Patent Protection and the Industrial Composition of Multinational Activity: Evidence from U.S. Multinational Firms

Olena Ivus, Walter Park, and Kamal Saggi*

Abstract

Using data on U.S. firms' technology licensing to local agents in developing countries, this paper examines the impact of patent protection on internal and arms-length technology transfer. The effects of protection vary across products according to their complexity. Simple products are relatively easy to imitate and so firms producing these products choose the more secure means of transfer via affiliates and subsidiaries, and also rely on a host country's patent rights to further limit the risk of technology misappropriation. Consistent with theories of internalization, stronger patent protection enables local firms to attract more arms-length technology transfer. The attractiveness of affiliated licensing rises as well among simple-product firms, strongly enough that the composition of their licensing shifts towards affiliated parties. The results withstand several robustness checks, and are equally strong whether patent protection is measured by its intensity or by the timing of reforms. The results have significance for recent work on the internalization theories of multinational firms as well as for patent policy in the developing world, where access to knowledge is critical.

Keywords: International Technology Transfer, Licensing, Developing Countries, Product Complexity, Intellectual Property Rights, and Imitation Risk

JEL classification: O34, O33, F23, K11

*Olena Ivus: Smith School of Business, Queen's University, Goodes Hall, 143 Union Street, Kingston, ON K7L 3N6, Canada. E-mail: oivus@business.queensu.ca. Walter Park: Department of Economics, American University, Washington, D.C. 20016, USA. E-mail: wgp@american.edu. and Kamal Saggi: Department of Economics, Vanderbilt University, PMB 351828, 2301 Vanderbilt Place, Nashville, TN 37235, USA. E-mail: k.saggi@vanderbilt.edu. The statistical analysis of firm level data on U.S. multinational companies and their foreign affiliates was conducted at the Bureau of Economic Analysis, United States (U.S.) Department of Commerce, under arrangements that maintain legal confidentiality requirements. Views expressed in this paper are those of the authors and do not necessarily reflect official positions of the U.S. Department of Commerce. The authors thank seminar participants at the U.S. Bureau of Economic Analysis, the Canadian Economics Association conference (2015), and the Western Economics Association International conference (2015) for their helpful comments.

1 Introduction

Multinational companies can exploit their knowledge assets either internally, within firm boundaries, or externally by contracting with independent entities. A key question in the theory of internalization has always been when and why multinational firms opt to transfer technology internally (where it is potentially more secure) as opposed to doing so via arms-length market transactions (see Contractor, 1984 and Antràs and Yeaple, 2014). On the policy side, governments of developing countries have sometimes tended to view market mediated technology transfer relatively more favorably, perhaps because of the potential for greater technology spillovers locally.[1] Furthermore, the Agreement on Trade Related Intellectual Property rights (TRIPS) ratified by the World Trade Organization (WTO) in 1995 expressly declares as its objective that the "protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology."[2] Thus, from the perspective of both economic theory and policy analysis, it is important to better understand the market and policy determinants driving the international technology licensing decisions of firms.

This paper empirically examines how the degree of patent protection in developing countries affects the choice of U.S. multinationals between internal and arms-length technology licensing. This choice is fundamental from the perspective of developing economies, particularly regarding the ability of local, indigenous firms to access new technological knowledge and know-how. We focus on the composition of licensing (affiliated versus arms-length) and the cross-product differences in the technology transfer impact of patent rights (PRs). The analysis utilizes data from the U.S. Bureau of Economic Analysis (BEA) on affiliated and unaffiliated technology licensing by U.S. multinational companies to local agents in 44 developing countries over the 1993-2009 period.

Central to our analysis is the argument that the technological complexity of products acts as a barrier to imitation, and thereby affects the risk of imitation faced by the U.S. firms operating

[1] For example, China's current indigenous innovation policy forces multinationals to share their technologies with local companies as a precondition for market entry. See Saggi (2002) for an overview of the channels by which technologies transferred to developing countries can generate local productivity spillovers.

[2] The text of this multilateral agreement is at www.wto.org/english/docs_e/legal_e/27-trips_01_e.htm.

in developing countries and influences those firms' preferred modes of technology transfer (see, for example, Donoso, 2014). Strengthening PRs limits imitation, but the impact on the technology licensing decision of firms is expected to vary across products according to the complexity of their technology. To explore the role of product complexity, we employ the task-based measure of Naghavi et a l. (2015). The measure is obtained at the product category level, based on the factor content of tasks that require complex problem-solving skills.

Two key predictions emerge from our analysis. First, we find that product complexity has a significant influence on the licensing decisions of U.S. multinational firms. The composition of licensing is relatively more skewed towards affiliated parties among firms producing less complex (which we will refer to as simple) products. This product difference in the composition of licensing is particularly pronounced in countries with strong PRs. Intuitively, simple products are inherently easier to copy or invent around and so firms are less willing to transfer their technologies to external parties. Simple-product firms choose the more secure means of transfer via affiliates and subsidiaries, and also rely on a host country's PRs to further limit the risk of technology misappropriation.

Second, we find that product complexity plays a key role in determining the technology transfer impact of PRs. Consistent with theories of internalization, strengthening PRs in developing countries makes the licensing of innovations to unaffiliated parties more attractive. This effect is equally strong across all firms, regardless of the complexity of their products. Among simple-product firms, the attractiveness of affiliated licensing rises as well when PRs are strengthened, strongly enough that the composition of their licensing shifts towards affiliated parties. For complex-product firms, by contrast, strengthening PRs reduces the attractiveness of affiliated licensing and shifts the composition of licensing further towards unaffiliated parties.

Our results are robust to different model specifications. We considered the OLS estimator with firm-by-country fixed effects, which permits regressors to be endogenous provided that they are correlated with only a time-invariant component of the error. This form of endogeneity does not explain our results. We also employed Heckman's two-stage estimation procedure, to allow for selection of firms into licensing. We show that a selection bias does not explain our results. Next, we implemented the instrumental variable estimator using colonial origin to isolate exogenous variations in PRs. We find that the endogeneity of the strength of countries' PRs also does not drive our results. Furthermore, our results are robust to additional controls (the quality of the institutional environment and the industry measure of product life-cycle lengths), and remain qualitatively unchanged when we adopt alternative definitions of the composition of licensing, use different measures of intangible assets (i.e., stocks or flows of licensing) or different measures of patent protection (i.e., the intensity of PRs or the year of major patent reform).

This paper contributes to the literature studying the impact of intellectual property rights (IPRs) on international technology transfer.[3] Like us, Ferrantino (1993), Yang and Maskus (2001), and Nicholson (2007) also focus on licensing as a channel of technology transfer.[4] Using cross country data for 1982, Ferrantino (1993) finds that intellectual property treaties interacted with the duration of patents positively influence licensing transactions. Nicholson (2007) argues that high capital costs can act as a natural barrier against imitation; all else constant, licensing should be preferred over foreign direct investment (FDI) but when IPRs are weak, FDI is more prevalent. Yang and Maskus (2001) use a panel of 23 countries over the 1985-1995 period and find a positive association between arms-length licensing and the strength of IPR protection when IPRs are above a critical level; however, the relationship between IPR protection and affiliated licensing turns out to be relatively weak. The authors argue that these findings are consistent with the internalization theory of multinational investment, namely that problems of transacting information are more

[3]The three main modes of technology transfer considered in the literature are exporting, foreign direct investment, and licensing. Maskus and Penubarti (1995), Smith (1999), Rafiquzzaman (2002), Co (2005), Falvey et al. (2009), and Ivus (2010) study exporting. Mansfield and Romeo (1980), Javorcik (2004), Nunnenkamp and Spatz (2004), Branstetter et al. (2011), Berry (2014), and Bilir (2014) analyze FDI and related multinational decisions, such as location, affiliate production, sales, and innovation. Ferrantino (1993), Yang and Maskus (2001), Park and Lippoldt (2005), Branstetter et al. (2006), and Nicholson (2007) study licensing. See Watson (2011) for a review of the empirical literature on TRIPS and technology transfer.

[4]Licensing involves the transfers of know-how and intangible assets, such as industrial processes (which account for the bulk), goodwill, trademarks, copyrights, and neighboring rights.

acute for unaffiliated licensing.[5] Park and Lippoldt (2005) focus on unaffiliated licensing by U.S. firms over the 1992-2003 period and find that patent protection in foreign countries encourages firms to transact with arms-length entities abroad. Branstetter et al. (2006) focus on affiliated licensing by U.S. parent firms over the 1982-1999 period and find that patent reforms abroad increase technology transfer from parent firms to affiliates, particularly when parents use PRs heavily.

This paper builds upon the previous literature in several important respects. First, it extends beyond the question of how patent protection affects the total volume of technology transfer via licensing to also consider how it affects the composition (affiliated versus unaffiliated) of licensing. This is in line with Yang and Maskus (2001) who stress the importance of analyzing affiliated and unaffiliated licensing in an integrated framework, and with Aulakh et al. (2010, 2013) on the need to go beyond studying *whether* firms license to *how* they license. Second, we distinguish between product categories by their complexity and study the interaction between the measure of product complexity and the nature of licensing (affiliated versus arms-length). The earlier literature allowed the impact of PRs on licensing to vary across industries, but did not examine the difference in the impact across products of different complexity.

This paper is also related to Naghavi et al. (2015) which studies the impact of PRs on the choice of multinationals between procurement from related parties and from independent suppliers. As in our paper, the focus is on how patent protection in foreign countries interacts with product complexity. Naghavi et al. (2015) also argue that simple products depend most on the strength of PRs because their underlying technologies can be easily communicated and misappropriated. A key difference between our paper and that of Naghavi et al. (2015) is that we examine the technology licensing decisions of multinationals, while Naghavi et al. (2015) studies the product sourcing decisions.

[5] See Markusen (2001) for a treatment of internalization issues in foreign direct investment. Canals and Şener (2014) in related work study the offshoring activities of high-tech firms within and beyond firm boundaries. Naghavi (2007) addresses the welfare implications of the mode of entry.

Distinguishing products by their complexity is important since product complexity affects the ease with which technologies can be imitated and therefore the incentive for internalization in international licensing.[6] Ivus (2011) studies industry variation in the technology transfer impact of IPRs when exports are the only mode of technology transfer and finds that stronger IPRs expand exports more in industries that face higher imitation risk. Ivus et al. (2015) significantly extend the North-South theoretical framework of Ivus (2011) by endogenizing the choice between arms-length licensing and foreign direct investment (FDI). They show that firms license in complex industries where the risk of imitation is low and engage in FDI in simple industries where the imitation risk is high. In their model, differences in Southern IPRs affect Northern rents and imitation risks and therefore matter for the scale and composition of technology transfer to the South. In particular, their model predicts that strengthening IPRs in developing countries will increase multinational production predominantly in simple industries, with the composition of multinational activity shifting towards arms-length licensing (as firms switch to arms-length licensing from FDI) in complex industries and towards FDI in simple industries (as firms switch to FDI from Northern production).

Other work supports the view that product characteristics matter for the effects of property rights on technology transfer. Antràs (2005) highlights the fact that products undergo a cycle: initially, they are novel and innovative, requiring investments in product development, and eventually they become standardized and require merely assembly.[7] Hence, one would expect that in the face of weak property rights or insecure contract enforcement, firms would be more likely to engage in arms-length licensing of standardized products. Bilir (2014) shows that product life determines whether or not PRs matter for multinational investment, since if products have a short

[6]The existing literature underscores the importance of the risk of imitation in determining the impact of IPRs on international technology transfer. Smith (2001), for example, shows that intellectual property protection matters more in countries where the threat of imitation is substantial. Imitation risk and appropriability conditions also vary by industry (Mansfield et al., 1981; Anand and Khanna, 2000; Cohen et al., 2000). Complexity of production can also shape the nature of intra-firm trade in other ways. Keller and Yeaple (2008), for example, show how technological complexity, along with the costs of technology transfer, determines the choice between local production and importation from parent firms.

[7]See also Şener and Zhao (2009) for a treatment of the iPod cycle and the impacts of IPRs.

life, technologies may become obsolete before imitation can occur in which case patent protection becomes irrelevant.

Two other aspects of our study deserve mention. First, we use firm-level data, whereas prior empirical studies generally use highly aggregated data.[8] Among other advantages, our approach allows us to correct for selection of firms into licensing. Second, we focus on U.S. firms' transactions with developing countries, where concerns about weak intellectual property protection have been the most prominent and where access to new technologies is crucial. The previous studies, in contrast, have generally pooled developed and developing countries together.

The rest of the paper proceeds as follows. Section 2 outlines our empirical framework and Section 3 describes our data. Section 4 examines the impact of PRs on the volume and composition of licensing and the differences in impact across products according to their complexity. Section 5 explores the sensitivity of our results, and Section 6 concludes and provides some thoughts on the policy implications.

2 Empirical Framework

The unit of analysis is the U.S. parent firm i which may transfer its proprietary technology to a foreign affiliate or unaffiliated party located in host country j in year t. The basic model of technology transfer is as follows:

$$T_{ijt} = \alpha + \beta_1 P_{jt} + \beta_2 X_{jt} + \beta_3 R_{it} + \beta_4 A_{it} + \beta_5 A_{it} \times P_{jt} + \alpha_j + \alpha_t + \tau_{jt} + \varepsilon_{ijt}, \quad (1)$$

where the outcome variable T_{ijt} is the technology transfer via the licensing of intangible assets. We distinguish between affiliated and unaffiliated licensing flows, and use the ratio of unaffiliated to affiliated licensing flows as an outcome variable to study the effects of stronger patent protection

[8] Noteworthy exceptions are Branstetter et al. (2006, 2011), Berry (2014), and Bilir (2014), where firm-level data are also used.

on the composition of licensing. The independent variable P_{jt} is the strength of patent protection in host country j at time t. X_{jt} is the vector of time-varying host country controls, including the level of real gross domestic product (GDP), wages relative to the U.S., corporate income tax rates, and a measure of inward capital restrictions. R_{it} is the parent firm R&D intensity, measured by the ratio of the parent's R&D spending to its sales. A_{it} is the ranking of a firm in its use of patents, and $A_{it} \times P_{jt}$ is the interaction of A_{it} with the host's strength of patent protection. Similar to Branstetter et al. (2006), we include $A_{it} \times P_{jt}$ to allow the impact of patent protection on technology transfer to vary with the extent to which firms utilize PRs.[9] Next, α_j and α_t are the country and year fixed effects, and τ_{jt} is the vector of country-specific linear time trends. Last, α is the constant term and ε_{ijt} is the stochastic error term.

Central to our analysis is the argument that the technological complexity of products acts as a barrier to imitation and so affects the product dependence on patent protection. The impact of PRs on technology transfer is expected to differ across products according to their technological complexity. To examine the role of product complexity, we augment the model (1) as follows:

$$T_{ijt} = \alpha + \beta_1 P_{jt} + \beta_2 X_{jt} + \beta_3 R_{it} + \beta_4 A_{it} + \beta_5 A_{it} \times P_{jt} + \beta_6 Z_p + \beta_7 Z_p \times P_{jt} + \alpha_j + \alpha_t + \tau_{jt} + \varepsilon_{ijt}, \quad (2)$$

where Z_p is the level of complexity of product category p and $Z_p \times P_{jt}$ the interaction between the product complexity measure and the host's patent protection. The variable Z_p allows technology transfer to differ among the product categories for reasons other than the strength of PRs. Each firm i produces within a single product category p over time.

The coefficient on P_{jt} in the model (2) is expected to be positive when either unaffiliated or affiliated licensing is the outcome variable. Unaffiliated licensing involves sharing technology with arm's length firms which are generally independent of control. It carries high risk of imitation for U.S. firms operating in developing countries with weak PRs. Affiliated licensing is also risky, since

[9]In contrast with Branstetter et al. (2006), where the measure of patent rank is constant over time, A_{it} is time-varying.

it requires firms to transfer proprietary technical information to their subsidiaries in developing countries which in turn may be misappropriated by the subsidiary's employees and used to start up imitative production. Stronger host's patent protection limits imitation and so is expected to promote the licensing of innovations to both affiliated and unaffiliated parties.

Importantly, the licensing impact of stronger PRs is expected to depend on the complexity of a firm's products. The risk of imitation is particularly high for firms producing simple products, the underlying technologies of which can be easily communicated and misappropriated. Accordingly, we expect simple-product firms to choose the more secure means of transfer via affiliates and subsidiaries, while still heavily relying on the host country's PRs to ensure a lower risk of technology misappropriation. Thus, we expect a negative coefficient on $Z_p \times P_{jt}$ when affiliated licensing is the outcome variable. This would imply that the impact of PRs on affiliated licensing is particularly strong among firms producing simple products. We also expect the coefficients on Z_p and $Z_p \times P_{jt}$ to be positive ($\beta_6 > 0$ and $\beta_7 > 0$) when the ratio of unaffiliated to affiliated licensing is the outcome variable. This would imply that the composition of licensing is relatively more skewed towards affiliated parties among simple-product firms, particularly so in host countries with strong PRs.

3 Data

Our data come primarily from a micro database of U.S. parent companies with foreign direct investments and operations around the world.[10] The data are collected by the BEA in its benchmark and annual surveys of the operations of U.S. multinational companies, its quarterly balance of payments survey of U.S. direct investment abroad, and its annual and quarterly surveys of U.S. international services transactions. The BEA surveys cover both direct investment activities abroad and service transactions, such as the licensing of intangible assets.

[10] Our data sources are summarized in Appendix I.

We focus on technologies transferred by U.S. parent companies to 44 developing countries.[11] Together, these countries account for over 96% of affiliated, and over 98% of unaffiliated, licensing fees and royalties received by U.S. multinational firms from the developing world. The data are annual from 1993 to 2009. Only large U.S. parent companies are required to complete a detailed survey form that includes the reporting of parent company R&D and so the sample is skewed towards large U.S. parent companies that engage in R&D and patenting.[12] In total, 1,185 U.S. firms operated across these 44 developing countries—some operated in only one country, while others in multiple countries—giving us 5,309 unique firm-by-host country pairs. Some of these pairs are observed in our data for a short period, while others exist for a longer period.

To obtain the level of unaffiliated licensing, we aggregated all licensing fees and royalties received by the parent firm from unaffiliated parties in host country j at year t. Likewise, the level of affiliated licensing was obtained by aggregating all the licensing fees and royalties received from its foreign affiliate(s) in host country j at year t. The data are in real 2005 PPP dollars.

The analysis is performed on the flow of licensing. In Section 5, we reanalyze the data using the stock of licensing capital as an alternative measure. We do this to confirm that our results are not driven by our choice of the measure of licensing. To construct the stock measure, we use the perpetual inventory method with a depreciation rate of 20%.[13] The stock measure serves to account for any cumulative effects of technology transfer. Due to the characteristics of "knowledge" assets, a licensing transaction that gives access to knowledge could create some persistence in benefits.

[11] The countries are listed in Appendix II. Our classification of developing countries is based on that of the United Nations (see UNCTAD *Handbook of Statistics*, Geneva 2009). Though some of these countries have exhibited rapid growth during the sample period—for example, South Korea and Singapore—there had been major concerns with their IP provision and enforcement, imitative activities, and piracy during that period (see Business Software Alliance *Global Software Piracy Study*, Washington, D.C. 2002). This makes it relevant to include them in a study of the impacts of their IPR reforms and sources of technology catch-up.

[12] As for the foreign affiliates of U.S. parents, the affiliates must be above a certain threshold level of assets or sales in order to be reported on the BEA surveys. The threshold amounts are usually lower in benchmark years (every five years) and as a result, the sample of foreign affiliates surveyed is not universal across years. In non-benchmark years, smaller affiliates under the threshold are not surveyed and data for them are extrapolated forward from benchmark years in order to generate a steady universal coverage.

[13] The stock of licensing in year t is $Stock_{ijt} = T_{ijt} - \delta Stock_{ijt-1}$ and the initial stock is $Stock_{ij0} = T_{ij0}/(g + \delta)$, where T_{ij0} is the initial flow, g the sample average growth rate of licensing flows, and δ the depreciation rate. We set $\delta = 0.2$. Alternative depreciation rates (e.g., 0.05, 0.1, and 0.15) yield similar results.

Unlike with physical rental properties, the licensee does not "return" the intangible asset or know-how upon the conclusion of the terms of a technology transfer agreement. Some of the knowledge assets acquired with the flow of licensing is retained by the licensee and continues to benefit the licensee until it is fully depreciated. The economic effects of technology transfer can therefore persist beyond the transaction period, even if the licensing agreement prohibits future use or exploitation of the intellectual property without the appropriate fees or royalties. The strength of patent protection in a host country could affect the formation of this type of technology capital as well as impact the flow of technology transfers.

We measure the strength of patent protection by the Park (2008) index of PRs. The index varies across countries and over time. It is based on legislation and case laws which establish how such legislative provisions are interpreted and enforced. The components which comprise the PRs index include membership in international agreements, duration of protection, the patentability of certain types of inventions such as software, enforcement mechanisms, and the presence of any restrictions on PRs such as compulsory licensing and working requirements. To avoid contemporaneous influence from foreign technology transfers to the setting of domestic patent protection, we lag the index four years.[14]

In Section 5, we also consider a patent reform dummy variable as an alternative measure of the strength of patent protection. This dummy equals one for the year of major patent reform(s) and all years thereafter. When selecting the year of major patent reform(s), we considered only the most significant shifts in the patent system during our sample period and ignored minor revisions to countries' patent laws and practices.[15]

To explore the role of product complexity, we employ the task-based measure from Naghavi et al.

[14] The sample period goes up to 2009, but the PRs index goes up to 2005. The index values follow a step function, shifting approximately every five years during the sample period. Lagging the index mitigates the endogeneity concern, but does not necessarily correct for endogeneity. We employ alternative methods of treating endogeneity in Section 5.

[15] This is comparable to a change of at least a half standard deviation in the PR index. The year of a major reform(s) in each country is listed in Appendix II.

(2015). The measure is obtained at the product category level (2-digit *Nomenclature of Economic Activity* (NACE) codes), based on the factor content of tasks that require complex problem-solving skills. It is constructed as the interaction of three variables. First is the complexity score for 809 (8-digit) occupations as defined in the Standard Occupational Classification. The score is derived using expert information on the level and importance of complex problem-solving skills provided in the O*NET data. Second is the industry occupational intensity, using information on the employment of labor across different occupations by 3-digit *Standard Industrial Classification* (SIC) industries from the U.S. Bureau of Labor Statistics' Occupational Employment Statistics. Third is the share of industry in the production of each product. The overall measure indexes each product category according to the complexity level of the tasks involved in the product's manufacturing. In our analysis, we focus on 15 high-tech manufacturing product categories, for which patent protection is expected to matter most. To match the measure of product complexity to our data, we sort the 4-digit NAICS codes associated with each firm into the corresponding product categories. Appendix III summarizes these data.

Data on U.S. patents granted by firm (utility patent counts) are from the National Bureau of Economic Research's Patent Data Project. Starting with the firms in the BEA parent firm sample, we matched the firm employer-identification-numbers (EINs) to the Committee on Uniform Securities Identification Procedures (CUSIP) codes of firms in Compustat, since the NBER database uses CUSIP codes. This allowed us to find the U.S. patents granted to a partial sample of the parent firms in our data. We match the rest of the data manually by comparing firm names and/or company initials.[16]

To obtain parent patent rank A_{it}, we computed the four-year moving average of U.S. patents granted to each firm in each year. The time averaging of a firm's patent portfolio helps capture the intensity of the firm's use of patents beyond a short run horizon. Then for each year, we split firms into two groups depending on the amount of U.S. patent grants that a firm received in a

[16] About 56% of our sample of firms (i.e., U.S. parent firms engaging in FDI in the 44 developing countries) were matched to NBER's Patent Database using CUSIP codes. The rest of the data was matched manually.

given period. $A_{it} = 0$ for firms below median U.S. firm patenting and $A_{it} = 1$ for firms above median U.S. firm patenting. A_{it} is time-varying because a firm may be ranked low in one year but high in another. To mitigate the concern that a firm's patenting strategies may depend on its licensing and commercialization decisions, we use the three-year lagged patent rank.[17]

The parent firm R&D intensity is defined as the ratio of the parent firm R&D spending to its sales. The corporate income tax rate faced by the foreign affiliates of the parent firm in the host country is defined as the ratio of income taxes paid to the firms' pre-tax net income. Both of these measures come from the BEA data. As Griffith et al. (2014) show, this tax rate can be an important influence on the location of IP assets.[18] The measure of inward capital restrictions is a dummy variable which equals one if a host country placed capital controls on inward foreign direct investment in a given year. These data are from the International Monetary Fund. To control for the market size of host countries, we use real GDP levels (in constant 2005 PPP dollars) from the World Development Indicators. We also use data on relative hourly wages (in U.S. dollars) in the manufacturing industry to control for the relatively low cost of labor in developing countries, which motivates parent firms to establish foreign affiliates in these countries. The relative wage variable is constructed as the ratio of the host's hourly wage to the U.S. hourly wage. The hourly wage data are compiled by the Occupational Wages around the World (OWW) Database.[19]

In our sensitivity analysis, we use three additional variables: the quality of legal and economic institutions; the industry measure of product life-cycle length; and the cost of patenting abroad

[17] Since patenting is costly, a firm may choose not to acquire or maintain patents if it does not see much profit potential from licensing.

[18] Specifically for each host country, the income taxes of the parent's affiliates were aggregated and then divided by the aggregate pre-tax net incomes of these affiliates. The median ratio is used to represent the corporate income tax rate for that country. Net income is defined as gross income minus total costs and expenses. The tax base uses net, rather than gross, income to obtain a measure of taxable income. Countries vary in terms of their statutory tax rates and regulations on tax deductions, so that gross income would not consistently measure what is taxable.

[19] The OWW database offers several options. We chose the country-specific calibration method, which refers to how the wage dataset was cleaned up (for example, by making the wage figures consistent with country-specific figures on GDP per capita). We also selected the lexicographic method of treating differences in the reporting of data on hours worked and wages. This method assigns hours worked first by city, then by gender, then by pay concept, and so forth. These options are recommended for providing the largest sample. Details are discussed in Oostendorp (2012).

per market size. The data on institutional quality are from Kunčič (2014). These institutional measures are composite indicators which combine the information of several institutional indices from the Heritage Foundation, the Wall Street Journal, Freedom House, Fraser Institute, World Bank World Governance Indicators, and so forth. Our measure of the industry product life-cycle length is binary. To generate this variable, we used the data in Bilir (2014). Specifically, we calculated the median product life-cycle length and then constructed a dummy variable which takes the value of one if an industry's product life-cycle length is above the median and zero if it is below the median. The cost of patenting is from Park (2010). The measure covers both the cost of procurement (filing, attorney, translation, search and examination fees) and maintenance (renewal fees). It varies by host country and year. We divide the cost of patenting by GDP to obtain the cost of patenting per market size.

Table 1 summarizes data on the three outcome variables (i.e., the flow of unaffiliated licensing, the flow of affiliated licensing, and the ratio of unaffiliated to affiliated licensing flows) and two firm-level controls (R&D intensity and patent rank) across all parent firms and across firms by product complexity (below and above median). Compared to parent firms in simple industries, parent firms in more complex industries receive on average a greater flow of licensing income from unaffiliated parties and a lower flow of licensing income from foreign affiliates. The respective differences in means are 358.0 and -160.9. When unaffiliated licensing flow is evaluated relative to its affiliated counterpart, we see that this ratio is 0.823 points higher for firms in more complex industries. We also see that firms in more complex industries have on average 2.97 percentage points greater R&D intensity and 0.12 points higher patent rank (meaning they utilize PRs relatively more). All the differences in means are highly statistically significant. Overall, these results point to important differences across products of different complexity and suggest that the complexity of products influences the technology transfer impact of PRs.

The results in Table 1 are not driven by aggregation of product categories into two groups but also hold at the level of individual industries. Table 2 summarizes the results for 8 industries. It shows that product complexity is highest in *Machinery and equipment*, *Electronics and components*, and *Transportation*. These complex-product industries together account for as much as 89.4% of the total unaffiliated licensing by U.S. multinational firms in the 44 developing countries. At the same time, these industries' combined share of the total affiliated licensing is only 44.8%. Across industries with lower product complexity, by contrast, affiliated licensing is generally more common than its unaffiliated counterpart. The share of affiliated licensing is relatively high in all discrete industries, except *Energy*. Two industries (i.e., *Pharmaceuticals* and *Non-pharmaceutical chemicals*) account for 49.3% of all affiliated licensing in manufacturing.

Figure 1 further plots unaffiliated to affiliated licensing flows (in thousands of real 2005 U.S. dollars) for host countries grouped by the strength of their PRs. Here, the U.S. parent firms' royalty fees and licensing receipts are pooled across all firms during the sample period. It is apparent that affiliated licensing is the most common. This is true in all three country groups, regardless of the strength of PRs, but the gap between affiliated and unaffiliated licensing is narrowest in countries with the strongest levels of patent protection. These country-level comparisons further reveal that countries with weak PRs (compared to the top third countries) supply on average a lower flow of licensing income from both unaffiliated parties and foreign affiliates. The difference is particularly striking for unaffiliated licensing. One possible explanation, which we explore in detail in Section 4, is that unaffiliated licensing carries the highest risk of technology misappropriation and imitation for U.S. firms operating in countries with weak PRs.

4 The Volume and Composition of Licensing

In this section, we examine the effects of patent protection on unaffiliated licensing, affiliated licensing, and the ratio of the two, controlling for other factors. The results are presented in two parts. In Section 4.1, we estimate the model (1), which does not allow the impact of PRs to differ across products according to their complexity. We then introduce the measure of product complexity and estimate the model (2) in Section 4.2. The models are estimated using the random effects estimator which treats the firm-by-country specific effects as a random time-invariant component of the error. We do this to allow the estimation of time-invariant factors of interest, such as product complexity. As a robustness check, we also estimate the model (2) using the OLS estimator with firm-by-country fixed effects in Table 5, Section 5.1. We show that our results are not driven by our choice of the model, and that the firm-by-country specific effects could be treated as random.

4.1 Aggregate Results

Table 3 shows the results of estimating the model (1). The outcome variables (in logs) are: unaffiliated licensing fees and royalty receipts (T^U), affiliated licensing fees and royalty receipts (T^A), and the ratio of unaffiliated to affiliated receipts (T^U/T^A). All regressions include fixed effects for each country and year, as well as host-country specific time trends. Standard errors are clustered by country×year in all tables.[20]

It is apparent from Table 3 that the coefficient on the PRs index is positive and statistically significant at the 5% level in columns (1) and (2) and not statistically different from zero in column (3), where T^U/T^A is the outcome variable. These findings suggest that when product complexity is not taken into account, stronger PRs promote unaffiliated and affiliated licensing to a similar degree, leaving the composition of licensing unchanged. We show later that these aggregate results fail to hold when we allow the impact of PRs to differ across products according to their complexity.

The coefficients on the parent firm patent rank A_{it} and its interaction with the host's index of PRs are not statistically significant at the 5% level in column (3). Thus the data do not provide

[20] We cluster standard errors by country×year, rather than by country alone, to increase the number of clusters. The number of clusters must be large relative to the cluster sizes in order to correct for the presence of within-cluster correlations. Petersen (2009) noted that "when there are too few clusters, clustered standard errors are biased even when clustered on the correct dimension" (from p.475). Keller and Yeaple (2013), for example, also cluster errors by country×year, and use firm-level data on U.S. multinationals to study barriers to transferring knowledge across space.

evidence that the composition of licensing differs across firms below and above median U.S. firm patenting. Also, the impact of stronger PRs on the composition of licensing does not vary with the parent firm patent ranking. The coefficients on the hosts' relative wages and corporate income tax rates are statistically insignificant. Inward capital restrictions abroad encourage firms to access foreign markets by partnering or transacting with unaffiliated parties, as suggested by the positive and significant coefficient on the capital restrictions variable in column (1). Importantly, none of these factors affect the ratio of unaffiliated to affiliated licensing. They all seem to have a balanced or neutral effect on the licensing volumes so that the composition of licensing is left unchanged. The host country's level of GDP and parent firm R&D intensity are the only exceptions. These two variables are positively associated with unaffiliated and affiliated licensing but negatively associated with the licensing ratio. Thus, R&D-intensive parent firms favor affiliated over unaffiliated licensing. To the extent that R&D-intensive firms invest more heavily in their innovations, they are more prone to keep their knowledge assets within firm boundaries. The positive and highly statistically significant, coefficient on the parent firm patent rank in column (2) is in line with this finding as it shows that relative to firms below median U.S. firm patenting, firms above median U.S. firm patenting engage in more affiliated licensing.

4.2 Complexity Results

We now examine whether the incentive to shift to unaffiliated licensing, or to share knowledge with external parties, as PRs become more secure depends on the complexity of products. Table 4 shows the results. As in Table 3, the outcome variables are T^U, T^A, and T^U/T^A. In addition to the controls in Table 3, we include the measure of product complexity (Z_p) and its interaction with PRs ($Z_p \times P_{jt}$). All regressions include fixed effects for each country and year, as well as host-country specific time trends.

We first consider the effects of product complexity. From column (3), the coefficients on Z_p and $Z_p \times P_{jt}$ are positive and highly statistically significant when T^U/T^A is the outcome variable.

Thus, all else being equal, firms producing simple products (relative to firms producing complex products) have, on average, a lower ratio of unaffiliated to affiliated licensing. In other words, the composition of licensing is relatively more skewed towards affiliated parties among simple-product firms. This product difference in the composition of licensing is particularly pronounced in countries with strong PRs. Intuitively, simple products are inherently easier to copy or invent around and so firms are less willing to transfer their technologies to external parties. Simple-product firms choose the more secure means of transfer via affiliates and subsidiaries, and also rely on a host country's PRs to further limit the risk of technology misappropriation.

The results in column (3) imply that product complexity, by itself and together with patent protection, plays a key role in determining the composition of licensing. The results in columns (1) and (2) further our understanding of this role. In column (1), where T^U is the outcome variable, the coefficient on Z_p is positive and statistically significant at the 5% level and the coefficient on $Z_p \times P_{jt}$ is negative but not statistically significant at the 5% level. Thus across all firms, simple-product firms engage in unaffiliated licensing less. This is because licensing proprietary technology to an arm's length firm in a developing country carries a high risk of technology misappropriation. The product difference in unaffiliated licensing is similar across developing countries, regardless of the level of their PRs. In column (2), where T^A is the outcome variable, the coefficients on Z_p and $Z_p \times P_{jt}$ are both negative and statistically significant at the 5% and 1% level. Thus firms producing simple products engage in affiliated licensing relatively more. This is especially true in countries with strong PRs.

We now consider the effects of stronger patent protection. From column (1), the elasticity of unaffiliated licensing with respect to the index of PRs is $d \ln T^U / d \ln PRs = 0.314 - 0.042 \bar{A}_{it}$.[21] In our data, the mean patent rank is $\bar{A}_{it} = 0.48$ and so, $d \ln T^U / d \ln PRs > 0$ for any Z_p. This result implies that strengthening PRs in developing countries makes the licensing of innovations to unaffiliated parties more attractive. This effect is equally strong across all firms, regardless of the

[21]The coefficient on Z_p interacted with PRs is not statistically significant at the 5% level in column (1) and so is not taken into account.

complexity of their products. From column (2), $d \ln T^A / d \ln PRs = 1.394 - 4.165 Z_p > 0$ for any $Z_p < 0.335$. The variable Z_p ranges from a minimum of 0.1839178 to a maximum of 0.4221271. Thus it follows that among simple-product firms, the attractiveness of affiliated licensing rises as well when PRs are strengthened. The results further indicate that the increase in affiliated licensing among simple-product firms is strong enough that the entire composition of their licensing shifts towards affiliated parties. This follows from column (3), since $d \ln(T^U/T^A)/d \ln PRs = -1.069 + 3.512 Z_p < 0$ for any $Z_p < 0.304$. For complex-product firms, by contrast, strengthening PRs reduces the attractiveness of affiliated licensing and shifts the composition of licensing further towards unaffiliated parties.

The coefficients on the other controls in Table 4 are similar to those in Table 3. As before, R&D intensity and host country GDP are positively associated with both types of licensing, but their association is stronger with affiliated licensing, as evidenced by the negative and highly statistically significant coefficients -0.038 and -1.027 in column (3). The coefficients on A_{it} are positive and statistically significant at the 5% level in columns (1) and (2). These results suggest that firms above median U.S. firm patenting engage in relatively more unaffiliated and affiliated licensing, as they have more technologies, inventions, and other intangible assets to license. At the same time, the coefficient on the interaction of A_{it} with the host's index of PRs is negative and statistically significant at the 5% level in column (1). This result suggests that stronger PRs are more important to the unaffiliated technology transfers of firms with small, rather than large, patent portfolios. As Masurel (2002) finds, small-medium enterprises tend to have a smaller patent portfolio since the cost of patenting is more burdensome for them and since they do not have in-house specialists dealing with patents. Consequently, parent firms with large portfolios are initially better protected and so may depend relatively less on PRs. Restrictions on FDI favor unaffiliated licensing. The host's corporate income tax rate and relative wage do not have a statistically significant impact on either type of licensing. Importantly, none of these four variables (i.e., parent patent rank, capital restrictions on FDI, host corporate income tax, and relative wage) affects the composition of licensing.

To check that our results in Table 4 are not driven by cross-product differences in technology transfer independent of PRs, we include product fixed effects. Column (1) in Table 1A, Appendix IV, reports the results for the ratio of unaffiliated to affiliated receipts as the outcome variable. The coefficient on Z_p is not identified in this model (since all cross-product variation is consumed by product fixed effects), but the coefficients on P_{jt} and $Z_p \times P_{jt}$ remain of the same sign and statistical significance. The coefficient on $Z_p \times P_{jt}$ rises in magnitude. In column (2) of Table 1A, we also include 9 interactions of industry effects with the strength of PRs. We do this to allow for the industry-specific impact of PRs, which could be important since the impact of PRs is expected to vary across industries for reasons other than industry differences in product complexity. For example, we observe a lot of unaffiliated licensing in the *Machinery and equipment* and *Electronics and components* industries because of their specific input-output structure. Components and intermediate inputs produced in these industries are used in other products or designed to work with other pieces. Often, multiple patented inventions comprise a single product (e.g., smartphone), each owned by different parties from within and outside the firm network. Consequently, cross-licensing and outsourcing of production, assembly, or marketing tasks to agents external to the firm—which necessitate authorizing and giving access to know-how and technology to unaffiliated parties—are predominant in these categories. Changes in bargaining power or prospecting opportunities resulting from changes in the strength of PRs are also expected to impact licensing in these industries. The interactions of industry effects with the strength of PRs absorb cross-industry variation in the impact of PRs, leaving within-industry cross-product variation in complexity (as well as within-country over time variation in the strength of PRs) to identify the coefficient on $Z_p \times P_{jt}$. The coefficient is still positive and highly statistically significant, but is larger.

5 Sensitivity Analysis

In this section, we examine the sensitivity of our results. We proceed in three steps. First, we confirm that our results are robust to different model specifications. We consider the OLS estimator with firm-by-country fixed effects, the two-stage selection model, and the instrumental variable (IV) estimator using colonial origin to isolate exogenous variations in PRs. Tables 5-7 follow. Second, we confirm that our results are robust to additional controls. We add the quality of institutional environment and the industry measure of product life-cycle lengths in Table 8. Last, we reanalyze the data with a different measure of intangible assets (i.e., stocks instead of the flows of licensing), an alternative definition of the composition of licensing, and an alternative measure of patent protection (i.e., the patent reform dummy). Tables A2-A4 in Appendix IV show the results.

5.1 Model specification

The results in Section 4 were obtained using the random effects estimator which treats the firm-by-country specific effects as a random time-invariant component of the error. This estimator is inconsistent if the firm-by-country specific effects are in fact correlated with the regressors, in which case the regressors are endogenous. To allow for this form of endogeneity, we re-estimate the model (2) using the OLS estimator with firm-by-country fixed effects. Table 5 shows the results. The firm-by-country fixed effects wipe out all cross-sectional variation in our data, leaving variation within firm-country pairs over time to identify the coefficients on our variables of interest. Since the product complexity measure does not vary over time, it cannot be estimated here. It is apparent that the results in Table 5 are very similar to those in Table 4. The coefficients on P_{jt} and $Z_p \times P_{jt}$ have the same sign and are close in magnitude. The statistical significance of these coefficients is also largely unaffected. The coefficient on P_{jt} is statistically significant at the 5% level in all three columns, and the coefficient on $Z_p \times P_{jt}$ is statistically significant at the 5% level in columns (2) and (3).

Not all firms license to all countries and so some of the licensing flows are recorded as zero in our data. We disregarded these zero firm-country pairs so far but if the occurrence of zeros is non-random, our results may be biased because they do not account for selection of firms into licensing. To ensure that our results do not suffer from a selection bias, we next use Heckman's two-stage estimation procedure (Heckman, 1979). Stage 1 is the selection equation which models the probability of a firm selecting into licensing. Stage 2 is a linear regression equation which models the flow of licensing correcting for selection bias. We use the cost of patenting relative to a country's market size (i.e., scaled by GDP) as the exclusion restriction. Firms that license abroad typically file for patent protection first in order to protect what they are licensing to others. The cost of filing may affect the decision to patent and then license, but it should not affect the volume of licensing directly. In other words, patenting cost affects firms' *decisions* to protect and market an asset, but not their extent of activity with the asset once they acquire the protection.

Table 6 shows the two-stage estimation results, with stage 1 results in Panel A and Stage 2 results in Panel B. In Panel A, the dependent variable is equal to one if the flow of unaffiliated licensing is non-zero in column (1); if the flow of affiliated licensing is non-zero in column (2); or if the ratio of unaffiliated to affiliated licensing is non-zero in column (3). It is apparent from the coefficient on the cost of patenting is negative and highly statistically significant. Thus the cost of patenting is an appropriate exclusion restriction. From Panel B, the coefficient on the inverse Mills ratio λ is not statistically different from zero in all columns. As such, there is no evidence of selection bias.[22]

A key issue in examining the impact of patent protection is the treatment of endogeneity (Maskus and Penubarti, 1995). A wide range of domestic factors may influence countries' inflows of innovative products and technologies and their implementation of patent laws.[23] Moreover, the decision to strengthen PRs could be driven by foreign technology transfers themselves and the desire of a country to build and protect its own innovative capacity. Techniques employed so far—lagging the index of PRs four years and including country and firm-by-country fixed effects—mitigate these concerns, but do not necessarily correct for endogeneity.

[22]We also used the cost of patenting without scaling by GDP as the exclusion restriction and obtained similar results.

[23]For example, competition policy, innovative capacity, openness to trade, economic integration, and the level of development.

To estimate the causal effect of patent protection, we adapt the IV approach from Ivus (2010) in which colonial origin is used to isolate exogenous variation in PRs. Specifically, Ivus (2010) argues that the imposition of TRIPS provided an exogenous shock to the PRs protection offered in a subset of developing countries. To isolate this exogenous variation, Ivus (2010) distinguishes developing countries by their colonial origin: countries which were not colonized by Britain or France (Non-colonies) are classified as treated, while those formerly colonized by Britain or France (Colonies) are classified as non-treated. The data show that over the 1990-2005 period, Non-colonies increased their PRs relatively more than Colonies; and colonial origin is relevant for explaining variation in changes of PRs over time.

To implement the IV approach, we difference the data over 15-year periods and relate changes in licensing between 1993-1994 and 2008-2009 to changes in PRs between 1990 and 2005.[24] The resulting data are a cross-section of firms. Among 44 developing countries in our sample, 25 are Non-colonies and 19 are Colonies. We use three variables—a Non-colony dummy variable (NC_j) and the interactions of NC_j with the product complexity measure and the parent patent rank—as excluded instruments for the three endogenous variables—the changes in PRs (ΔP_{jt}) and the interactions of ΔP_{jt} with the product complexity measure and the parent patent rank. Our IV approach is valid under the assumption that colonial origin has no effect on the outcome of interest, other than its effect through changes in PRs. This assumption might be too strong when growth in licensing flows is the outcome variable. This is because it requires colonial origin to be unrelated to unobserved measures of licensing growth, which we cannot rule out. The assumption is, however, far less restrictive when the growth in the ratio of unaffiliated to affiliated licensing, $\Delta(T^U/T^A)$, is the outcome variable. It requires that the colonial origin of a developing country does not directly determine the growth in the *composition* of licensing, which is far more credible.

Table 7 shows the IV estimates. Columns (1)-(3) report the first-stage regression results, where each of the three endogenous variables are the outcome variables; and column (4) reports the

[24] Recall that the sample period goes up to 2009, but that the PRs index goes up to 2005. The licensing data are averaged over two consecutive years (e.g., 1993 and 1994) before changes are calculated.

second-stage regression results, where $\Delta(T^U/T^A)$ is the outcome variable. In the first-stage regression results, the test of underidentification rejects the null hypothesis of underidentification at the 0.001% level and indicates that the instruments are relevant. The Weak Identification test suggests that the instruments are not weak; the robust Kleibergen-Paap Wald rk F statistic equals 65.29. Also, the endogeneity test of endogenous regressors does not reject the null hypothesis that the PRs changes regressor and its interactions are exogenous variables, suggesting that the results reported so far do not suffer from the endogeneity bias. Indeed, the IV estimates are in line with the estimates in Table 4. From column (4), the coefficient on the PRs changes is negative and the coefficient on the interaction of PRs changes with the product complexity measure is positive. Both coefficients are highly statistically significant.

5.2 Additional controls

Next, we check if our results are robust to additional controls. We add controls for the quality of legal and economic institutions, since our measure of PRs could be picking up the effects of broader institutional changes correlated with patent protection. We also include the industry measure of product life-cycle lengths (by itself and interacted with the strength of PRs), since this measure matters for multinational activity (Bilir, 2014) and could be correlated with our product complexity measure.

It is apparent from Table 8 that we obtain similar results. The coefficients on P_{jt}, $Z_p \times P_{jt}$ and Z_p are of the same sign and are all highly statistically significant in columns (3) and (6). We also observe that the coefficient on the interaction of the index of PRs with the product life-cycle length is positive and statistically significant at the 5% level in columns (1) and (4). Thus, as in Bilir (2014), we find that patent protection is more effective in industries with longer product life-cycle. At the same time, the length of product life cycle does not affect the impact of PRs on the composition of licensing, as evidenced by the statistically insignificant coefficients on $Z_p \times P_{jt}$ in columns (3) and (6). Interestingly, we also find that affiliated licensing is more common in industries with a long product life-cycle, while unaffiliated licensing is more common in industries with a short product life-cycle. Bilir (2014) argues that if product life-cycle is short, obsolescence is more likely to occur before imitation. Low risk of product imitation may be the reason why we observe more unaffiliated licensing in industries with a shorter product life-cycle.

5.3 Measures of licensing and PRs

We also check if our results are sensitive to our measure of licensing. We first re-estimate the model (2) using the stock measure of licensing. The results, reported in columns (1)-(3) of Table A2, are remarkably similar to those in Table 4, where the flow measure of licensing was used. The signs and the statistical significance of the coefficients on P_{jt} and $Z_p \times P_{jt}$ remain the same. In columns (4) and (5), we redefine our measure of the composition of licensing as the share of unaffiliated licensing in total licensing. The results in column (4) are for licensing flows and those in column (5) are for licensing stocks. It is apparent that our results are qualitatively unchanged.

Our findings are also not driven by our measure of PRs. We show this using the patent reform dummy variable as an alternative measure. It measures whether or not a reform occurs and allows us to study changes in technology transfer that occur around the time of reform. The PRs index, on the other hand, captures the degree to which PRs are affected and allows us to study the relationship between technology transfer and the intensity of patent protection. Table A3 shows these results, where the models are estimated using the random effects estimator in columns (1)-(3) and the OLS estimator with firm-by-country fixed effects in columns (4)-(6).

6 Conclusion

This paper studies the impact of patent protection on U.S. multinational firms' technology transfers to developing countries, where the security of patent rights protection has been (and still remains) a major concern. It moves beyond previous work by focusing on the composition of licensing (between affiliated and arms-length) and the cross-product differences in the technology transfer impact of PRs. The analysis utilizes data from the U.S. Bureau of Economic Analysis (BEA) on affiliated and unaffiliated technology licensing by U.S. multinational companies to local agents in 44 developing countries over the 1993-2009 period. This is the time period over which a large number of WTO members had to strengthen their degree of patent protection to ensure their intellectual property regimes were TRIPS compliant.

Our results show that the incidence of arms-length licensing is starkly lower among firms producing simple products. A rather small share of parent companies' royalties and licensing receipts from developing countries in simple-product industries, such as pharmaceuticals, come from unaffiliated parties. Simple products are inherently easier to copy or invent around and so simple-product firms choose the more secure means of transfer via affiliates and subsidiaries, and also rely on host country's PRs to further limit the risk of technology misappropriation. Strengthening PRs in developing countries limits imitation and so provides all firms with a stronger incentive to increase their engagement in unaffiliated licensing. The attractiveness of affiliated licensing also rises among firms producing simple products, strongly enough that the composition of their licensing shifts towards affiliated parties. For firms producing complex products, by contrast, the composition of licensing further shifts towards unaffiliated parties. Our regression analysis picks up these compositional shifts, once we allow for variations in product complexity.

These results are robust to different model specifications: the OLS estimator with firm-by-country fixed effects, the two-stage selection model, and the instrumental variable estimator. The results are also robust to controlling for the quality of the institutional environment and the industry measure of product life-cycle lengths, and remain qualitatively unchanged when we adopt alternative definitions of the composition of licensing and use different measures of intangible assets or different measures of patent protection.

This research contributes to the discussion concerning the role of IPR protection in business strategy (Hagedoorn et al., 2005; Allred and Park, 2007; Coeurderoy and Murray, 2008; Wang et al., 2012; Aulakh et al., 2013). The study is significant for recent work on the internalization theories of multinational firms. Imperfections in contracting (e.g., due to weak IPRs) can impede transfers of proprietary knowledge between independent entities, as multinational firms choose largely to internalize the market for technology within firm boundaries (or even to concentrate their critical R&D in their headquarters, as Di Minin and Bianchi (2011) find). This explains why affiliated licensing, or technology transfer between parents and affiliates, tends to dominate. Firms producing products subject to high imitation risks tend to have a greater incentive for internalization and a stronger reliance on a host country's patent protection.

Our work also has significant policy implications. One of the objectives of global IPR reforms is to provide developing countries with a greater access to new knowledge and new technologies. This is an explicit principle embodied in the TRIPS agreement, as we pointed out earlier. By specifically targeting incentives for *unaffiliated* licensing, policy-makers can push technological knowledge beyond the multinational firm network. Although beneficial in its own right, greater flows of intra-firm technology transfers may not promote widespread access to new technologies in developing countries, particularly if the control of such technologies remains largely privileged within the boundaries of multinational firms. For example, local (arms-length) firms may not obtain crucial know-how merely by relying upon knowledge externalities from affiliate activity of foreign companies. Typically, formal licensing contracts between unaffiliated parties are needed to convey such tacit knowledge. Furthermore, policy proposals to facilitate technology diffusion in the South often call for increased research collaboration, industry clusters, or joint ventures with local partners. These are activities where arms-length licensing may especially be necessary. Our results indicate that patent protection is an enabling factor for that purpose. Other benefits of unaffiliated licensing include providing opportunities for indigenous firms to enter markets, local or foreign, and increase competition. Foreign innovations may be better adapted (or exapted) to serve local needs if local agents obtain access to the technologies and know-how.

A useful future extension of this paper would be to examine how patent reforms and technology transfers affect prices. After all, prices of goods and services are critical in determining whether or not local access to new knowledge is enhanced; for example, post IPR reforms, are new products or innovations (like medicines, seeds, digital products, clean technologies, and so forth) affordable for local consumers in developing countries? Another direction would be to examine how other forms of intellectual property protections, such as copyrights and trade secrecy laws, affect international knowledge transfer (see Lippoldt and Schultz, 2014). A future extension could also incorporate the effects of IPR flexibilities on non-market mediated technology transfers, such as reverse engineering, migration, and imitation (see Maskus, 2004).

References

[1] Allred, Brent B. and Walter G. Park. (2007), "Patent rights and innovative activity: evidence from national and firm-level data," *Journal of International Business Studies*, 38(6): 878-900.

[2] Anand, Bharat N. and Tarun Khanna (2000), "The Structure of Licensing Contracts," *Journal of Industrial Economics*, 48(1): 103-135.

[3] Antràs, Pol and Stephen R. Yeaple (2014), "Multinational Firms and the Structure of International Trade," in Elhanan Helpman, Kenneth Rogoff and Gita Gopinath (eds.), *Handbook of International Economics*, vol. 4, North-Holland, Amsterdam, 55-30.

[4] Antràs, Pol (2005), "Incomplete Contracts and the Product Cycle," *American Economic Review*, 95(4): 1054-1073.

[5] Aulakh, Preet, Marshall Jiang, and Li Sali (2010), "International Technology Licensing: Monopoly Rents, Transactions Costs, and Exclusive Rights," *Journal of International Business Studies*, 41(4): 587-605.

[6] Aulakh, Preet, Marshall Jiang, and Li Sali (2013), "Licensing Technological Potential and Exclusive Rights in International Licensing: A Multilevel Model," *Journal of International Business Studies*, 44(7): 699-718.

[7] Berry, Heather (2014), "Global Integration and Innovation: Multicountry Knowledge Generation Within MNCs," *Strategic Management Journal*, 35(6): 869-890.

[8] Bilir, Kamran, L. (2014), "Patent Laws, Product Lifecycle Lengths, and Multinational Activity," *American Economic Review*, 104(7): 1979-2013.

[9] Branstetter, Lee, Ray Fisman, and C. Fritz Foley (2006), "Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-Level Panel Data," *Quarterly Journal of Economics*, 121(1): 321-349.

[10] Branstetter, Lee, Ray Fisman, C. Fritz Foley, and Kamal Saggi (2011), "Does Intellectual Property Rights Reform Spur Industrial Development?" *Journal of International Economics*, 83(1): 27-36.

[11] Canals, Claudia and Fuat Şener (2014), "Offshoring and Intellectual Property Rights Reform," *Journal of Development Economics*, 108: 71-31.

[12] Co, Catherine (2004), "Do Patent Regimes Matter?" *Review of International Economics*, 12(3): 359-373.

[13] Coeurderoy, Regéis and Gordon Murray (2008), "Regulatory environments and the location decision: Evidence from the early foreign market entries of new-technology-based firms," *Journal of International Business Studies*, 39(4): 670-687.

[14] Cohen, Wesley, Richard Nelson, and John Walsh, (2000). "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not)," *NBER Working Paper 7552*.

[15] Contractor, Farok (1984), "Choosing between Direct Investment and Licensing: Theoretical Considerations and Empirical Tests," *Journal of International Business Studies*, 15(3): 167-188.

[16] Di Minin, Alberto and Mattia Bianchi (2011), "Safe Nests in Global Nets: Internalization and Appropriability of R&D in Wireless Telecom," *Journal of International Business Studies*, 42(7): 910-934.

[17] Donoso, Jose (2014), "Do Complex Inventions Need Less International Patent Protection?" *Economics Letters*, 125(2): 278-281.

[18] Falvey, Rod, Neil Foster, and David Greenaway (2009), "Trade, Imitative Ability, and Intellectual Property Rights," *Review of World Economics*, 145(3): 373-404.

[19] Ferrantino, Michael J. (1993), "The Effect of Intellectual Property Rights on International Trade and Investment," *Weltwirtschaftliches Archiv*, 129: 300-331.

[20] Griffith, Rachel, Helen Miller, and Martin O'Connell (2014), "Ownership of Intellectual Property and Corporate Taxation," *Journal of Public Economics*, 111: 12-23.

[21] Hagedoorn, John, Danielle Cloodt, and Hans Van Kranenburg (2005), "Intellectual property rights and the governance of international R&D partnerships," *Journal of International Business Studies*, 36(2): 175-186.

[22] Harhoff, Dietmar, Frederic Scherer, and Katrin Vopel (2003), "Citations, Family Size, Opposition, and the Value of Patent Rights," *Research Policy*, 32: 1343-1363.

[23] Heckman, James J. (1979), "Sample selection bias as a specification error," *Econometrica*, 47(1): 153-161.

[24] Ivus, Olena (2010), "Do Stronger Patent Rights Raise High-Tech Exports to the Developing World?" *Journal of International Economics*, 81(1): 38-47.

[25] Ivus, Olena (2011), "Trade-Related Intellectual Property Rights: Industry Variation and Technology Diffusion," *Canadian Journal of Economics*, 44(1): 201-226.

[26] Ivus, Olena, Walter Park, and Kamal Saggi (2015), "Intellectual Property Protection and the Industrial Composition of Multinational Activity," *Economic Inquiry*, doi:10.1111/ecin.12314.

[27] Jaffe, Adam and Manuel Trajtenberg (eds.) (2002), *Patents, Citations, and Innovations*, MIT Press, Cambridge, MA.

[28] Javorcik, Beata (2004), "The Composition of Foreign Direct Investment and Protection of Intellectual Property Rights: Evidence from Transition Economies," *European Economic Review*, 48: 39-62.

[29] Keller, Wolfgang and Stephen Yeaple (2008), "Global Production and Trade in the Knowledge Economy," *National Bureau of Economic Research Working Paper* No. 14626.

[30] Keller, Wolfgang and Stephen Yeaple (2013), "The Gravity of Knowledge," *American Economic Review*, 103(4): 1414-1444.

[31] Kunčič, Aljaz (2014), "Institutional quality dataset," *Journal of Institutional Economics*, 10(01), 135-161.

[32] Lippoldt, Douglas and Mark Schultz (2014), "Uncovering Trade Secrets - An Empirical Assessment of Economic Implications of Protection for Undisclosed Data," *OECD Trade Policy Papers*, No. 167, OECD Publishing.

[33] Mansfield, Edwin and Anthony Romeo (1980), "Technology Transfer to Overseas Subsidiaries by U.S. Based Firms," *Quarterly Journal of Economics*, 95(4): 737-750.

[34] Mansfield, Edwin, Mark Schwartz, and Samuel Wagner (1981), "Imitation costs and patents: an empirical study," *The Economic Journal*, 91(364): 907-918.

[35] Markusen, James (2001), "Contracts, Intellectual Property Rights, and Multinational Investment in Developing Countries," *Journal of International Economics*, 53(1): 189-204.

[36] Maskus, Keith (2004), "Encouraging International Technology Transfer," *International Center for Trade and Sustainable Development*, Issue Paper No. 7.

[37] Maskus, Keith and Mohan Penubarti (1995), "How Trade-Related Are Intellectual Property Rights?" *Journal of International Economics*, 39: 227-48.

[38] Masurel, Enno (2002), "Patenting Behavior by SMEs," *International Journal of Entrepreneurship and Innovation Management*, 2(6): 574-583.

[39] Naghavi, Alireza (2007), "Strategic Intellectual Property Rights Policy and North-South Technology," *Review of World Economics*, 143: 55-78.

[40] Naghavi, Alireza, Spies Julia, and Toubal Farid (2015), "Intellectual Property Rights, Product Complexity, and the Organization of Multinational Firms," *Canadian Journal of Economics*, forthcoming.

[41] Nicholson, Michael (2007), "The Impact of Industry Characteristics and IPR Policy on Foreign Direct Investment," *Review of World Economics*, 143(1): 27-54.

[42] Nunnenkamp, Peter and Julius Spatz (2004), "Intellectual Property Rights and Foreign Direct Investment: A Disaggregated Analysis," *Review of World Economics*, 140(3): 525-533.

[43] Oostendorp, Remco (2012), "The Occupational Wages Around the World (OWW) Database: Update for 1983-2008." `www.nber.org/oww`

[44] Park, Walter G. (2008), "International Patent Protection: 1960 - 2005," *Research Policy*, 37(4): 761-766.

[45] Park, Walter G. and Douglas Lippoldt (2005), "International Licensing and the Strengthening of Intellectual Property Rights in Developing Countries during the 1990s," *OECD Economic Studies*, 40: 7-48.

[46] Park, Walter G. (2010), "On Patenting Costs," *The WIPO Journal: Analysis of Intellectual Property Issues*, 2(1): 38-48.

[47] Petersen, Mitchell A. (2009), "Estimating standard errors in finance panel data sets: Comparing approaches," *Review of financial studies* 22(1): 435-480.

[48] Rafiquzzaman, Mohammed (2002), "The Impact of Patent Rights on International Trade: Evidence from Canada," *Canadian Journal of Economics*, 35(2): 307-330.

[49] Saggi, Kamal (2002), "Trade, Foreign Direct Investment, and International Technology Transfer: A Survey," *World Bank Research Observer*, 17: 191-235.

[50] Şener, Fuat and Laixun Zhao (2009), "Globalization, R&D and the iPod Cycle," *Journal of International Economics*, 77(1): 101-108.

[51] Smith, Pamela (1999), "Are Weak Patent Rights a Barrier to U.S. Exports?" *Journal of International Economics*, 48: 151-177.

[52] Smith, Pamela (2001), "How do Foreign Patent Rights Affect U.S. Exports, Affiliate Sales, and Licenses?" *Journal of International Economics*, 55: 411-439.

[53] Wang, Chengqi, Junjie Hong, Mario Kafouros, and Mike Wright. (2012), "Exploring the role of government involvement in outward FDI from emerging economies," *Journal of International Business Studies*, 43(7): 655-676.

[54] Watson, Amanda (2011), "Does TRIPS Increase Technology Transfer to the Developing World? The Empirical Evidence," *Information and Communications Technology Law*, 20(3): 253-278.

[55] Yang, Guifang, and Keith E. Maskus (2001), "Intellectual property rights and Licensing: An Econometric Investigation," *Review of World Economics*, 137(1): 58-79.

Appendix

I. Data Description

Variable	Description	Source
Affiliated Licensing	Royalties and licensing receipts from foreign affiliates (Firm level)	BEA *Benchmark Surveys of U.S. Direct Investment Abroad (USDIA)* (BE-10 surveys); *Quarterly Balance of Payment Surveys of USDIA* (BE-577 surveys)
Unaffiliated Licensing	Royalties and licensing receipts from unaffiliated parties (Firm level)	BEA *Quarterly Survey of Transactions in Selected Services and Intellectual Property with Foreign Persons* (BE-125 surveys); *Annual Survey of Royalties, Licensing Fees, and Other Receipts and Payments for Intangible Rights between U.S. and Unaffiliated Foreign Persons* (BE-93 survey)
Parent R&D, Sales	R&D performed by parent company and Total sales of parent company (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys) and *Benchmark Surveys of USDIA* (BE-10)
Income Taxes	Income taxes of foreign affiliates (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys); *Benchmark Surveys of USDIA* (BE-10)
Net Income	Net income of foreign affiliates (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys) and *Benchmark Surveys of USDIA* (BE-10)
U.S. Patents Granted	Utility patent counts (Firm level)	NBER *Patent Data Project*
Patent Rights, Patent Reform	Index of the strength of patent protection (Country level)	Park (2008)
Product Complexity	Complexity level of the tasks involved in the product's manufacturing (Product category level)	Naghavi et al. (2015)
Patent cost	The cost of procurement (filing, attorney, translation, search and examination fees) and maintenance (renewal fees) (Country level)	Park (2010)
GDP, PPP Conversion Factor	GDP in constant 2005 dollars and PPP conversion factor to market exchange rate ratio (Country Level)	World Bank *World Development Indicators*
Inward Capital Restrictions	Presence of capital controls on inward foreign direct investment (Country level)	IMF *Annual Report on Exchange Arrangements and Exchange Restrictions* (various years)
Hourly Wages	Hourly wages (in USD) in manufacturing–country-specific calibration and lexicographic weighting (Country level)	Occupational Wages Around the World (OWW) Database `www.nber.org/oww`

II. Developing Countries and their Year of Major Patent Reform

Algeria 2000	Dominican Rep. 2000	Mexico 1995	Singapore 1995
Angola 2000	Ecuador 2000	Morocco 2000	Slovakia 1995
Argentina 1996	El Salvador 1996	Nicaragua 2000	South Africa 1996
Brazil 1995	Ghana 2000	Nigeria 2005	South Korea 1994
Bulgaria 2000	Guatemala 2005	Panama 2000	Sri Lanka 2000
Chad 2000	Hong Kong 2000	Peru 1995	Taiwan 1995
Chile 1995	Hungary 1996	Philippines 2000	Thailand 2000
China 1996	India 1999	Poland 1996	Trinidad Tobago 2000
Cote D'Ivoire 2000	Jamaica 2000	Romania 1996	Venezuela 1995
Cyprus 2000	Kenya 1995	Russia 1996	Vietnam 1995
Czech Rep. 2000	Malaysia 1995	Saudi Arabia 2005	Zimbabwe 2000

III. Product Complexity Data

Complexity	Product Category Description	NAICS Codes
.4221271	Computers & related	3341, 3343-3346
.3798102	Radio, television & communic. equipment & apparatus	3342
.3790194	Commercial Machinery	3333
.3113132	Machinery & equipment n.e.c.	3331-3332, 3334-3336, 3339
.3073564	Electrical machinery & apparatus n.e.c.	3351-3353, 3359
.3033172	Trade, maint. & repair services of motor vehicles & motorcycles; retail sale of auto fuel	3362-3363
.3031925	Medical, precision & optical instruments, watches & clocks	3391
.2878633	Fabricated metal products, exc. machinery & equipment	3329
.2786216	Basic metals	3311-3315, 3321-3327
.2748125	Other transport equipment	3364-3366, 3369
.2596836	Motor vehicles, trailers & semi-trailers	3361
.2580898	Chemicals, chemical products & man-made fibres	3251, 3253-3256, 3259
.2537238	Coke, refined petroleum products & nuclear fuels	3242-3244
.2058220	Rubber & plastic products	3252, 3261-3262, 3271-3273
.1839178	Other non-metallic mineral products	3279
N/A	Other miscellaneous manufacturing	3399

IV. Additional Tables

Table A1: **Complexity results, with product fixed effects**

	Unaff./Aff. Lic. Ratio (1)	Unaff./Aff. Lic. Ratio (2)
log (host's PRs)	-0.996***	
	(0.228)	
log (host's PRs)×Product complexity	3.292***	3.986***
	(0.745)	(1.058)
log (parent R&D/sales)	-0.020***	-0.024***
	(0.007)	(0.007)
log (host GDP)	-1.045***	-0.990***
	(0.336)	(0.332)
log (host/U.S. wages)	-0.087	-0.056
	(0.364)	(0.362)
Capital restrictions dummy	0.073	0.074
	(0.060)	(0.060)
Host corporate income tax	0.027	0.027
	(0.068)	(0.067)
Parent patent rank	-0.051	-0.078*
	(0.045)	(0.047)
log (host's PRs)×Parent patent rank	-0.032	-0.003
	(0.043)	(0.045)
log (host's PRs)×Pharmaceuticals		-0.496*
		(0.297)
log (host's PRs)×Non-pharmac. chemicals		-1.284***
		(0.299)
log (host's PRs)×Energy		-0.748**
		(0.314)
log (host's PRs)×Metals		-1.375***
		(0.328)
log (host's PRs)×Transportation		-1.766***
		(0.352)
log (host's PRs)×Machinery & equipment		-1.064***
		(0.374)
log (host's PRs)×Electronics & components		-1.457***
		(0.390)
log (host's PRs)×Other manufacturing		-1.205***
		(0.255)
Product fixed effects	Yes	Yes
Constant	15.740***	14.827***
	(5.547)	(5.470)
Observations	29,533	29,533
R^2	0.124	0.135

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table A2: **Sensitivity test: Measure of licensing**

	Stock of Unaff. Licen. (1)	Stock of Affil. Licen. (2)	Unaff./Aff Lic. Stocks Ratio (3)	Share of Unaff. in Total Stock (4)	Share of Unaff. in Total Flow (5)
log (host's PRs)	0.627***	2.022***	-1.395***	-1.135***	-0.826***
	(0.091)	(0.221)	(0.235)	(0.208)	(0.200)
Product Complexity	0.665*	-2.409**	3.101***	4.263***	3.312***
	(0.389)	(0.950)	(0.972)	(0.835)	(0.650)
log (host's PRs)×Product Complexity	-1.506***	-6.458***	4.953***	3.669***	2.191***
	(0.300)	(0.621)	(0.711)	(0.614)	(0.619)
log (parent R&D/Sales)	0.007***	0.036***	-0.030***	-0.031***	-0.044***
	(0.002)	(0.006)	(0.006)	(0.006)	(0.006)
log (host GDP)	0.037	0.495	-0.458*	-0.546**	-1.426***
	(0.121)	(0.310)	(0.264)	(0.275)	(0.279)
log (Host/U.S. Wages)	0.048	-0.452	0.501	0.369	-0.079
	(0.162)	(0.360)	(0.313)	(0.310)	(0.310)
Capital restrictions dummy	0.057***	0.069	-0.012	-0.036	-0.004
	(0.021)	(0.061)	(0.057)	(0.057)	(0.055)
Host corporate income tax	-0.028	0.001	-0.029	-0.009	0.033
	(0.038)	(0.081)	(0.064)	(0.063)	(0.055)
Parent patent rank	0.149***	0.160***	-0.013	-0.097***	-0.102***
	(0.020)	(0.039)	(0.041)	(0.037)	(0.038)
log (host's PRs)×Parent patent rank	-0.119***	-0.059*	-0.060*	0.002	0.038
	(0.018)	(0.031)	(0.033)	(0.030)	(0.037)
Constant	-1.063	-2.621	1.550	2.977	21.485***
	(2.033)	(5.312)	(4.541)	(4.732)	(4.640)
Observations	33,784	33,784	33,784	33,784	29,533
R^2	0.0376	0.0671	0.0547	0.0619	0.0459

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table A3: **Sensitivity test: Measure of PRs**

	Unaff. Licen. (1)	Affil. Licen. (2)	Unaff./Aff. Lic. Ratio (3)	Unaff. Licen. (4)	Affil. Licen. (5)	Unaff./Aff. Lic. Ratio (6)
Patent reform dummy	0.337***	1.078***	-0.747***	0.352***	1.018***	-0.666***
	(0.080)	(0.144)	(0.162)	(0.097)	(0.155)	(0.182)
Product complexity	0.738***	-3.839***	4.606***			
	(0.247)	(0.482)	(0.504)			
Patent reform ×Product complexity	-0.754***	-2.772***	2.040***	-0.771**	-2.564***	1.794***
	(0.260)	(0.450)	(0.515)	(0.304)	(0.502)	(0.594)
log (parent R&D/sales)	0.010***	0.045***	-0.037***	-0.001	0.029***	-0.030***
	(0.002)	(0.007)	(0.007)	(0.003)	(0.008)	(0.009)
log (host GDP)	0.526***	1.377***	-0.847***	0.511***	1.429***	-0.918***
	(0.152)	(0.270)	(0.325)	(0.146)	(0.273)	(0.326)
log (host/U.S. wages)	-0.010	0.116	-0.130	0.069	0.036	0.033
	(0.191)	(0.343)	(0.368)	(0.212)	(0.333)	(0.383)
Capital restrictions dummy	0.060**	-0.010	0.070	0.052*	-0.008	0.060
	(0.027)	(0.056)	(0.059)	(0.029)	(0.053)	(0.060)
Host corporate income tax	-0.003	0.001	-0.004	-0.002	0.006	-0.007
	(0.039)	(0.059)	(0.069)	(0.037)	(0.059)	(0.072)
Parent patent rank	0.018	0.118***	-0.099***	0.050***	0.098***	-0.048
	(0.015)	(0.028)	(0.032)	(0.018)	(0.034)	(0.039)
log (host's PRs)×Parent patent rank	-0.024	-0.052*	0.027	-0.030	-0.060*	0.030
	(0.018)	(0.030)	(0.035)	(0.020)	(0.033)	(0.038)
Firm-by-country fixed effects				yes	yes	yes
Constant	-9.156***	-20.649***	11.394**	-9.426***	-23.016***	13.590**
	(2.504)	(4.450)	(5.354)	(2.619)	(5.108)	(6.029)
Observations	30,001	30,001	30,001	30,001	30,001	30,001
R^2	0.0926	0.0481	0.0676	0.612	0.604	0.585

Notes: Random effects estimator in columns (1)-(3) and OLS estimator in columns (4)-(6).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms.
Robust standard errors in parentheses are clustered by country×year.
All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table 1: **U.S. Parent Firm Sample Statistics, by Product Complexity**

		Unaffil. Licensing Flows	Affil. Licensing Flows	Ratio of Unaff. to Aff. Lic.	Ratio of R&D to Sales (%)	Patent Rank
All U.S. Parent Firms	Mean	318.8	576.2	0.553	4.31	0.48
	Std Dev	(5266.8)	(3825.3)			(0.77)
Above Median Complexity	Mean	531.2	487.3	1.090	6.55	0.54
	Std Dev	(7930.0)	(4053.7)			(0.80)
Below Median Complexity	Mean	173.2	648.2	0.267	3.58	0.42
	Std Dev	(1733.9)	(3692.2)			(0.72)
Difference in means		358.0***	-160.9***	0.823***	2.97***	0.12***

Notes: The licensing figures are in thousands of real 2005 U.S. dollars.

*** indicate statistical significance at the 1% level.

Table 2: **Licensing and Product Complexity by Industry**

	Unaffil. Lic., % Share of Manufacturing	Affil. Lic., % Share of Manufacturing	Ratio of Unaffil. to Affil. Lic.	Mean Value of Product Complexity
Electronics and Components	36.3	13.1	1.53	0.381
Machinery and Equipment	32.5	13.6	1.32	0.351
Transportation	20.6	18.1	0.63	0.283
Metals	0.1	1.0	0.06	0.280
Pharmaceuticals	0.9	8.3	0.06	0.258
Energy	2.7	0.6	2.56	0.254
Non-pharm Chemicals	6.7	41.0	0.09	0.258
Other Manufacturing	0.2	4.3	0.02	0.204
Total	100	100	0.55	0.298

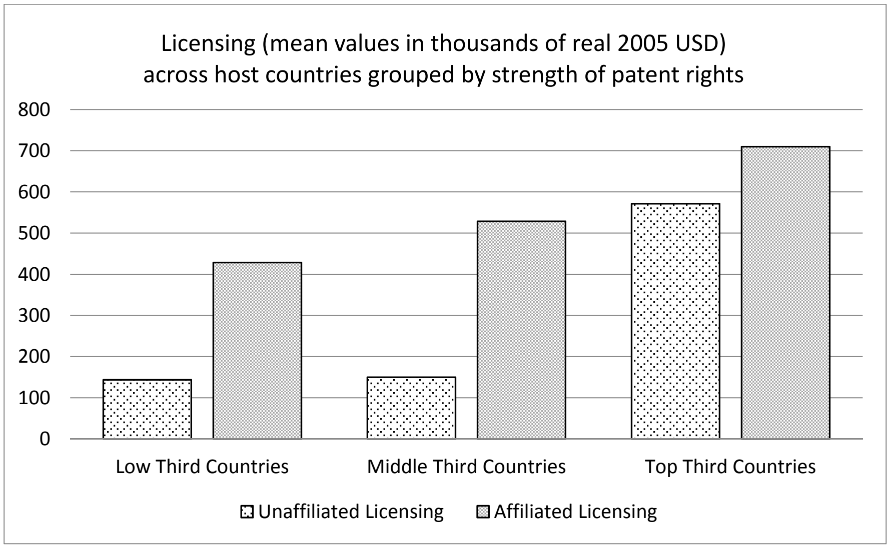

Figure 1: **U.S. Licensing by Destination**

Table 3: **Aggregate results**

	Unaff. Licen. (1)	Affil. Licen. (2)	Unaff./Aff. Ratio (3)
log (host's PRs)	0.124**	0.200**	-0.070
	(0.054)	(0.090)	(0.094)
log (parent R&D/sales)	0.010***	0.038***	-0.030***
	(0.002)	(0.007)	(0.007)
log (host GDP)	0.501***	1.452***	-0.947***
	(0.163)	(0.292)	(0.341)
log (host/U.S. wages)	-0.083	0.021	-0.106
	(0.201)	(0.351)	(0.361)
Capital restrictions dummy	0.064**	-0.007	0.070
	(0.030)	(0.057)	(0.061)
Host corporate income tax	-0.013	-0.043	0.030
	(0.047)	(0.066)	(0.070)
Parent patent rank	0.043*	0.110***	-0.063
	(0.022)	(0.039)	(0.045)
log (host's PRs)×Parent patent rank	-0.041*	-0.034	-0.011
	(0.021)	(0.037)	(0.042)
Constant	-8.440***	-22.752***	14.216**
	(2.703)	(4.834)	(5.629)
Observations	29,940	29,940	29,940
R^2	0.091	0.025	0.048

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table 4: **Complexity results**

	Unaff. Licen. (1)	Affil. Licen. (2)	Unaff./Aff. Ratio (3)
log (host's PRs)	0.314***	1.394***	-1.069***
	(0.102)	(0.216)	(0.232)
Product complexity	0.891**	-1.558**	2.509***
	(0.383)	(0.762)	(0.782)
log (host's PRs)×Product complexity	-0.638*	-4.165***	3.512***
	(0.353)	(0.679)	(0.755)
log (parent R&D/Sales)	0.010***	0.045***	-0.038***
	(0.002)	(0.007)	(0.007)
log (host GDP)	0.522***	1.554***	-1.027***
	(0.164)	(0.294)	(0.343)
log (host/U.S. wages)	-0.099	-0.011	-0.092
	(0.202)	(0.347)	(0.361)
Capital restrictions dummy	0.065**	-0.008	0.072
	(0.030)	(0.057)	(0.060)
Host corporate income tax	-0.015	-0.041	0.026
	(0.048)	(0.064)	(0.068)
Parent patent rank	0.043**	0.107***	-0.060
	(0.022)	(0.040)	(0.045)
log (host's PRs)×Parent patent rank	-0.042**	-0.025	-0.021
	(0.021)	(0.037)	(0.043)
Constant	-9.039***	-23.997***	14.838***
	(2.723)	(4.870)	(5.652)
Observations	29,533	29,533	29,533
R^2	0.092	0.048	0.068

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table 5: **OLS with firm-by-country fixed effects**

	Unaff. Licen. (1)	Affil. Licen. (2)	Unaff./Aff. Ratio (3)
log (host's PRs)	0.302**	1.510***	-1.208***
	(0.141)	(0.238)	(0.278)
log (host's PRs)×Product complexity	-0.527	-4.441***	3.914***
	(0.481)	(0.811)	(0.961)
log (parent R&D/sales)	-0.001	0.031***	-0.032***
	(0.003)	(0.008)	(0.009)
log (host GDP)	0.511***	1.599***	-1.087***
	(0.161)	(0.293)	(0.340)
log (host/U.S. wages)	-0.026	-0.093	0.068
	(0.226)	(0.339)	(0.374)
Capital restrictions dummy	0.057*	-0.010	0.067
	(0.031)	(0.053)	(0.061)
Host corporate income tax	-0.015	-0.037	0.022
	(0.046)	(0.063)	(0.072)
Parent patent rank	0.093***	0.091*	0.002
	(0.024)	(0.050)	(0.055)
log (host's PRs)×Parent patent rank	-0.065***	-0.039	-0.026
	(0.023)	(0.043)	(0.048)
Constant	-9.332***	-25.949***	16.617***
	(2.901)	(5.474)	(6.279)
Observations	29,533	29,533	29,533
R^2	0.667	0.659	0.643

Notes: OLS estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, firm-by-country fixed effects, and host-country specific time trends.

Table 6: **Two-stage selection model**

	Unaff. Licen. (1)	Affil.Licen. (2)	Unaff./Aff. Ratio (3)
Panel A: Stage 1			
log (host's PRs)	0.215	0.203	0.215
	(0.142)	(0.142)	(0.142)
Product complexity	-0.153	-0.208	-0.153
	(0.466)	(0.465)	(0.466)
log (host's PRs)×Product complexity	-0.524	-0.483	-0.524
	(0.472)	(0.471)	(0.472)
log (parent R&D/sales)	0.022***	0.023***	0.022***
	(0.005)	(0.005)	(0.005)
log (Host GDP)	0.006	0.008	0.006
	(0.015)	(0.015)	(0.015)
log (Host/U.S. wages)	1.232***	1.239***	1.232***
	(0.213)	(0.213)	(0.213)
Capital restrictions dummy	0.042	0.041	0.042
	(0.039)	(0.039)	(0.039)
Host corporate income Tax	-0.040	-0.045	-0.040
	(0.065)	(0.065)	(0.065)
Parent patent rank	0.040	0.042	0.040
	(0.032)	(0.032)	(0.032)
log (host's PRs)×Parent patent rank	-0.070**	-0.071**	-0.070**
	(0.034)	(0.034)	(0.034)
The cost of patenting cost per market size	-0.406***	-0.401***	-0.406***
	(0.122)	(0.122)	(0.122)
Constant	4.467***	4.450***	4.467***
	(0.000)	(0.000)	(0.000)
Panel B: Stage 2			
log (host's PRs)	0.380***	1.330***	-0.943***
	(0.113)	(0.197)	(0.224)
Product complexity	0.937**	-3.666***	4.621***
	(0.392)	(0.683)	(0.774)
log (host's PRs)×Product complexity	-0.549	-2.896***	2.327***
	(0.371)	(0.645)	(0.734)
log (parent R&D/sales)	0.044***	0.070***	-0.026***
	(0.005)	(0.009)	(0.010)
log (host GDP)	0.099***	0.049***	0.049**
	(0.011)	(0.018)	(0.021)
log (host/U.S. wages)	1.282***	-2.594***	3.887***
	(0.225)	(0.389)	(0.440)
Capital restrictions dummy	0.180***	0.097*	0.083
	(0.029)	(0.050)	(0.057))
Host corporate income Tax	-0.027	0.081	-0.107
	(0.050)	(0.086)	(0.098)
Parent patent rank	-0.047*	0.137***	-0.184***
	(0.028)	(0.048)	(0.054)
log (host's PRs)×Parent patent rank	0.008	0.020	-0.011
	(0.028)	(0.049)	(0.056)
Inverse Mills ratio λ	0.455	-1.820	2.346
	(0.744)	(1.263)	(1.428)
Constant	-3.781***	4.990***	-8.795***
	(0.452)	(0.783)	(0.887)

Notes: 32,238 observations. Stage 1: Probit model. Stage 2: OLS. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.

Table 7: **IV estimation**

	First stage			Second stage
	PRs Changes	PRs Changes ×Patent rank	PRs Changes ×Complexity	T^U/T^A Changes
	(1)	(2)	(3)	(4)
Non-colony dummy	0.027***	-0.021***	-0.009***	
	(0.005)	(0.005)	(0.002)	
Non-colony×Product complexity	-0.020	-0.014	0.051***	
	(0.016)	(0.014)	(0.006)	
Non-colony×Parent patent rank	-0.000	0.059***	-0.000	
	(0.001)	(0.002)	(0.000)	
PRs changes				-1.196***
				(0.273)
PRs changes×Product complexity				3.704***
				(0.633)
PRs changes×Parent patent rank				-0.134**
				(0.058)
Parent R&D/Sales changes	-0.008	-0.010	-0.001	-0.151***
	(0.008)	(0.010)	(0.002)	(0.041)
Host GDP changes	-0.014	-0.013	0.021	0.473
	(0.162)	(0.205)	(0.053)	(0.445)
Host/U.S. wages changes	1.550***	0.988	0.447***	1.624**
	(0.362)	(0.646)	(0.122)	(0.798)
Capital restrictions changes	0.557***	0.355**	0.176***	-0.597*
	(0.144)	(0.145)	(0.044)	(0.308)
Host corporate income tax changes	-0.227***	-0.113	-0.056*	-0.260
	(0.073)	(0.087)	(0.022)	(0.167)
Constant	0.043***	0.028***	0.013***	-0.008
	(0.002)	(0.004)	(0.001)	(0.013)

Notes: 2,567 observations. 2SLS estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Changes are measured as differences in natural logarithms.
Robust standard errors in parentheses are clustered by country×product.
Underidentification test (Kleibergen-Paap rk LM statistic): χ^2=65.29, p-value=0.0000
Weak identification test (Kleibergen-Paap Wald rk F statistic): 26.35
Endogeneity test of endogenous regressors: χ^2=3.620, p-value=0.3055

Table 8: **Additional controls**

	Unaff. Licen. (1)	Affil. Licen. (2)	Unaff./Aff. Lic. Ratio (3)	Unaff. Licen. (4)	Affil. Licen. (5)	Unaff./Aff. Lic. Ratio (6)
log (host's PRs)	0.302***	1.419***	-1.106***	0.358***	1.272***	-0.910***
	(0.102)	(0.217)	(0.234)	(0.103)	(0.217)	(0.236)
Product complexity	1.349***	-1.722**	3.159***	1.660***	-2.187***	3.919***
	(0.394)	(0.753)	(0.785)	(0.405)	(0.738)	(0.782)
log (host's PRs)×Product Complex.	-1.017***	-4.519***	3.467***	-1.394***	-3.791***	2.388***
	(0.392)	(0.675)	(0.786)	(0.391)	(0.672)	(0.763)
log (parent R&D/sales)	0.011***	0.044***	-0.036***	0.010***	0.045***	-0.038***
	(0.002)	(0.007)	(0.007)	(0.002)	(0.007)	(0.007)
log (host GDP)	0.610***	1.696***	-1.083***	0.480***	1.592***	-1.104***
	(0.182)	(0.334)	(0.383)	(0.173)	(0.324)	(0.370)
log (host/U.S. wages)	-0.297	-0.100	-0.196	-0.246	-0.158	-0.085
	(0.202)	(0.406)	(0.417)	(0.208)	(0.441)	(0.453)
Capital restrictions dummy	0.071**	-0.011	0.082	0.067**	-0.009	0.074
	(0.030)	(0.058)	(0.062)	(0.029)	(0.059)	(0.061)
Host corporate income tax	-0.010	-0.035	0.026	-0.010	-0.034	0.024
	(0.047)	(0.065)	(0.069)	(0.047)	(0.065)	(0.068)
Parent patent rank	0.048**	0.102**	-0.050	0.033	0.130***	-0.091*
	(0.023)	(0.040)	(0.046)	(0.023)	(0.041)	(0.047)
log (host's PRs)×Parent Patent Rank	-0.047**	-0.024	-0.028	-0.024	-0.062*	0.032
	(0.022)	(0.038)	(0.043)	(0.022)	(0.037)	(0.041)
Product life dummy	-0.139***	0.081*	-0.225***	-0.158***	0.102**	-0.266***
	(0.034)	(0.045)	(0.055)	(0.034)	(0.046)	(0.057)
log (host's PRs)×Product Life Dummy	0.109***	0.080*	0.034	0.143***	0.056	0.093
	(0.037)	(0.041)	(0.060)	(0.036)	(0.042)	(0.060)
Quality of legal institutions	0.060	0.062	-0.003			
	(0.063)	(0.117)	(0.123)			
Quality of economic institutions				-0.040	-0.051	0.013
				(0.027)	(0.042)	(0.042)
Constant	-10.483***	-26.577***	15.978**	-7.988***	-24.599***	16.375***
	(3.135)	(5.737)	(6.550)	(2.894)	(5.342)	(6.081)
Observations	28,328	28,328	28,328	27,372	27,372	27,372
R^2	0.0969	0.0515	0.0726	0.0968	0.0501	0.0719

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All dependent variables are in natural logarithms. Robust standard errors in parentheses are clustered by country×year. All regressions include year fixed effects, country fixed effects, and host-country specific time trends.