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

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Abstract

Multinational corporations have long been recognized as both major creators of technology and as conduits of technology transfer. Technology transfer can happen directly, when the affiliate licenses the technology from the parent, or indirectly, when the affiliate imports intermediate goods with embodied technology. This paper estimates the effect of the affiliates' productivity relative to the frontier — the technology gap — on the choice of licensing the technology or importing it through intermediate goods. A novel measure of multinational technology transfer is employed using data on technology licensing payments versus imports from U.S. multinationals across many countries and industries. The main finding of this paper is that a large technology gap of an affiliate favors indirect knowledge transfer through imports. On average, a 10% increase in the technology gap decreases the share of licensing versus importing inputs embodying the technology by 1.5%. Considering that access to ideas and generation of new ones are crucial for long-run economic growth and convergence of a country, this study highlights the policy implications for countries to raise their productivity levels.

Keywords: Multinationals, technology transfer, productivity gap, intermediate inputs, royalties and license fees

JEL: F23, F1, O33, L24

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1 Introduction

There has been a significant increase in the levels of global trade in goods and services. Two components of this increase are noteworthy: currently, global trade in ideas is reaching annual levels of $250 billion (World Development Indicators),[1] and trade in intermediate inputs comprises 57% of total trade in goods in OECD countries (Miroudot, Lanz and Ragoussis 2009).

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

A MNC can transfer its technology to foreign affiliates in *disembodied* form (know-how, industrial processes, computer software) or in *embodied* form (intermediate inputs). Flows of royalty and license receipts from affiliates to parents for the use of intangible technology is evidence of disembodied technology transfer, while exports of goods for further processing from parents to affiliates can indicate embodied technology transfer. It is well known that technology transfer is an important determinant of long-term cross-country income, economic growth and convergence of countries. However, the mode of technology transfer in embodied versus disembodied form has a differential impact not only on access to current knowledge and economic growth, but also on innovation, economic welfare, and convergence. The history of the soft drink "Fanta", which was invented by the German affiliate of the Coca-Cola Company, offers one example. Possessing the recipe for Coca-Cola but lacking all the required ingredients due to a shortage in World War II-era Germany, Coca-Cola Deutschland invented this new soft drink by using the only available ingredients instead. In addition, the mode of technology transfer might also affect the degree of knowledge spillovers from multinational affiliates to domestic firms, which improves

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

the productivity of the latter.[2]

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

A panel data on the activities of U.S. multinationals in 46 host countries and across 7 manufacturing industries is employed to analyze the relationship between the affiliate's technology gap and the share of importing technology versus inputs. Focusing on the activities of U.S. MNCs is attractive as there is information on both the technology and input flows within firms. These data come from legally mandated benchmark surveys, conducted every five years by the Bureau of Economic Analysis (BEA), which enable the identification of U.S. parent-affiliate tangible and intangible technology transfers across FDI host countries and industries. The technology gap is measured as the deviation of the affiliate's labor productivity from the parent productivity in the same industry and year. The main finding of this paper is that the technology gap is negatively related to the share of disembodied versus embodied technology transfer, with a 10 percent increase in the technology gap on average decreasing the share of licensing versus importing inputs by 1.5 percent.

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

The significance of this paper stems from the realization that MNCs tend to share know-how with country affiliates that are more productive, but export intermediate goods to the less productive ones. The fact that affiliates which are far from the frontier receive technology in the form of goods and not disembodied ideas, leads to policy implications that for developing less-productive countries the reduction in the technology gap would involve direct access to knowledge and ideas. This not only gives such countries access to current information, but also stimulates the creation of new knowledge which in itself is important for long-run economic growth and convergence. Possible channels through which developing countries can reduce their technology gap are through subsidizing research to build up their knowledge stocks, thus being able to absorb intangible ideas, and investment in human capital.[3]

The theory on multinational enterprises identifies horizontal and vertical directions for Foreign Direct Investment (FDI). Horizontal FDI arises when multinationals replicate their production in host countries to gain market access (Markusen 1984), whereas vertical FDI arises when different stages of production are fragmented to take advantage of differences in factor prices (Helpman 1984), intra-industry considerations (Alfaro and Charlton 2009), or international transaction costs (Keller and Yeaple 2013).[4] Country empirical studies have found that market sizes, country similarity, factor endowments, and barriers to trade are among the most important determinants of FDI, while country-industry studies find that these factors have a differential impact on FDI in various industries.[5]

This paper contributes to the growing body of literature on vertical production sharing within multinationals, where part of production takes place locally in affiliates while the other is imported from parents (Hanson, Mataloni and Slaughter 2005; Fouquin, Nayman and Wagner 2007; Keller and Yeaple 2013). Hanson and coauthors find that MNC foreign affiliate's demand for imported inputs is higher in affiliate countries with lower trade costs, lower wages

[3] I am grateful to an anonymous referee for pointing out these channels.

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

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

for less-skilled labor, and lower corporate income tax rates (Hanson, Mataloni and Slaughter 2005). Keller and Yeaple (2013) formalize and empirically confirm that knowledge intensity is another important determinant for the location of intermediate input production, where it is more difficult to transfer technology in more knowledge-intensive industries. This paper differs from the work of Hanson and colleagues and Keller and Yeaple by employing a direct measure which differentiates between transfer of tangible intermediate inputs versus intangible technology from U.S. parents to affiliates. Some new literature has emphasized the importance of especially intangible technology transfer in contrast to goods transfer within vertical production sharing (Atalay, Hortaçsu and Syverson 2014, Ramondo, Rappoport and Ruhl 2016, and Cho 2015).

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

This paper adds to the first body of literature a relative measure of embodied and dis-

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

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

embodied technology to empirical analysis of multinationals' vertical production networks. In relation to the second body of literature, this paper explicitly identifies two forms of knowledge transfer within MNCs and highlights productivity differences of affiliates as an important factor in determining the mode of technology transfer. As the decision of transfer occurs within the firm, affiliate productivity may be endogenously determined by MNCs. This is addressed in the present study by using instrumental variables and various proxies for technology gap. Furthermore, across country and across year variation in labor productivity of affiliates of U.S. MNCs within the same manufacturing industry is used to identify not only the direction of the impact, but also parameter estimates. In addition, differences in industries are controlled for in multiple specifications. A limitation of this paper is the usage of aggregated country-industry level data due to inaccessibility of confidential firm-level data from the U.S. Bureau of Economic Analysis.

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

2 Theoretical Foundation

The theoretical model that motivates the empirical analysis that follows is based on Keller and Yeaple (2013) and literature on absorptive capacity and productivity differences across countries. The model of multinational production of Keller and Yeaple (2013) builds on the transaction costs of international activities where shipping costs and communication costs play a central role in import share of affiliates and affiliate sales. There exist shipping costs to transfer intermediates that embody technological information from the U.S. parents to affiliates and communication costs to transfer disembodied technology. Shipping costs of moving goods across borders increase with distance from the parent, while communication costs of transferring disembodied technology are higher in more knowledge-intensive industries than in less knowledge-intensive industries. The model predicts that the share of intermediate inputs that are imported from home country decreases with increase in trade costs, but the decrease is slower in more knowledge-intensive industries. Although the model does not derive the specific mode of technology transfer (licensing-import share), the predictions of the model imply that the higher the trade costs one should see more disembodied technology transfer through intermediate inputs, and the higher the knowledge intensity one should see more embodied technology transfer through licensing. According to this theory, it is harder to transfer technology in more knowledge-intensive industries because technology is tacit and hard to codify, which means it is best conveyed face-to-face.[8] In the absence of in-person communication, the technology transfer may be more imperfect the more knowledge-intensive the industry is. Thus, a multinational firm faces a tradeoff between sharing disembodied technology or technology embodied in intermediate goods with its foreign affiliates, which depends on shipping and communication costs.

However, the ability of multinational affiliate to utilize embodied versus disembodied knowledge will also depend on its ability to absorb the knowledge- absorptive capacity. Cohen and Levinthal (1990) showed that the ability of firms to utilize knowledge is based on the prior level of knowledge, while Keller (1996) showed that it is tied to the skill level of a country. As mentioned in introduction, productivity differences in subsidiaries of foreign companies are important for knowledge flows within MNC (see Bjorn, Johannes and Ingmar, 2005; Driffield, Love and Menghinello, 2010; Fouquin, Nayman and Wagner, 2007). Thus, productivity differences of affiliates in terms of their gap to the technological frontier can serve as a potential measure of absorptive capacity. The affiliates that are closer to the productivity frontier can absorb disembodied knowledge more easily because their level of human capital and/or prior knowledge is high, while the affiliates that are far from the productivity frontier might not. The example of Intel Corporation mentioned in the introduction illustrates this hypothesis.

Based on the theoretical foundations outlined above, the empirical objective of the paper is to estimate the connection between the technological gap of MNC affiliates and the mode of international knowledge transfer from the multinational parents to affiliates across countries

[8] For a discussion of the importance of face-to-face communication for transfering technology, see for example Koskinen and Vanharanta (2002) and Hovhannisyan and Keller (2015).

and industries. This paper focuses on one parent country's (the United States) affiliates abroad as it imposes certain homogeneity in terms of affiliate activities. Assume that U.S. multinationals decided where to locate their foreign affiliates.[9] The remaining decision involves the type of knowledge transfer, which is measured by the transfer of technology (know-how, industrial processes) versus intermediate goods from the U.S. parents to host country affiliates.[10] Direct measures of technology licensing payments and imports of goods for further processing are used to specifically pin down the share of disembodied versus embodied technology transfer from the U.S. parents to affiliates. The technology gap of an affiliate is measured by the deviation of its labor productivity from the parent's labor productivity in the same industry and year.

I specify that the share of technology transfer (in intangible and tangible forms) to an affiliate country c in industry i, TT_{ci} is a function Φ of the technology gap of an affiliate country c in industry i, TG_{ci} and of other observed and unobserved determinants, Z_{ci}:

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

where Θ is a vector of unknown parameters. Equation (1) can serve as a reduced-form of a model of technology transfer within multinational corporations.

The main hypothesis of this paper is the following:

The share of technology transfer TT_{ci} will depend negatively on the technology gap TG_{ci}, so we would expect that the estimated coefficient on technology gap is negative, namely that more productive affiliates will receive disembodied knowledge, while less productive affiliates will receive embodied knowledge through imported intermediate products.

The economic theory described above supports the empirical prediction because MNC faces a tradeoff between sharing disembodied and embodied technology with its affiliates, which will

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

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

depend on shipping and communications costs, R&D and other determinants, but it will also depend on how far in terms of productivity the affiliates are from the frontier.

The following section discusses the empirical methodology.

3 Empirical Methodology

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

$$Lic\_imp\_share_{cit} = \alpha + \beta TechGap_{cit} + \gamma X1_{cit} + \theta X2_{it} + \eta X3_{ct} + \delta_c + \mu_t + \varepsilon_{cit}, \tag{2}$$

where c indexes affiliate countries, i indexes industries, t indexes time. δ_c are affiliate country fixed effects, and μ_t are time fixed effects. In some specifications industry fixed effects are added as well. Licensing-import share is defined as

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

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

Technology gap is defined as

$$TechGap_{cit} = \frac{ParentLabprod_{it} - Labprod_{cit}}{ParentLabprod_{it}} \tag{4}$$

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

Turning to remaining variables of equation (2), $X1$ is a vector of control variables at the country-industry-year level such as trade costs, $X2$ is a vector of control variables at the industry-year level such as knowledge intensity, $X3$ is vector of control variables at the country-year level such as R&D expenditures, population, GDP per capita, and human and physical capital per worker. It is expected that the coefficient on β will be negative, implying that the smaller the technology gap of an affiliates is (closer to frontier productivity), the more the affiliate will import technology directly (paying royalties and license fees) relative to importing goods for further processing.[11]

Before turning to the empirical analysis and results, the next section gives an overview of the data and descriptive statistics of the main variables.

4 Data

4.1 Main Variables

The primary data used in this paper are based on operations of U.S. MNCs abroad and come from the United States Bureau of Economic Analysis (BEA). The data cover 46 countries where U.S. multinationals have affiliates, span 7 NAICS manufacturing industries, and include 2 benchmark survey years (1999 and 2004). The manufacturing industries used in the analysis are food, chemicals, primary and fabricated metals, machinery, computers and electronic products, electrical equipment, appliances and components, and transportation equipment. The list of affiliate countries used in the analysis is given in Table 1. The analysis is restricted to the benchmark survey years because US exports of goods for further manufacture, processing and assembly is only collected in benchmark survey years which happen every five years. Additionally, industry classification has changed from SIC to NAICS in 1997 and "computers and electronic products" manufacturing category was added, which would not allow for direct comparison with earlier benchmark years (1989 and 1994). It is not possible to use later benchmark surveys (2009 and 2014) because data on U.S. parents royalties and license fee receipts by industry was discontinued

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

from 2006.

Licensing-Import Share is constructed using data on royalties and license fees received by U.S. parents and on U.S. exports of goods shipped to majority-owned affiliates for further processing. Royalties and license receipts, net of withholding taxes, received by U.S. parents from its affiliates comes from the balance of payments and direct investment position data in 1999 and 2004. A more precise measure would be royalties and license receipts by U.S. parents from its majority-owned foreign affiliates or payments to U.S. parents by its majority-owned foreign affiliates. Unfortunately, that type of detailed data broken down by country-industry is not available. Overall, around 90% of royalties and license fee receipts by U.S. parents from foreign affiliates are from majority-owned foreign affiliates.

Using data on royalties and license fees which are net of withholding taxes, tax policy differences across affiliate countries should be mitigated. Data on royalties and license receipts offer an appropriate measure of direct technology as these receipts are for the use or sale of intangible property or rights such as patents, industrial processes, trademarks, copyrights, franchises, manufacturing rights, and other intangible assets or proprietary rights (U.S. Direct Investment Abroad: Final Results from the 1999 Benchmark Survey, 2004).[12] Overall, approximately 50% of royalties and license fee payments from foreign affiliates to U.S. parents are for industrial processes which are most closely related to the payments for the usage of disembodied technology.[13]

Royalty and license receipts reflect the value of technology transfer, which could reflect changes in the volume of technology or changes in price. There are widely known difficulties with pricing and units of output of intangibles (Robbins 2009). Robbins notes that royalty payments for licensing of industrial processes often consist of a lump-sum payment and a royalty

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

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

as a percentage of receipts.[14] In terms of price, transfer pricing is such that under U.S. law multinationals are required to charge the same price for intra-firm transactions on intangible assets as for unrelated arm's length transactions (Feenstra et al. 2010). Another difficulty with royalty and license receipts lies in the value of technology transfer that firms report, particularly coming from different countries. Branstetter and coauthors argue that under U.S. tax codes and the laws of foreign countries, there are restrictions on how U.S. multinationals make and value royalty payments. Furthermore, U.S. multinationals charge the same royalties for affiliates in different countries in order to avoid scrutiny from tax authorities (Branstetter et al. 2006).

Data on the U.S. exports of goods comes from 1999 and 2004 benchmark surveys and is measured by the United States (either from the U.S. parent or another party) exports of goods shipped to majority-owned affiliates for further processing, assembly, or manufacture. Although the U.S. exports of goods for further manufacture includes goods shipped from the U.S. parents or other U.S. entities, overall around 85% of imports by affiliates from the United States is from the U.S. parents. In 2004, exports for further processing from the U.S. parents to foreign affiliates were 60% of total exports and 90% within the manufacturing industry. Because of non-disclosure and confidentiality, the BEA does not provide small portion of data for royalties and license fees and for U.S. exports of goods for further manufacture broken down by country and industry. Data given in a range [-$500,000; $500,000] is coded as $500,000; data is filled in with the same number for observations where country-industry data is available for one year and missing for another (11% for exports, and 3% for royalties). The estimation results do not change if these observations are dropped from the analysis.

Technology gap is constructed using data on the gross product and number of employees of U.S. MNC parents and majority-owned foreign affiliates from the BEA. First, labor productivity of MNC parents is calculated as gross product (value added) divided by the number of employees for a given industry and year. It is taken as the frontier for a given industry and year. Then, labor

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

productivity of majority-owned foreign affiliates is calculated as gross product (value added) divided by the number of employees for a given country, industry and year. Due to confidentiality, a small portion of employment figures is given in ranges; in those cases, the midpoint of the range is taken. The results do not change if these observations are dropped from the analysis. The technology gap of a given affiliate is constructed as a relative difference from the frontier labor productivity (see equation 4). In this form, differences in productivity across industries are controlled for, and the identification of technology gap comes from variation across affiliate countries and years in a given manufacturing industry. In addition, in some specifications industry fixed effects are directly added to further mitigate any remaining differences between industries.

4.2 Controls

Although the empirical analysis controls for country and year fixed effects (and industry fixed effects in some specifications), there may still be differences across host country affiliates over time, and across industries. One of the most important factors that will impact licensing-import share is trade costs, as it is costly to transfer goods across borders. Following the methodology of Hanson and colleagues (2005) and Keller and Yeaple (2013), ad-valorem trade costs at country-industry-year level are constructed as a sum of freight costs and tariffs:

$$\tau_{cit} = 1 + freight_{cit} + tariff_{cit}, \tag{5}$$

Freight costs are calculated as the ratio of import charges over customs value of imports.[15] Tariffs are obtained from the TRAINS database using WITS software of the World Bank.[16]

Another important factor that will impact licensing-import share is communication costs

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

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

in transferring disembodied knowledge (Keller and Yeaple 2013). Higher knowledge-intensive industries require higher communication costs compared to lower knowledge-intensive industries. Following Keller and Yeaple (2013), knowledge intensity by industry and year is measured by U.S. parent Research and Development (R&D) expenditures divided by sales using data from the BEA.

R&D expenditures are considered an important determinant of technology transfer. To control for differences in country-level R&D, R&D expenditures as a percentage of GDP are employed from World Development Indicators. For the year where R&D expenditures were missing, data for a given country were linearly interpolated, however the results do not change if these observations are dropped from the analysis. Data on R&D expenditures of affiliates is not used in the analysis because of endogeneity concerns.

There are vast differences across affiliate countries in the level of development, size, factor endowments and other economic factors that might drive differences in U.S. FDI. To control for host country's development level and size, population and GDP per capita are obtained from Penn World Tables (PWT 6.3). Intellectual Property Rights Protection (IPR) in affiliate countries might also be an important determinant for the transfer of technology from the U.S. parent to affiliate.[17] The IPR protection index is obtained from Park (2008). Physical capital per worker is constructed using capital and employment data from Penn World Tables 8.0 (Feenstra et al. 2015). Human capital per worker is proxied by human capital index available from Penn World Tables 8.0 (Feenstra et al. 2015), which is based on (Barro and Lee 2010) Educational Attainment Dataset.

4.3 Descriptive Statistics

The final sample is an unbalanced panel of 46 countries, 7 manufacturing industries, and 2 years (1999 and 2004). Summary statistics of the main variables are presented in Table 2. On average, exports of goods for further manufacture is around 6 times larger than royalties and license

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

receipts.[18] Both royalties and license fees and exports of goods for further processing are quite dispersed with a large standard deviation. Licensing-import share, representing a technological measure of preference between imports of goods versus technology, is bounded between 0 and 1 by construction, with the smaller values representing a preference towards importing of intermediates and the larger values preference towards licensing the technology. Figure 1 presents a histogram of licensing-import share which shows that around 30% of observations are close to zero, with 15% of values being strictly zero because of 15% of royalties and license fees being zero and 3% of values being 1 because of 3% of U.S. exports of goods for manufacture being zero.

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

The next section presents the empirical results.

5 Results

The goal of the empirical analysis is to estimate a relationship between the technology gap of U.S. multinationals foreign affiliates and licensing-import share: import of technology versus import of goods. Table 3 presents initial estimation results of the equation (2) using Ordinary Least Squares (OLS). All columns include affiliate country and year fixed effects, while in column 6 industry fixed effects are added as well. Robust standard errors, which allow for clustering by country-year, are shown in parentheses.[19] Column 1 shows that there is a strong negative correlation between affiliates' technology gap and their licensing-import share: within an industry, foreign affiliates with a large technology gap from parents import relatively less technology in

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

[19] Clustering by country-year is performed because some control variables do not vary by industry (e.g. IPR protection index), while both licensing-import share and technology gap vary by industry.

the form of blueprints and designs and more in the form of intermediate goods.

The addition of trade costs and knowledge intensity in column 2 does not change the coefficient of technology gap while it remains highly significant at 1 percent. As expected, trade costs are estimated to be positive and significant, showing that import of goods is negatively related to trade barriers, resulting in a larger licensing-import share. Knowledge intensity is negative and significant showing that in industries that are more knowledge intensive licensing is lower or imports are higher, which results in a smaller licensing-import share. In column 3 R&D expenditures as a percentage of GDP are added. The coefficient on R&D is positive and significant, meaning that affiliate countries with high R&D are licensing more disembodied technology rather than technology embodied in intermediate goods, which is what one would expect.

Additional country-year level controls are added in column 4. The coefficient on population is negative and significant, while GDP per capita has a positive effect on licensing-import share but it is not significant. The negative coefficient on population might imply that affiliates in countries with larger size receive a larger fraction of goods for further manufacture, assembly and processing. As expected, IPR protection index is estimated to be positive and significant, implying that countries with strong protection of intellectual property receive more technology in the form of blueprints relative to intermediate goods. In column 5, endowments of human and physical capital are added, but they are not significantly estimated. With the inclusion of all control variables, the coefficient of technology gap is around -0.12.

What is the magnitude of the estimated coefficient? The mean of licensing-import share is 0.26, while the mean of technology gap (parent frontier) is 0.33 (see Table 2). Based on the estimated coefficient, this means that at the mean a 10% increase in the technology gap of a U.S. MNC affiliate, compared to the parent in the same industry, decreases the share of licensing versus importing inputs embodying the technology by 1.5%.[20] The magnitude of the estimated coefficient is economically sizeable.

[20] At the mean, the regression is $[0.26 = -0.12 * 0.33]$, thus a 10% increase in the right hand side is 0.00396, which lowers the licensing-import share by $0.00396/0.26 = 1.5\%$

To mitigate across-industry differences in technology gap and licensing-import share, industry fixed effects are added in column 6. The technology gap is still negative and significant at 10%, while the magnitude of the coefficient decreases only slightly from around -0.12 to around -0.1. However, trade costs, knowledge intensity, R&D expenditures and IPR protection cease to be significant. Overall, the results from table 3 indicate that there is a significant effect of technology gap on licensing-import share.

Although the OLS results reported in Table 3 provide important benchmark estimates, additional econometric models are estimated in Table 4. For convenience, column 1 repeats the OLS regression presented in Table 3 (column 5), while other econometric specifications are presented in columns 2 to 8. As mentioned previously, the dependent variable is a share with values strictly between 0 and 1 and around 15 percent of zeroes. In column 2, the licensing-import share is estimated by OLS after log(+0.01) transformation. The coefficient on technology gap is still negative and significant but the magnitude of the coefficient is larger. In columns 3 and 4 equation 1 is estimated as a two-way censored Tobit model without and with industry fixed effects. To compare OLS estimates with Tobit, in columns 3 and 4, marginal effects at the mean of two-way censored Tobit model are presented. Column 3 shows that technology gap has a negative and significant effect on licensing-import share, but the magnitude of the estimates are smaller than OLS. The coefficient on technology gap at the mean is -0.045 compared to -0.117 with OLS. The addition of industry fixed effects in column 4 decreases the estimate of technology gap to -0.034. As an alternative to Tobit model, the fractional logit estimates, which model conditional mean as a logistic function, are presented in columns 5 and 6. The coefficients on fractional logit are close to the tobit estimates. In addition, Poisson model with and without fixed effects is estimated in columns 7 and 8. On the whole, in all alternative econometric specifications, the technology gap variable is estimated negative and highly significant.

Licensing-import share is constructed by combining data on embodied and disembodied technological transfer. To understand the differences between these two types of technology transfer, decomposition of the dependent variable is performed in Table 5. For convenience, column 1 of Table 5 repeats the benchmark estimates of Table 3 (column 5) with licensing-import share as the dependent variable. In columns 2 and 3, the dependent variable is intermediate goods import intensity, constructed as U.S. exports of goods for further manufacture divided by affiliate sales. As one would expect the coefficient is positive - affiliates with a large technology gap on average import more intermediate goods - and significant at 10% without industry fixed effects. The coefficient on trade costs is negative and significant, meaning that trade costs decrease intermediate goods import intensity consistent with previous literature. With the addition of industry fixed effects (column 3) both technology gap and trade costs cease to be significant. Turning to columns 4 and 5, where the dependent variable is disembodied technology transfer intensity (royalty and license fees divided by affiliate sales), the coefficient on technology gap is negative and significantly estimated at 1% implying that affiliates with a small technology gap on average receive more disembodied technology.

5.1 Robustness

The technology gap of affiliates is constructed using parent productivity as the frontier and labor productivity of affiliates (see equation 4). Table 6 presents results using alternative measures of technology gap using different frontiers as well as a proxy for labor productivity of affiliates. Column 1 repeats the benchmark estimates of Table 3 with industry fixed effects (column 6) for convenience. It is possible to argue that labor productivity of affiliates may be endogenously determined by the MNC. In column 2 instead of US MNC affiliate labor productivity, a proxy for affiliate country labor productivity is constructed using data from the United Nations Industrial Statistics Database (INDSTAT4). Data on affiliate country value added and employment by 3 and 4 digit Standard Industrial Classification (SIC) is obtained from INDSTAT4 database and matched to BEA industries. Then domestic labor productivity of each affiliate country is calculated as value added divided by employment by industry and year, which is used to construct technology gap. The results using this proxy are presented in column 2. The coefficient on technology gap using domestic labor productivity from INDSTAT4 is -0.076, slightly smaller than the benchmark estimate of -0.093, and is significant at 5%.

Another feasible option for defining technology gap involves using a different frontier measure. To test the robustness of using parent productivity as a frontier, we can define the frontier as the most productive affiliate in the same industry and year, as it is possible that parents and affiliates perform different tasks. Then, the technology gap of a given affiliate is defined as a relative difference from the most productive affiliate in the same industry and year. In all cases the frontier affiliate comes from a high-income country affiliate. The results of this exercise are reported in column 3 of Table 6. Using affiliate frontier, the coefficient on technology gap is estimated to be negative and significant but significantly larger at -0.237. Additionally, the signs and estimates of the controls are very similar to the benchmark estimates. In column 4, the technology gap is constructed using the most productive affiliate in the same industry and year as the frontier (as in column 3), but replacing the affiliate labor productivity with the domestic labor productivity by country, industry and year from INDSTAT4 (as in column 2). The estimated technology gap is negative and significantly estimated.

As an additional robustness check, technology gap in column 5 is constructed using data just from INDSTAT4 database. Maximum labor productivity by industry-year is used as the frontier and domestic labor productivity for each affiliate country by industry-year is used to replace the affiliate labor productivity. The coefficient of technology gap is negative -0.260 and is significant at 10%. Overall, this table shows that the main results of this paper are not sensitive to the definition of frontier and the labor productivity of affiliates used in the construction of technology gap. Although the magnitudes of the coefficients are different, in all cases technology gap is negatively associated with licensing-import share.

It is possible to argue that if U.S. MNC affiliates have access to more disembodied technology (ideas), they can become more productive over time. To address the possibility of reverse causality, Table 7 uses 5-year lagged technology gap as an instrument for technology gap. This instrument is valid as 5-year lagged technology gap is highly correlated with current technology gap but is not correlated with the current licensing-import share. For convenience column 1 repeats the OLS benchmark estimates of Table 3 (column 5). In column 2, equation 1 with the benchmark technology gap, using US parent productivity as frontier, is estimated through Instrumental Variables (IV) methodology using 2 Stage Least Squares (2SLS) estimator. The coefficient on technology gap from 2SLS is negative at -0.144 and is highly significant. The magnitude of the coefficient of IV is more negative than OLS suggesting that there existed a negative bias from reverse causality. Because of data limitations lagging technology gap by 5 years reduces the number of observations from 476 to 225 and effectively uses one year for estimation. Nevertheless, the IV results show that the coefficient on technology gap is still negative and highly significant. Columns 3 and 4 of table 7 use technology gap where the frontier is the most productive affiliate in a given industry-year. Column 3 repeats the OLS estimates of Table 6 column 3, while column 4 presents IV estimates of 2SLS using 5-year lagged value of technology gap (affiliate frontier) as an instrument for technology gap (affiliate frontier). The IV estimates of technology gap (affiliate frontier) are negative and highly significant but are more negative compared to OLS estimates as was the case above. Overall, this table shows that after controlling for reverse causality a larger technology gap of affiliates causes more embodied technology transfer versus disembodied technology transfer.

A number of additional robustness checks have been conducted (see table 8). Although the empirical analysis controls for country fixed effects and other determinants of differences across countries, it is interesting to analyze whether the results are driven by developing versus developed countries. One might argue that developing countries that are technologically dissimilar to the U.S. should have a higher technology gap, ceteris paribus. To see whether the results are driven by developing versus developed countries, only developed countries sample is estimated in column 2 of table 8.[21] This reduces the number of observations to 217 and the estimated coefficient on technology gap is slightly larger at -0.121 and highly significant. If we just compare means of technology gap and licensing-import share between the high-income sample and

[21] The developed countries based on GDP per capita are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Italy, Japan, Netherlands, Norway, Singapore, Sweden, Switzerland, and United Kingdom.

the full sample, as expected, the technology gap is on average smaller for high-income countries but the averages of licensing-import share are similar. This might be explained by the fact that even within developed countries sample there is quite a bit of variation across countries.

To understand whether the results are driven by high-tech or low-tech industries, in column 3 of table 8 the analysis is repeated using only high-tech industries based on R&D intensity of US MNC parents. High-tech industries are Chemicals, Computers, Electronics, Machinery and Transportation. The coefficient on technology gap is still negative and highly significant and similar in magnitude to the full sample. When considering high-tech industries sample, it is interesting that on average there are no significant differences between the means of licensing-import share and technology gap compared to those of the full sample.

To address the possibility of differential effect of trade costs and R&D in column 4 interaction of trade costs with R&D is included. The coefficient on interaction is positive and significant, while the coefficient on technology gap decreases slightly from -0.117 to -0.116 but remains significant. One might also argue that type of FDI matters for embodied versus disembodied technology transfer. If FDI is horizontal and market entry is the primary goal, affiliates might be replicating U.S. production abroad, so we would expect royalties to be higher. In the case of vertical FDI however, the main goal is further processing and assembly, so we would expect exports of goods for further processing to be higher. To test this hypothesis, the fraction of local affiliate sales to all affiliate sales for each country-year is calculated from BEA benchmark surveys and added to the regression. The results are shown in column 5. The results on technology gap are unchanged, while the coefficient on local to all sales is negative and significant suggesting that countries that sell more locally import more intermediate inputs than technology in disembodied form. This result is contrary to what one would expect but might be driven by the aggregated country-level nature of sales. In addition, to test whether there is a differential effect of the type of FDI with technology gap, in column 6 the interaction of technology gap with the fraction of local affiliates sales to all sales is added. The interaction is positive and not significantly estimated, while the coefficient on technology gap is slightly increased to -0.124.

6 Conclusions

Multinational corporations are the main mediators of the worldwide increase in technology trade. Intermediate inputs and know-how are the two forms of technology (tangible and intangible) transferred within multinational corporations that this paper has examined. This paper analyzed what determines the decision of multinationals on the form of technology transfer to its affiliates, using data on U.S. multinational activity in 46 countries, 7 manufacturing industries and 2 years. Detailed data on exports of goods for further processing, as well as royalties and license payments observed between U.S. MNC parents and their affiliates, enables us to specifically identify two types of knowledge transfer from parents to affiliates.

The main finding of this paper is that the technology gap, measured as the relative labor productivity difference from the frontier, is negatively related to the share of direct versus indirect transfer of knowledge from U.S. parents to affiliates. Relatively more productive affiliates get technology in the form of know-how, industrial processes, etc., while relatively less productive affiliates receive technology in the form of intermediate inputs. The magnitude of the effect is sizeable: a 10 percent increase in the technology gap of affiliates decreases the share of licensing versus importing inputs by 1.5 percent, on average. These results suggest that productivity of affiliates is an important determinant for knowledge transfer within multinational corporations.

The transfer of technology is central to modern economics because of its implications for long-term cross-country income, economic growth and convergence of countries. Access to knowledge and know-how are obtained by MNC affiliates from their parents, as well as via spillovers from those affiliates to domestic firms. Regardless of how such knowledge is gathered, it amounts to an avenue for innovation and income growth. Based on the results mentioned above, this study points to policy implications for countries to raise their productivity levels and thus decrease technology gap. Take the case of South Korea. The mean of technology gap across industries was .424 in 1999, but it decreased to .09 in 2004. In parallel, the mean of licensing-import share across industries increased from .087 to .302. As the case of South Korea illustrates, if countries can reduce their technology gap, they can get technology in the form of disembodied technology which has a significant impact on future innovation, economic welfare, and convergence. Although this paper does not specifically deal with the channels through which technology gap can be reduced, some possible avenues are for countries to subsidize research to build up their knowledge stocks, thus being able to absorb intangible ideas, and investment in human capital.[22]

While this paper provides initial evidence on the relationship between the technology gap and the mode of technology transfer in multinational corporations, there are important extensions that should be considered in future work. First, obtaining firm-level or more disaggregated industry data will enable the examination of this question without potential aggregation bias. Second, it would be interesting to add a direct measure of technology, and explicitly model the process of innovation in the framework of technology transfer. Third, it would be useful to extend this analysis to other samples to see if the results continue to hold. A promising avenue involves the use of data on Swedish multinationals. Fourth, it would be interesting to analyze the type of technology transfer and its dynamic impact on economic growth. Finally, there are important questions on whether the type of FDI matters for the mode of technology transfer.

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Table 1: Countries in the Sample

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

Table 2: Descriptive Statistics

Variable	Mean	Standard Deviation	Min	Max
Royalties & license receipts ($mln)	37.767	176.939	0.000	3047
US exports of goods for manufacture ($mln)	227.777	572.756	0.000	4924
Licensing-Import share	0.261	0.303	0.000	1.000
Technology gap -parent frontier	0.330	0.604	-5.353	2.574
Technology gap -affiliate frontier	0.696	0.261	0.000	2.028
Trade costs	0.128	0.101	0.006	1.120
Knowledge intensity	0.045	0.036	0.005	0.121
R&D expenditures as a % of GDP	-0.024	1.012	-3.181	1.422
Population	10.262	1.473	8.202	14.077
GDP per capita	9.617	0.742	7.781	10.597
Intellectual property protection	1.280	0.302	0.207	1.541
Physical capital per person	12.736	1.470	8.574	18.136
Human capital per worker (index)	2.793	0.392	1.732	3.490

Note: Number of observations for all variables is 476. The sample includes 46 countries, 7 manufacturing industries and 2 years (1999 and 2004). Trade costs, R&D expenditures, population, GDP per capita, IPR and physical capital per worker are in natural logarithms.

Figure 1: Distribution of Licensing-Import Share

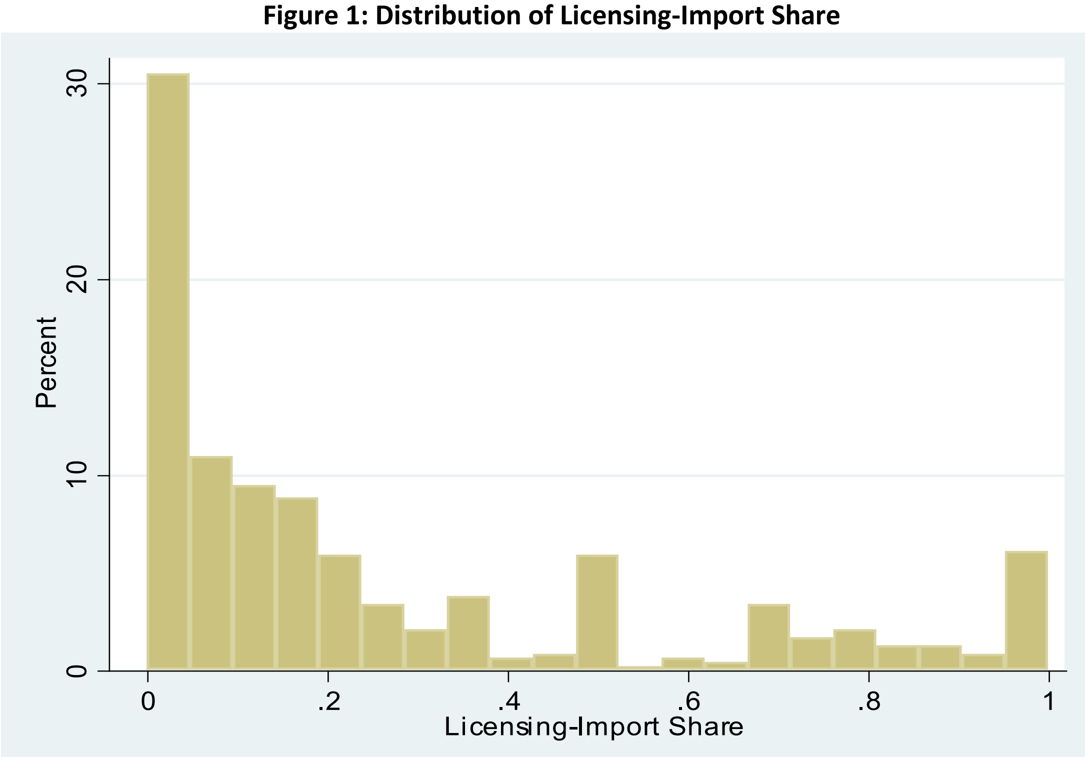

Table 3: Benchmark Regression

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Licensing-Import Share					
Technology gap	-0.118***	-0.118***	-0.118***	-0.118***	-0.117***	-0.093***
	(0.026)	(0.023)	(0.023)	(0.023)	(0.023)	(0.024)
Trade costs		0.665***	0.697***	0.725***	0.714***	-0.189
		(0.216)	(0.209)	(0.211)	(0.216)	(0.235)
Knowledge intensity		-0.852**	-0.826**	-0.819**	-0.901**	-1.061
		(0.343)	(0.341)	(0.341)	(0.358)	(1.455)
R&D			0.132**	0.106	0.106	-0.039
			(0.060)	(0.073)	(0.072)	(0.059)
Population				-0.921**	-0.940**	-0.212
				(0.432)	(0.446)	(0.378)
GDP per capita				0.174	0.185	0.355***
				(0.149)	(0.144)	(0.130)
IPR protection index				0.128**	0.136**	0.013
				(0.056)	(0.055)	(0.050)
Physical capital per worker					-0.007	0.006
					(0.012)	(0.012)
Human capital per worker					-0.138	-0.008
					(0.104)	(0.095)
Industry fixed effects						X
Observations	476	476	476	476	476	476
R-squared	0.301	0.345	0.346	0.349	0.350	0.437

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

Table 4: Various Econometric Specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS Ln(+0.01)	Tobit	Tobit	Fractional Logit	Fractional Logit	Poisson	Poisson
Dependent variable	Licensing-Import Share							
Technology gap	-0.117***	-0.445***	-0.045***	-0.034***	-0.039***	-0.029***	-0.288***	-0.205***
	(0.023)	(0.135)	(0.010)	(0.010)	(0.009)	(0.010)	(0.054)	(0.062)
Trade costs	0.714***	3.244***	0.103***	-0.026	0.099***	-0.029	1.850***	-0.929
	(0.216)	(1.020)	(0.032)	(0.035)	(0.029)	(0.026)	(0.481)	(0.585)
Knowledge intensity	-0.901**	-3.744*	-0.049**	-0.026	-0.041**	-0.027	-4.259***	-2.667
	(0.358)	(2.037)	(0.019)	(0.081)	(0.018)	(0.088)	(1.496)	(8.659)
R&D	0.106	0.586	-0.004**	-0.000	-0.001	0.001	0.588**	-0.115
	(0.072)	(0.425)	(0.002)	(0.002)	(0.001)	(0.001)	(0.231)	(0.204)
Population	-0.940**	-5.013**	-10.986**	-2.694	-5.277	-0.331	-4.700***	0.653
	(0.446)	(2.416)	(5.466)	(4.646)	(3.724)	(3.943)	(1.646)	(1.650)
GDP per capita	0.185	0.783	1.877	3.734**	2.795**	3.104***	0.367	1.339***
	(0.144)	(0.689)	(1.662)	(1.465)	(1.164)	(1.159)	(0.469)	(0.473)
IPR protection index	0.136**	0.368	0.163**	-0.014	0.157*	0.010	0.959***	-0.092
	(0.055)	(0.265)	(0.080)	(0.071)	(0.092)	(0.092)	(0.317)	(0.306)
Physical capital per worker	-0.007	-0.174**	-0.360*	-0.187	-0.109	0.058	-0.035	0.016
	(0.012)	(0.075)	(0.212)	(0.207)	(0.168)	(0.177)	(0.048)	(0.055)
Human capital per worker	-0.138	-0.393	-0.227	0.154	-0.290	0.071	-0.666	0.265
	(0.104)	(0.651)	(0.353)	(0.313)	(0.267)	(0.259)	(0.415)	(0.377)
Industry fixed effects				X		X		X
Observations	476	476	476	476	476	476	476	476
R-squared	0.350	0.285						

Notes: All specifications include country and year fixed effects. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. Marginal effects are reported for Tobit and Fractional Logit regressions (columns 3-6).

Table 5: Decomposition of Licensing-Import Share

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Licensing-Import Share	Intermediate Goods Import Intensity	Intermediate Goods Import Intensity	Royalty & License Fee Intensity	Royalty & License Fee Intensity
Technology gap	-0.117***	0.008*	0.005	-0.011***	-0.010***
	(0.023)	(0.005)	(0.005)	(0.003)	(0.004)
Trade costs	0.714***	-0.189***	-0.071	0.019***	0.003
	(0.216)	(0.058)	(0.068)	(0.007)	(0.009)
Knowledge intensity	-0.901**	0.326***	-0.710	0.052***	-0.024
	(0.358)	(0.088)	(0.554)	(0.016)	(0.101)
R&D	0.106	-0.006	-0.002	-0.003	-0.004
	(0.072)	(0.019)	(0.019)	(0.004)	(0.004)
Population	-0.940**	0.052	0.086	-0.007	-0.004
	(0.446)	(0.147)	(0.144)	(0.021)	(0.020)
GDP per capita	0.185	-0.003	-0.004	-0.003	-0.002
	(0.144)	(0.050)	(0.049)	(0.008)	(0.008)
IPR protection index	0.136**	-0.021	-0.022	0.000	0.000
	(0.055)	(0.019)	(0.019)	(0.003)	(0.003)
Physical capital per worker	-0.007	-0.002	-0.001	-0.001	-0.001
	(0.012)	(0.003)	(0.003)	(0.000)	(0.000)
Human capital per worker	-0.138	0.047	0.048	-0.001	-0.001
	(0.104)	(0.055)	(0.056)	(0.012)	(0.012)
Industry fixed effects			X		X
Observations	476	449	449	461	461
R-squared	0.350	0.466	0.483	0.379	0.433

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

Table 6: Robustness-Alternative Measures of Technology Gap

	(1)	(2)	(3)	(4)	(5)
Dependent variable			Licensing-Import Share		
Technology gap (benchmark)	-0.093***				
	(0.024)				
Technology gap- (domestic labor productivity)		-0.076**			
		(0.029)			
Technology gap- (affiliate frontier)			-0.237***		
			(0.080)		
Technology gap- (affiliate frontier & dom. labor prod.)				-0.336**	
				(0.162)	
Technology gap - (max. dom. labor prod. frontier & dom. labor prod)					-0.260*
					(0.132)
Trade costs	-0.189	0.053	-0.182	0.062	0.064
	(0.235)	(0.310)	(0.232)	(0.303)	(0.302)
Knowledge intensity	-1.061	-0.313	-1.341	-0.820	-0.217
	(1.455)	(1.744)	(1.456)	(1.741)	(1.772)
R&D	-0.039	-0.097	-0.037	-0.090	-0.093
	(0.059)	(0.114)	(0.060)	(0.112)	(0.112)
Population	-0.212	-0.432	-0.329	-0.379	-0.333
	(0.378)	(0.555)	(0.387)	(0.545)	(0.537)
GDP per capita	0.355***	0.367	0.320**	0.257	0.340
	(0.130)	(0.230)	(0.139)	(0.266)	(0.237)
IPR protection index	0.013	0.065	-0.009	0.032	0.051
	(0.050)	(0.067)	(0.051)	(0.062)	(0.064)
Physical capital per worker	0.006	0.018	0.007	0.021	0.021
	(0.012)	(0.014)	(0.012)	(0.014)	(0.014)
Human capital per worker	-0.008	0.055	-0.018	0.094	0.080
	(0.095)	(0.105)	(0.095)	(0.114)	(0.109)
Industry fixed effects	X	X	X	X	X
Observations	476	411	476	411	411
R-squared	0.437	0.376	0.435	0.379	0.377

Notes: All specifications include country and year fixed effects. Technology gap (benchmark) is constructed using US MNC parent productivity in the same industry-year as the frontier and labor productivity of affiliates. Technology gap (domestic labor productivity) is constructed using US MNC parent productivity in the same industry-year as the frontier and domestic labor productivity from INDSTAT4 instead of affiliate labor productivity. Technology gap (affiliate frontier) is constructed using the most productive affiliate in the same industry-year and labor productivity of affiliates. Technology gap (affiliate frontier and domestic labor productivity) is constructed using the most productive affiliate in the same industry-year as frontier and domestic labor productivity from INDSTAT4 instead of affiliate labor productivity. Technology gap (max. domestic labor prod frontier & domestic labor prod) is constructed using the maximum labor productivity by industry-year from INDSTAT4 as frontier and domestic labor productivity from INDSTAT4 instead of affiliate labor productivity. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Robustness- Reverse Causality

	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Dependent variable	Licensing-Import Share			
Technology gap (benchmark)	-0.093***	-0.144***		
	(0.024)	(0.040)		
Technology gap (affiliate frontier)			-0.237***	-0.585**
			(0.080)	(0.250)
Trade costs	-0.189	-0.362	-0.182	-0.296
	(0.235)	(0.539)	(0.232)	(0.542)
Knowledge intensity	-1.061	-3.976***	-1.341	-3.614***
	(1.455)	(0.818)	(1.456)	(0.834)
R&D	-0.039	3.545***	-0.037	3.806***
	(0.059)	(0.100)	(0.060)	(0.141)
Population	-0.212	2.140***	-0.329	2.329***
	(0.378)	(0.073)	(0.387)	(0.119)
GDP per capita	0.355***	-0.225***	0.320**	-0.286***
	(0.130)	(0.038)	(0.139)	(0.056)
IPR protection index	0.013	-47.820***	-0.009	-51.341***
	(0.050)	(1.263)	(0.051)	(1.895)
Physical capital per worker	0.006	-0.001	0.007	-0.010
	(0.012)	(0.013)	(0.012)	(0.013)
Human capital per worker	-0.008	3.359***	-0.018	3.692***
	(0.095)	(0.096)	(0.095)	(0.200)
Industry fixed effects	X	X	X	X
Observations	476	225	476	225
R-squared	0.437	0.504	0.435	0.493

Notes: All specifications include country and year fixed effects. In IV regression of column (3), 5 year lagged value of technology gap (benchmark) is used as an instrument for technology gap (benchmark). In IV regression of column (5), 5 year lagged value of technoloy gap (affiliate frontier) is used as an instrument for technology gap (affiliate frontier). Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Other Robustness Results

	(1) Full Sample	(2) Developed Countries	(3) High-tech Industries	(4) Full Sample	(5) Full Sample	(6) Full Sample
Dependent variable			Licensing-Import Share			
Technology gap	-0.117***	-0.121***	-0.110***	-0.116***	-0.117***	-0.124***
	(0.023)	(0.024)	(0.025)	(0.023)	(0.023)	(0.028)
Trade costs	0.714***	1.291***	0.481***	1.011***	0.725***	0.724***
	(0.216)	(0.323)	(0.154)	(0.267)	(0.218)	(0.219)
Knowledge intensity	-0.901**	-1.603**	-0.388	-0.695*	-0.891**	-0.898**
	(0.358)	(0.607)	(0.390)	(0.375)	(0.361)	(0.365)
R&D	0.106	-0.152	0.177**	-0.064	0.141*	0.140*
	(0.072)	(0.191)	(0.081)	(0.052)	(0.079)	(0.079)
Population	-0.940**	1.391	-0.738*	-0.412	-0.591	-0.607
	(0.446)	(1.344)	(0.427)	(0.408)	(0.504)	(0.500)
GDP per capita	0.185	-0.732	-0.166	0.391***	0.155	0.158
	(0.144)	(0.497)	(0.130)	(0.130)	(0.148)	(0.148)
IPR protection index	0.136**	0.321	0.107*	0.064	0.147***	0.146***
	(0.055)	(0.361)	(0.061)	(0.049)	(0.054)	(0.055)
Physical capital per worker	-0.007	-0.020	0.004	-0.007	-0.007	-0.007
	(0.012)	(0.019)	(0.013)	(0.012)	(0.013)	(0.012)
Human capital per worker	-0.138	-0.101	-0.154	-0.071	-0.198*	-0.204*
	(0.104)	(0.120)	(0.153)	(0.100)	(0.100)	(0.104)
Trade costs* R&D				0.332***		
				(0.108)		
Local sales/All sales					-0.134**	-0.143**
					(0.059)	(0.070)
Technology gap* Local sales/All sales						0.020
						(0.095)
Observations	476	217	331	476	476	476
R-squared	0.350	0.365	0.504	0.361	0.353	0.353

Notes: All specifications include country and year fixed effects. Developed countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Italy, Japan, Netherlands, Norway, Singapore, Sweden, Switzerland, and United Kingdom based on GDP per capita. High-tech industries are Chemicals, Computers, Electronics, Machinery and Transportation based on R&D intensity of US MNC parents. Trade costs* R&D is the interaction of trade costs and R&D expenditures. Local sales/All sales is the fraction of local affiliate sales of all affiliate sales for each country-year. Technology gap * Local sales/All sales is the interaction of technology gap and Local sales/All sales. Robust standard errors which allow for clustering by country-year are reported in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.