1.158***	1.029***		
	[0.249]	[0.321]		
Phone Calls × Skill Level	-0.531***	-0.364**		
	[0.124]	[0.158]		
Skill Level	9.057***	6.006**	-2.225**	15.829***
	[2.501]	[2.958]	[1.012]	[1.913]
Population	4.746***	4.375***	2.159***	4.578***
	[1.712]	[1.004]	[0.437]	[0.876]
Real per-capita GDP	-0.034	-0.486	1.854***	3.991***
	[0.550]	[0.439]	[0.212]	[0.442]
K/L Ratio	0.006	0.316	-1.211***	-2.840***
	[0.381]	[0.323]	[0.168]	[0.340]
Trade Openness (Host)	1.344***	1.501***	-0.593***	-1.361***
	[0.313]	[0.256]	[0.167]	[0.331]
Market Potential	-0.205	0.099	-1.515***	-3.326***
	[0.731]	[0.470]	[0.343]	[0.717]
Real Exchange Rate	0.019	0.015	0.012	-0.076
	[0.118]	[0.074]	[0.051]	[0.103]
Top Corporate Tax	0.076	0.093	-0.176**	-0.314**
	[0.195]	[0.123]	[0.071]	[0.143]
BTT	0.153	0.219**	-0.208***	-0.348***
	[0.123]	[0.103]	[0.066]	[0.130]
BIT	0.063	-0.000	0.100	0.171
	[0.113]	[0.140]	[0.087]	[0.186]
FTA	-0.413*	-0.422***	-0.063	-0.154
	[0.210]	[0.130]	[0.082]	[0.171]
Foreign Born Pop. × Year	0.007*	0.004	0.010***	0.024***
	[0.004]	[0.004]	[0.002]	[0.004]
Calling Rate			-1.085***	-0.961***
			[0.172]	[0.306]
Time Zone Difference × Year			-0.006***	-0.014***
			[0.002]	[0.004]
Calling Rate × Skill Level			0.274***	-0.057
			[0.075]	[0.135]
Time Zone Diff. × Skill Level			0.272**	0.430*
			[0.126]	[0.249]
Country FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	462	462	462	462
R-squared	0.425	0.408	0.873	0.969
First Stage Statistics:				
Partial F-stat			21.35	21.74
Hansen J stat (p-val)		0.22 (0.90)		
Marginal effect of calling rates (evaluated at various levels of skill):				
at 1 std. below mean	0.179**	0.358**		
	[0.076]	[0.143]		
at sample mean	0.021	0.250*		
	[0.081]	[0.152]		
at 1 std. above mean	-0.137	0.141		
	[0.101]	[0.174]		

*** p<0.01, ** p<0.05, * p<0.1, + p<0.15; Robust standard errors in brackets

Note: The results correspond to the regression equation (6). All continuous variables are expressed in logs. The sample and variable descriptions included in Table 3 apply here as well. International Communication is measured in quantity terms as the volume of U.S. outbound phone calls in minutes. Phone call minutes are instrumented with the calling rate and the time zone difference between trading countries. The instruments are interacted with the average educational attainment to instrument for the interaction term $Calls \times Skill$. The instrumental variable results are reported in column 2, while the first stage estimates are reported in columns 3 and 4.

Table 5: Effect of Other Modes of Communication on the Export Share of Headquarter Services

	Dependent Variable: Share of HQ Services in Total Service Exports							
	Air Travel				*Internet Penetration*			
			1st Stage				1st Stage	
	OLS	**2SLS**	*Travel*	*Travel×Skill*	**OLS**	**2SLS**	*Internet*	*Internet×Skill*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Communication Volume	2.468***	1.405**			0.460***	0.434***		
	[0.406]	[0.555]			[0.146]	[0.116]		
Communication Vol. × Skill Level	-1.223***	-0.871***			-0.144*	-0.105		
	[0.202]	[0.275]			[0.076]	[0.080]		
Skill Level	11.305***	8.086***	-4.019***	9.749***	-1.958**	-2.005***	3.624***	6.460***
	[2.135]	[2.621]	[1.426]	[2.653]	[0.952]	[0.699]	[0.964]	[1.781]
Air Fare			-1.981***	-1.915**				
			[0.410]	[0.741]				
Flight Segments per Trip			0.104	5.173**				
			[1.134]	[2.084]				
Fuel × Distance			0.000	-0.092				
			[0.035]	[0.069]				
Air Fare × Skill Level			0.733***	0.505				
			[0.200]	[0.375]				
Flight Segments × Skill Level			-0.656	-3.578***				
			[0.498]	[0.926]				
Calling Rate							-1.963***	0.358
							[0.396]	[0.662]
Calling Rate × Skill Level							0.687***	-0.602*
							[0.184]	[0.308]
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	462	462	462	462	442	442	442	442
R-squared	0.453	0.427	0.809	0.950	0.469	0.465	0.955	0.957
First Stage Statistics:								
Partial F-stat			18.86	17.13			24.12	12.82
Hansen J stat (p-val)		3.87 (0.28)				n.a.		
Marginal effect of calling rates (evaluated at various skill levels):								
at 1 std. below mean	0.213**	-0.200			0.195***	0.241*		
	[0.103]	[0.220]			[0.053]	[0.138]		
at sample mean	-0.151	-0.460**			0.152**	0.210		
	[0.109]	[0.234]			[0.059]	[0.155]		
at 1 std. above mean	-0.515***	-0.719***			0.109	0.179		
	[0.143]	[0.273]			[0.072]	[0.174]		

*** p<0.01, ** p<0.05, * p<0.1, + p<0.15; Robust standard errors in brackets

Notes: The results correspond to the regression equation (6). All continuous variables are expressed in logs. The sample and variable descriptions included in Table 3 apply here as well. International communication is measured in quantity terms using two alternative proxies: the number of international air travelers, and the Internet penetration rate in the foreign country (i.e., Internet users per 100 people). Each communication measure and its interaction term with average education level in the foreign country are instrumented for using various cost determinants. Columns 3 and 4, respectively 7 and 8 report the list of excluded instruments and their first stage coefficients. All specifications include a complete set of control variables and fixed effects (identical to column 4 of Table 3), which are omitted from the table but available upon request.

Table 6: Falsification Test: U.S. Exports of Services to Unaffiliated Parties

Panle A

Dependent Variable:	**Value of Service Exports to Unaffiliated Parties**				
	Phone Calls			***Air Travel***	
	OLS	**OLS**	**2SLS**	**OLS**	**2SLS**
	(1)	(2)	(3)	(4)	(5)
Communication Cost	0.182				
	[0.318]				
Communication Cost × Skill Level	-0.020				
	[0.145]				
Communication Volume		0.141	-0.109	0.107	0.196
		[0.237]	[0.227]	[0.487]	[0.379]
Communication Volume × Skill Level		-0.079	-0.081	0.077	0.080
		[0.106]	[0.108]	[0.221]	[0.182]
Skill Level	-0.214	1.121	1.268	-1.104	-1.167
	[0.733]	[2.151]	[1.994]	[2.263]	[1.765]
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	462	462	462	462	462
R-squared	0.860	0.857	0.840	0.863	0.862
First Stage Statistics:					
Hansen J stat (p-val)			0.05 (0.816)		11.93 (0.008)

*** p<0.01, ** p<0.05, * p<0.1, + p<0.15; Robust standard errors in brackets

Panle B

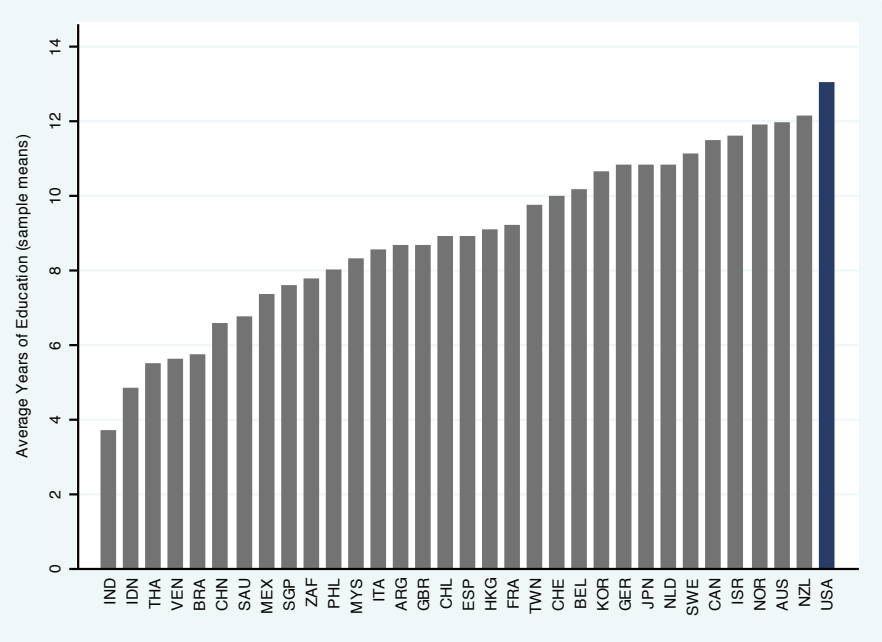
Dependent Variable:	**Share of Unaffiliated Party Service Exports in Total Service Exports**				
	Phone Calls			***Air Travel***	
	OLS	**OLS**	**2SLS**	**OLS**	**2SLS**
	(1)	(2)	(3)	(4)	(5)
Communication Cost	0.119*				
	[0.068]				
Communication Cost × Skill Level	-0.037				
	[0.028]				
Communication Volume		-0.048	-0.076	-0.249	-0.127
		[0.074]	[0.062]	[0.187]	[0.145]
Communication Volume × Skill Level		0.012	-0.016	0.136+	0.159**
		[0.033]	[0.032]	[0.858]	[0.671]
Skill Level	0.170	-0.134	0.399	-1.229	-1.508**
	[0.382]	[0.572]	[0.579]	[0.858]	[0.671]
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	462	462	462	462	462
R-squared	0.257	0.246	0.203	0.260	0.193
First Stage Statistics:					
Hansen J stat (p-val)			8.79 (0.003)		3.90 (0.273)

*** p<0.01, ** p<0.05, * p<0.1, + p<0.15; Robust standard errors in brackets

Note: The results correspond to the regression equation (6), but with the dependent variable changed to either the total export of other private services to unaffiliated parties (Panel A), or its share in total service exports (Panel B). All continuous variables are expressed in logs. Each specification includes the full set of control variables and fixed effects (identical to column 4 of Table 3). Both price-based (column 1) and quantity-based (columns 2 to 5) communication measures are used in the estimation, using information on phone calls and air travel flows. The quantity regressions are estimated by OLS and 2SLS using the same excluded instruments as previously presented in Tables 4 and 5 (first stage estimates are omitted but available upon request).

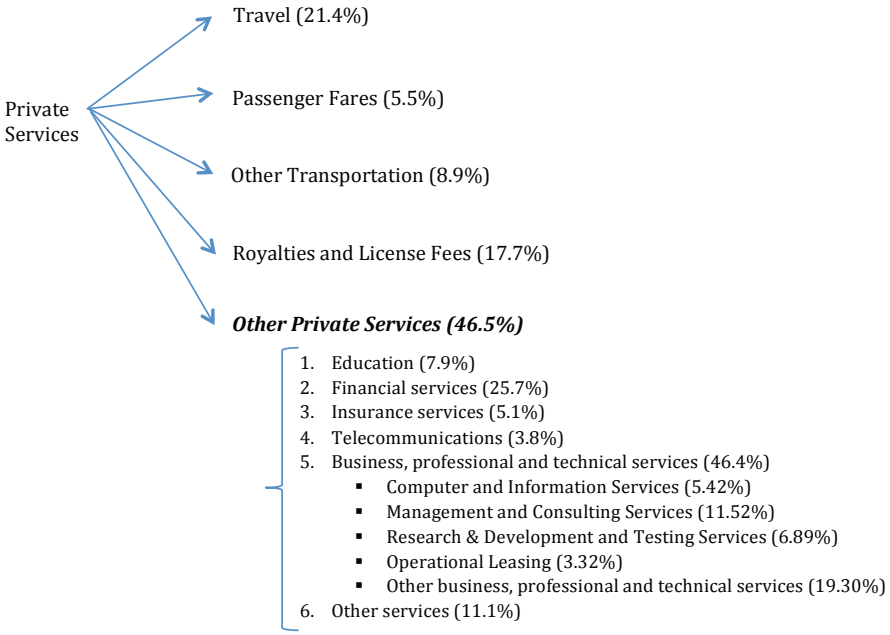
A Appendix Figures

Figure A1: Sample Means for Average Years of Education across Countries



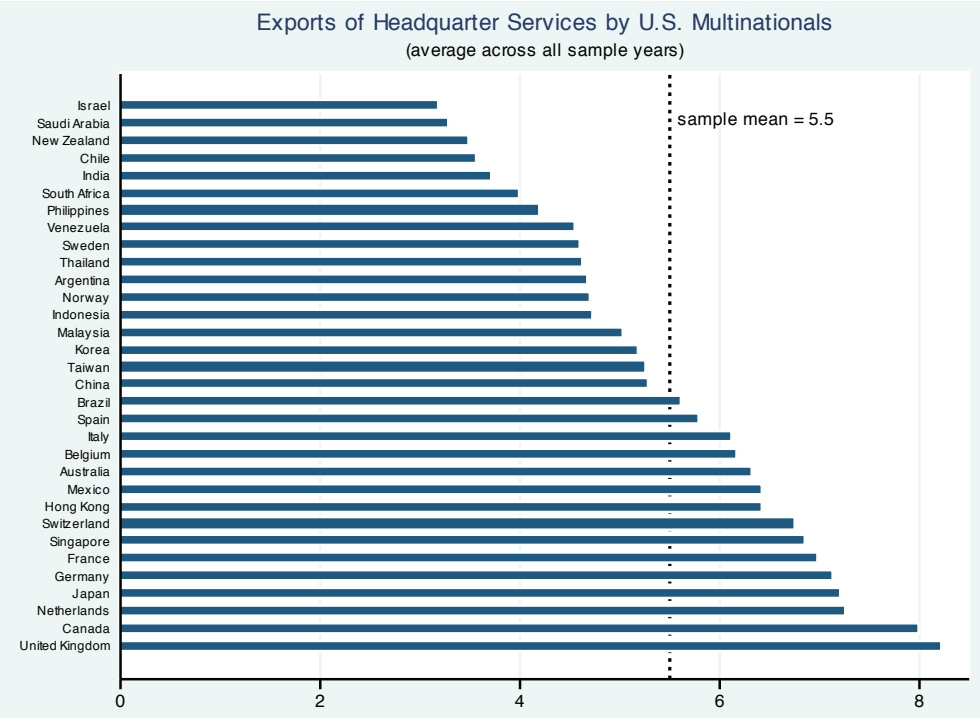
Note: The vertical bars measure the average years of education computed by country over the sample years. The source of the data is Barro and Lee (2010).

Figure A2: Classification of Services in the BEA Data



Note: The importance weights included in parentheses are based on total export values for year 2006.

Figure A3: Sample Means for the U.S. Exports of Headquarter Services by Country



Note: The horizontal bars measure the sample average for the value of intra-firm service exports by U.S. parents to their foreign affiliates. The data is restricted to other private services, and the source is the BEA.

B Appendix Tables

Table A1: List of Countries Included in the Estimation Sample

Nr. Crt.	Country Name	Nr. Crt.	Country Name
1	Argentina	17	Malaysia
2	Australia	18	Mexico
3	Belgium	19	Netherlands
4	Brazil	20	New Zealand
5	Canada	21	Norway
6	Chile	22	Philippines
7	China	23	Saudi Arabia
8	France	24	Singapore
9	Germany	25	South Africa
10	Hong Kong	26	Spain
11	India	27	Sweden
12	Indonesia	28	Switzerland
13	Israel	29	Taiwan
14	Italy	30	Thailand
15	Japan	31	United Kingdom
16	Korea	32	Venezuela

Note: The set of countries included in the estimation sample is limited by the availability of public BEA data on related party trade in other private services.