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

Olena Ivus, Walter Park, and Kamal Saggi*

Abstract

This paper examines how patent protection in developing countries affects the technology licensing strategy of U.S. multinational firms and the associated technology transfer flows. Strengthening patent rights lowers appropriability hazards and so reduces the firms' reliance on affiliated licensing as the more secure means of transfer (the internalization effect). However lower appropriability hazards also encourage the firms to increase the volume of technology transfer via licensing both within and outside the firm (the appropriability effect). Which effect prevails depends on the underlying technological complexity of the firms' products, as measured by the average intensity of complex problem-solving "tasks" involved in the products' manufacturing. We find that a strengthening of patent protection in the host country increases the incentive to license innovations to unaffiliated parties. While unaffiliated licensing flows rise among all firms, the volume of affiliated licensing falls among complex-technology firms but rises among simple-technology firms. The positive appropriability effect on affiliated licensing is strong enough among simple-technology firms that the entire composition of their licensing further shifts towards affiliated parties. The results are significant for recent work on the internalization theories of multinational firms and the interaction between firm strategy and the institutional environment, as well as for patent policy in the developing world, where access to knowledge is critical.

Keywords: International Technology Transfer, Licensing, Internalization, Appropriability, Intellectual Property Rights, Technological Complexity, 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.
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INTRODUCTION

Multinational firms seeking to exploit their knowledge assets may do so either internally, within company boundaries, or externally by contracting with independent entities. Key questions in the theory of internalization are when and why multinational firms opt to transfer technology internally (where it is potentially more secure) instead of via arms-length market transactions (see Contractor, 1984). For developing economies, transfers of technology from foreign multinational companies, whether internal or external, can be important inputs for their development. Alliances, partnerships, ventures, or licensing contracts may provide unaffiliated, local agents access to knowledge, technology, and marketing experience (see UNCTAD, 2001), and create prospects for wide technology spillovers locally (see Saggi, 2002).[1] The transfer of technology is an express objective of the Agreement on Trade Related Intellectual Property Rights (TRIPS), the foremost trade agreement governing intellectual property.[2] Thus, for both theoretical and practical purposes, it is important to understand the market and policy determinants driving firms' international technology licensing decisions in developing countries.

This paper examines how the strengthening of patent protection in developing countries affects international technology licensing. We focus on U.S. multinational firms' technology transfer via the licensing of intangible assets, distinguishing between affiliated and unaffiliated licensing flows, and examine the composition of licensing to study the effects of patent protection on the licensing strategy of U.S. multinational firms. The paper shows that the impact of stronger developing countries' patent rights (PRs) on U.S. firms' volume and nature of licensing is non-monotonic and depends critically on the strength of the appropriability regime as determined by the underlying technological complexity of the firms' products.

To the extent that appropriability hazards are high when knowledge is less complex because such

[1]Providing greater local access to foreign knowledge may have been the major motivating factor behing China's controversial indigenous innovation policy, which required multinationals to share their technologies with local companies as a precondition for market entry.

[2]The Agreement on TRIPS was ratified by the World Trade Organization (WTO) in 1995. It 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."The text of this agreement is at www.wto.org/english/docs_e/legal_e/27-trips_01_e.htm.

knowledge is easy to misappropriate and imitate, one would expect a negative relationship between the strength of host's PRs and the prevalence of affiliated licensing. Stronger PRs lower appropriability hazards and so reduce the firms' reliance on affiliated licensing as the more secure means of transfer (i.e., the internalization effect). However lower appropriability hazards also encourage the firms to increase the volume of technology transfer via licensing both within and outside the firm (i.e., the appropriability effect). Which effect prevails is theoretically ambiguous and depends on the underlying technological complexity of the firms' products. In order to evaluate the relative size of the two effects empirically, the two forms of licensing—affiliated and unaffiliated—have to be studied in an integrated framework, where firms decide on both the volume of licensing and the preferred mode of control. Previous literature has greatly increased our understanding of the role of patent protection and transaction characteristics in impacting firm strategy, but has not studied the interplay between the internalization and appropriability effects in the intergraded framework that this paper provides.

We develop hypotheses linking the underlying technological complexity of firms' products to the volume and nature of licensing activity in the context of a simple model of a foreign market entry strategy, which draws on concepts and extends insights of the economics and international business literature. In the model, the firm owns proprietary technology generated by R&D activity and would like to exploit it through foreign production. International exploitation of knowledge is difficult and carries the risk of technology misappropriation and product imitation by rivals, even when technology is transferred within organizations (e.g., Zander and Kogut, 1995; Poole, 2013; Berry, 2014).[3] The firm's strategy involves two interdependent decisions: the volume of licensing (i.e., how much technology to transfer via licensing into a country) and the mode of control (i.e., whether to license its technology to an affiliate or unaffiliated party, with unaffiliated licensing carrying the higher risk of product imitation.) The model predicts that the firm's response to the strength of host's PRs largely depends on the underlying technological complexity of the firm's

[3]Poole (2013), for example, argues that transferring technology within organizations to countries with weak PRs carries the risk of imitation because local employees can misappropriate the firm's technology to start up imitative production.

products, which we interpret as the technological complexity of tasks involved in the manufacture of products. Technological complexity is an important conditioning factor in the impact of host's PRs because it increases the time to product imitation (or more precisely, decreases the hazard rate by which innovations are imitated), strengthens the appropriability regime and with that, reduces the firm's reliance on host's PRs.

We test our hypotheses using 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. To explore the role of technological complexity we employ the task-based measure of Naghavi et al. (2015), which distinguishes products by the average intensity of complex problem-solving "tasks" involved in the products' manufacturing. This important distinction and its role in determining the licensing impact of PRs has been largely overlooked in the multinational licensing strategy literature, and is emphasized in this paper.[4] The measure of technological complexity is obtained from occupational data, where 809 occupations are ranked based on the level and importance of complex problem-solving skills. Occupations are interpreted as "tasks" that are embodied in products, and average task intensity in solving problems is interpreted as a measure of the underlying technological complexity of products.[5] The measure is at the product category level and we focus on 15 high-tech manufacturing product categories, for which patent protection is expected to matter most.

We find that a strengthening of patent protection in the host country increases the incentive to license innovations to unaffiliated parties. While unaffiliated licensing flows rise among all firms,

[4]There can be differences in technological complexity between the manufacturing stage and innovation stage. A pharmaceutical product, for example, may require tremendous knowledge and skills to discover (i.e., the innovation stage is complex), but once the breakthrough is made, it is easy/simple enough to manufacture. What is important for the ability to recoup the fixed costs of R&D is the ability to sell products based on the technology, and this depends critically on the ease of imitating the innovated product at the manufacturing stage. It is this ease of imitation that we intend to pick up with our (production) measure of technological complexity. We thank an anonymous reviewer for drawing our attention to this important distinction.

[5]A similar measure was used in Keller and Yeaple (2008). Zander and Kogut (1995) note that "[t]echnology...consists of the principles by which individual skill and competence are gained and used, and by which work among people is organized and coordinated and measure technological complexity as the degree of distinct and multiple kinds of competencies used to manufacture a product, arguing that "the more complex a manufacturing capability, the more difficult it should be to imitate." (p.77)

the change in the volume of affiliated licensing is non-monotonic: affiliated licensing falls among complex-technology firms but rises among simple-technology firms. This striking result is driven by the appropriability effect, which overtakes the internalization effect among simple-technology firms. Furthermore, the positive appropriability effect on affiliated licensing is strong enough among simple-technology firms that the entire composition of their licensing further shifts towards affiliated parties. These findings underscore the importance for simple-technology firms of carefully considering appropriability regimes when transferring their technology to developing countries.

RELATION TO PREVIOUS LITERATURE

The study is significant for existing work on the internalization theories of multinational firms (Buckley and Casson, 1976, 1998, 2009; Buckley and Pearce, 1979). A growing body of work in the international management literature has emphasized the high cost of sharing and managing knowledge across countries (e.g., Berry, 2006, 2014; Di Minin and Bianchi, 2011) and investigated the role of the local institutional environment (such as intellectual property protection) in impacting firm strategy (e.g., Hagedoorn et al., 2005; Allred and Park, 2007; Zhao, 2006; Coeurderoy and Murray, 2008; Hennart, 2009; Wang et al., 2012). A well-established finding is that imperfections in contracting (e.g., due to weak PRs) 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.

International transaction cost theory highlighted several transaction or project characteristics, such as asset specificity, the difficulty of contracting, the hazard of technological leakage, and the hazard of free-riding on brand name and reputation, which increase the appropriability hazards in contracting for the transfer of the technological innovation between independent entities. The empirical literature has further shown that these contractual hazards determine the impact of the institutional environment on multinational market entry mode. Oxley (1997, 1999), for example, focused on the difficulty of contracting, which encompasses the difficulty of specifying property or usage rights associated with the technology in a contract and the difficulty of monitoring and enforcing contractual terms.

A related strand of the literature studied the ability of innovating firms to profit from technological innovation and highlighted "appropriability hazards" which are distinct from contractual hazards discussed above and result from the technological leakage of information, leading to imitation by rivals (Mansfield et al., 1981; Levin et al., 1987; Anand and Khanna, 2000; Cohen et al., 2000). An important contribution to the literature is Teece (1986), which emphasized that an innovator's ability to capture the profits generated by an innovation depends critically on a regime of appropriability. Where the appropriability regime is weak, technology is very hard to protect and innovators must turn to business strategy in order to limit imitation. Two key dimensions of the appropriability regime are the efficacy of legal mechanisms of protection (such as patents) and the nature of technology. Teece (1986) argued that appropriability hazards are high when knowledge is less complex, because such knowledge is easy to misappropriate and imitate; and that the complex, tacit nature of knowledge, which is difficult to articulate and so imitate, reduces appropriability hazards.

The international trade literature highlighted the importance of the risk of imitation in determining the technology transfer impact of PRs.[6] Smith (1999), for example, showed that weak foreign PRs are a barrier to U.S. exports, but only to countries that pose a strong threat of imitation. Ivus (2011) emphasized industry differences in the impact of PRs and showed that stronger foreign PRs expand exports more in industries with higher imitation risk. More recently, Bilir (2014) examined how the impact of PRs on multinationals' manufacturing location decisions depends on product life-cycle lengths, arguing that firms with short life-cycle products are less sensitive to patent protection because their technologies may become obsolete before imitation can occur. Naghavi et al. (2015) argued that technological complexity of products acts as a barrier to imitation and distinguished products by the complexity level of the tasks involved in their production to study the impact of foreign PRs on the firms' product sourcing decisions.

[6] Maskus and Penubarti (1995), Smith (1999), Javorcik (2004), and Ivus (2010).

Building upon these important factors—appropriability hazards and imitation risks—we study how patent protection affects two forms of international licensing, affiliated and unaffiliated. We provide an integrated, empirical framework, where firms decide on both the volume of licensing and the preferred mode of control. Previous studies have often worked with discrete choice indicators, allowing only for the observation of technology transfers at the external margin (i.e., whether or not a transfer takes place). This will not capture whether firms choose a different mode of transfer or adjust the levels of technology activities under each mode as the institutional regime shifts. In our framework, stronger foreign PRs could potentially expand both affiliated and unaffiliated licensing, shifting the composition of licensing in either direction, depending the strength of the appropriability and internalization effects of PRs. The findings provide a more nuanced understanding of how PRs affect technology transfers via licensing. The impact of PRs on the composition of licensing has significant policy implications since the two forms of licensing promote developing countries' access to new technologies to a different degree.[7]

Studies that are closest to our work include Aulakh et al. (2010, 2013). Their focus is on whether or not the licensing contract will be *exclusive*. IPRs can affect this choice in two opposing ways. First, if IPRs are secure, firms spend less time and effort monitoring the actions of the licensee; hence, stronger IPRs reduce transactions costs and can encourage multiple, non-exclusive, licensing. Second, stronger IPRs enhance the ability of the licensee to earn monopoly rents, and those rents will be higher if the licensees faces fewer competitors (from other licensees and form the licensor itself); hence, stronger IPRs can motivate exclusive licensing. Aulakh et al. (2010) find that IPRs have an insignificant effect on the exclusivity of licensing, suggesting that the two opposing effects may cancel.[8] Importantly, these studies focus on arms-length licensing and do not incorporate affiliated licensing, which a firm may choose to do if it possesses the necessary comple-

[7]Local agents in low-income developing countries especially seek licenses to sell or distribute such products as drugs, medicines, new plant varieties, or pesticides.

[8]In a follow-up study, Aulakh et al. (2013) analyze the effects of IPR on the exclusivity of unaffiliated licensing, controlling for the technological potential of a foreign licensee. A tradeoff exists here because, on one hand, a formidable licensee with much technological potential has the capacity to raise the transactional value of an exclusive license; but on the other hand, such a licensee may be in a position to appropriate the technology and become a competitor. Stronger IPRs help to raise the transactional value and minimize appropriation risks.

mentary assets to develop technologies in-house (see Arora and Ceccagnoli, 2006). Moreover, the studies do not examine the volume of arms-length licensing but consider instead a binary decision of whether to grant exclusive rights. IPRs may affect the volume of such licensing without affecting the external margin.

Another related study is Anand and Khanna (2000), which analyzes licensing by industry, Chemicals, Computers, and Electronics in particular. The study points out that there are industry-specific technological and product characteristics that affect the profitability and nature of licensing. The study focuses on unaffiliated licensing and examines the different features that such contracts can contain.[9] Again, their outcome variables are discrete choice variables of licensing, rather than the volume of licensing fees and royalties. Most importantly, their study does not contain an analysis of the impact of changes in foreign IPRs.[10]

Zhao (2006) helps to resolve a puzzle regarding why MNCs conduct R&D in weak IP countries, like China and India. Zhao (2006) demonstrates that it is largely because multinational companies are able to substitute internal organizations for external IPRs in countries with weak institutional environments. The multinational firm is in essence a mechanism for *arbitraging* institutional gaps around the world using, where available, its close internal global knowledge network so as to exploit underutilized human capital in areas with relatively weak IPR protections. As its dependent variable, Zhao (2006) uses the ratio of patent self-citations to total (patent) citations of a firm. It is intended to measure the degree of internalization, as a multinational affiliate that conducts R&D in a weak IP country would be more reliant on internal resources for technological development. Consistent with its hypotheses, Zhao (2006) finds that the self-citation ratio of MNCs that conduct R&D is indeed higher in weak IP countries and that such firms have greater

[9]For example, exclusivity, restrictions, a related-party license (in the sense that the contracting parties had a prior relationship), or a cross-licensing agreement.

[10]Anand and Khanna (2000) argue that cross-industry variations in licensing can be explained by differences in the strength of IPRs across industries. However, IPR laws generally do not vary across industries—other than whether or not particular inventions are patentable—but vary largely at the country level. Rather, different industries have different sensitivities to IP protection, due say to the complexity of their products or to the length of their product cycles.

cross-border collaborations, indicating that they also have stronger internal linkages. But the Zhao (2006) study focuses on affiliate activity, and does not analyze the arms-length technology transfers, which firms sampled also have the option to engage in. Indeed, it is just as puzzling that some MNCs not only conduct R&D in weak IP countries but they also license to unaffiliated parties in places like China and India.[11]

Studies that do integrate arms-length and affiliate governance structures include Oxley (1999) and Hagedoorn et al. (2005). Oxley (1999) examines the impact of IPRs on whether a U.S. firm chooses to engage in an equity joint venture or contractual (arms-length) alliance. The study finds that firms choose a hierarchical alliance, like an equity venture) when they partner with firms in weak IP countries. Hagedoorn et al. (2005) further confirms this by focusing on R&D ventures in a wider range of industries. Again, both focus on the (yes/no) decisions to engage in different hierarchical modes. Changes in IPR may not necessarily have drastic effects at the external margin, causing firms to abandon one structure for another, but rather may induce firms to adjust their levels of participation in either structure. Moreover, neither study controls for sectoral may be use differences in IP dependence, due say to technological complexity.

Empirical studies that analyze licensing at the intensive margin include Branstetter et al. (2006) and Park and Lippoldt (2005). Branstetter et al. (2006) analyzes the impact of foreign patent reforms on the affiliated licensing of U.S. multinational firms, while Park and Lippoldt (2005) examines the the impact of various types of IPR protection abroad (patent, trademark, and copyright) on unaffiliated licensing of U.S. firms. Neither study integrates both affiliated and unaffiliated licensing, and therefore do not address issues of internalization. Papageorgiadis et al. (2013) examines the share of affiliated licensing in total licensing, but does not study the effects of IPRs on the levels of affiliate and unaffiliated licensing separately. It is possible that IPRs raise the volume of both types of licensing, while favoring one type more than the other. Examining only

[11] In 2014, China accounted for about 6% of all U.S. firm's global unaffiliated licensing, while India accounted for about 1%. Consistent with internalization theories, affiliated licensing was more common (in volume). Specifically in 2014, the ratio of U.S. unaffiliated to affiliated licensing was about 0.7 in China and 0.73 in India. Data source: `www.bea.gov`.

the share does not reveal that possibility. Yang and Maskus (2001) examine levels of affiliate and unaffiliated licensing jointly; however, this study uses aggregate national data, which aggregates firms that may only engage in one type of licensing over another, and so would not properly capture switching or adjusting between modes. Country level data are also not suitable for studying the effects of technological differences in the impact of foreign IPR. We use firm-level data which has the advantage of capturing both the volume and substitution effect at the micro level, and also enabling us to account for the parents' decision to enter or not enter a given country. This is important since the location decision is interdependent with the choice of the mode of control and volume of licensing.[12]

Thus, this paper expands upon the existing literature on IPRs and foreign licensing by going beyond discrete choice analysis and examining internal and external licensing jointly. Furthermore, we capture the differential responses to IPRs across sectors, specifically across product categories.

The paper emphasizes the importance of studying the interaction between transaction characteristics and the institutional environment and so is related to Oxley (1997, 1999) and Henisz (2000), but the type of characteristics considered is different. Oxley (1997, 1999) and Henisz (2000) focused on the appropriability hazards in contracting for the transfer of the technological innovation. We instead focus on the appropriability hazards which result from the technological leakage of information that leads to imitation by rivals. These hazards are of great concern when transferring technology to developing countries even if the transfer is within firm boundaries. The two types of hazards are also fundamentally different in how they relate to the degree of tacitness of know-how: the hazard in contracting rises while the hazard of technological leakage and imitation falls as the degree of tacitness of know-how rises.[13] The analysis reveals that stronger PRs in the host country increase affiliated licensing among simple-technology firms, strongly enough that the composition of their licensing further shifts towards affiliates. These findings hold even after we control for the

[12]We isolate the location decision in the Sensitivity Analysis section, where we model the probability of a parent firm licensing into a country, and show that our results remain robust.

[13]This distinction is underscored in Oxley (1997).

firm's R&D intensity (as a percentage of sales), in order to proxy for contractual hazards as in Henisz (2000).

As the paper studies the interaction between firm strategy and the institutional environment, it is also related to Zhao (2006). In our paper, the firms take the imitation risk in a host country as given but the extent of their exposure to this risk varies: it is low among complex-technology firms and high among simple-technology firms. An explanation is that the more complex technologies could be fragmented to discourage imitation as in Zhao (2006), whereas the more simple ones have limited alternative methods of protection. Firms with more simple technologies choose the more secure means of transfer via affiliates and subsidiaries and also rely on a host's PRs to further limit the risk of imitation. This explains why the volume of their affiliated licensing rises in response to stronger host's PRs (in spite of the negative influence of the internalization effect), while it falls among complex-technology firms. This distinction is key to understanding the licensing impact of developing countries' PRs, and has not been highlighted previously.

Lastly, this paper contributes to the international development literature by examining the consequences of patent protection on multinational firms' licensing strategy. Development scholars have stressed the fundamental role of technology for economic growth and development, but remain divided on the role and relevance of patent rights in facilitating technology transfer from developed to developing countries. The policy debate, moreover, largely abstracts from firm strategies, such as how global companies manage and choose their entry modes, and how their decisions interact with the policy environment. Our work underscores the importance of IPR policy taking into account firm decision-making processes and thus helps advance public policy debate using insights from international business research. The paper focuses on host countries in the developing world, where patent systems are generally weaker and concerns about technological leakage of information and subsequent imitation by rivals are most prominent. The relative ease of imitation compels multinational firms to carefully consider appropriability regimes in their licensing strategies. The appropriability effect of stronger PRs is particularly important among simple-technology firms licensing to developing countries, and it overtakes the internalization effect.

The next section provides a conceptual framework for thinking about how appropriability and internalization motives condition the effects of PRs on a multinational firm's licensing strategies.

THEORY AND HYPOTHESES

Central to our analysis is the argument that the impact of stronger foreign PRs on the volume of licensing and the mode of control depends critically on the underlying technological complexity of the firms' products. To formalize this argument and develop testable hypotheses, we propose a simple model of the foreign market entry strategy, endogenous technological composition of licensing activity, and asymmetries in the impact of PRs.[14]

Let $z \in [0, 1]$ index the underlying technological complexity of a firms' products, with simple-technology firms having a lower z. Firms take the technological complexity of their products as given and decide on the volume of licensing (i.e., how much technology to transfer via licensing into a country) and the mode of control (i.e., whether to license its technology to an affiliate or unaffiliated party). Technological complexity determines the strength of the appropriability regime and so, influences the firm's ability to capture the profits generated by licensing technology. Teece (1986) argued that the complex, tacit nature of knowledge reduces appropriability hazards which result from technological leakage of information leading to imitation by rivals. Building on this insight, we assume that technological complexity z is negatively related to the hazard rate by which innovations are imitated. For simplicity, we assume that $m(z) \equiv \mu(1 - z)$.[15] The imitation rate falls from its maximum of μ to its minimum of zero as technological complexity z rises from its minimum of zero to its maximum of one. The parameter μ measures the strength of foreign patent rights which according to Teece (1986), is the second key dimension of the appropriability

[14] This model is a modified version of that developed in Ivus et al. (2015).

[15] One reason the risk of imitation is lower among complex-technology firms is that their product domain does not coincide with their technological domain (which is why patent classifications differ from industrial classifications). The same invention can usually be in multiple industrial products, and one industrial product can be the result of multiple inventions. Parties cannot produce a good or innovation without access to the multiple necessary technologies. For pharmaceuticals, by contrast, there is a greater mapping between product and invention.

regime.

Let $V^k(z)$ represent the expected present discounted value of the stream of profits for a firm which engages in affiliated ($k = A$) or unaffiliated ($k = U$) licensing. At every point in time, the firm with each z chooses the strategy with the maximum of the two options given by $V(z) \equiv \max[V^A(z), V^U(z)]$. Appropriability hazards are high when the firm transfers proprietary technical information to its subsidiaries in foreign countries with weak PRs (Zander and Kogut, 1995; Poole, 2013; Berry, 2014). Poole (2013), for example, finds that the firm's technology may be misappropriated by the subsidiary's employees and used to start up imitative production. Greater still are the appropriability hazards when technology is transferred to unaffiliated parties. Unaffiliated licensing involves sharing technology with arm's length firms which are generally independent of control. The inability of the firm to control the actions of a licensee creates an incentive to internalize transactions through affiliated licensing. We account for the greater appropriability hazards under unaffiliated licensing by assuming that unaffiliated licensing entails the imitation risk premium, $\iota > 1$, and that the terms of the licensing contract fail to limit this extra risk. Consequently, the imitation rate equals $m_A(z) = \mu(1 - z)$ when the firm engages in affiliated licensing and $m_U(z) = \iota\mu(1 - z)$ when the firm engages in unaffiliated licensing. The existence of $\iota > 1$ provides an internalization motive for affiliated licensing.

Once imitation occurs, the firm's future profits are driven to zero. Hence, the expected present discounted value of the stream of profits from licensing is risk-adjusted: $V^k(z) = \pi^k(z)/[r+m_k(z)]$, where $\pi^k(z)$ denotes instantaneous profits and r is the discount rate. The firm with a given z will choose unaffiliated licensing over affiliated licensing if profits from unaffiliated licensing, adjusted for higher risk, are sufficiently large:

$$\frac{\pi^U(z)}{r + m_U(z)} > \frac{\pi^A(z)}{r + m_A(z)}. \tag{1}$$

A licensing contract stipulates rent sharing between the licensor and the licensee. With Cobb-

Douglas preferences as in Ivus et al. (2015), the ratio of instantaneous profits $\pi^U(z)/\pi^A(z)$ is simply equal to λ_U/λ_A, where λ_U and λ_A are the shares of profits retained by the firm from unaffiliated and affiliated licensing respectively. Using this result, we rewrite the inequality (1) as follows:

$$\frac{\lambda_U}{\lambda_A} > \frac{r + m_U(z)}{r + m_A(z)}. \tag{2}$$

The market for technology licensing is imperfect (e.g., due to limited information and uncertainty in the outcomes of licensing transactions) and these imperfections limit the licensor's ability to extract rents from the licensee. Hazards in contracting and information, bargaining and enforcement costs discourage technology transfer to unrelated parties and encourage affiliated licensing instead. Costly renegotiation, for example, increases transaction costs for arm's length technology transfer, while exercise of command and control within the firm avoids renegotiation costs. Unaffiliated licensing is difficult to manage effectively but at the same time, it could be a more attractive model of control. One reason is that little or no equity need be granted. Another reason is that licensing an independent local firm to produce and distribute the product allows the licensor to lower the cost of training foreign workers and coordinating foreign manufacturing activities, which could be significant under affiliated licensing. Contracting out also yields a cost advantage to the firm if the firm lacks specialized complementary assets such as manufacturing and marketing (Teece, 1986; Arora and Ceccagnoli, 2006). As such, λ_U could exceed λ_A when the risk of imitation is zero. But the key question for us is how the relative profitability of unaffiliated licensing varies with the rate of imitation, as determined by the underlying technological complexity of a firms' products, z. We consider this next.

Technological complexity differences in the nature of licensing

It is easy to show that the term on the right hand side of the inequality (2) is high when z is low. This is because low-z firms face high appropriability hazards due to imitation and unaffiliated licensing entails the imitation risk premium (i.e., $\iota > 1$ and so $m_U(z) > m_A(z)$).

The relationship between z and the term on the left hand side of (2) is less clear. To the extent that greater technological complexity implies lower appropriability hazards which result from technological leakage and imitation by rivals, λ_U/λ_A should be positively related to z. If for example, the firms share rents with their licensees to deter imitation, then the licensors' profit share will be low among low-z firms with high imitation risk. Such profit sharing is optimal in the presence of asymmetric information (Gallini and Wright, 1990) and is most relevant for unaffiliated licensing, which carries the imitation risk premium.

At the same time, greater technological complexity could also imply greater appropriability hazards in contracting for the transfer of the technological innovation (Oxley, 1997; 1999; Henisz, 2000). Concerns over contractual hazards are expected to be particularly important when licensing technology to unrelated parties—for example, because an unrelated party is more likely to renege on the terms of a licensing agreement (Anand and Khanna, 2000)—but arm's length contracts can also overcome the problems in contracting for complex know-how—if for example, know-how is bundled with other complementary inputs with the superior enforceability of contracts in a technology package (Arora 1996).

The relationship between λ_U/λ_A and z is ambiguous but we can still establish the result that the inequality (2) is more likely to hold for high-z firms provided the imitation risk premium under unaffiliated licensing, ι, is high enough. If we further assume that $\lambda_U > \lambda_A$ (so that unaffiliated licensing is the preferred mode of control for the $z = 1$ firm with highly complex technology and zero imitation risk), we find that there exists a unique and interior cut-off level of technological complexity $\bar{z}$ such that the simple-technology firms with $z < \bar{z}$ choose the more secure means of transfer via affiliates and subsidiaries while the complex-technology firms with $z > \bar{z}$ choose unaffiliated licensing. We summarize the endogenous technological composition of licensing activity for a given strength of host's PRs in Hypothesis 1.[16]

[16] This is not to preclude other compounding effects at work. Complex products involving multiple actors (i.e., IP owners) and long supply chains may give rise to the prevalence of arms-length (unaffiliated) contracting. We thank an anonymous reviewer for this insightful comment.

Hypothesis 1 (H1): *Compared to firms producing technologically complex products, firms producing technologically simple products prefer affiliated over unaffiliated licensing, all else equal. The composition of licensing is thus relatively more skewed towards affiliated parties among firms with more simple technology, holding the strength of host's PRs constant.*

The licensing impact of strengthening PRs

Strengthening host's PRs limits imitation as measured by the parameter μ_k (i.e., $d\mu_k/dPRs < 0$) and as a result, has two effects on the firm's licensing strategy: the appropriability effect and the internalization effect. First, production reallocates from imitators to multinational firms, and the volume of unaffiliated and affiliated licensing rises within each firm as a result. This is the appropriability effect of stronger foreign PRs. Second, the relative attractiveness of licensing to unaffiliated parties rises, motivating some firms to switch from affiliated towards unaffiliated licensing (as the cut-off level of technological complexity $\bar{z}$ falls). This is the internalization effect. Unaffiliated licensing benefits from limited imitation under strong PRs the most because it carries the imitation risk premium. Stronger PRs protection also reduces the costs of achieving mutually agreeable licensing contracts and strengthens the licensor's bargaining power (Yang and Maskus, 2001). The relative share of profits from unaffiliated licensing λ_U/λ_A could rise as a result, which would reinforce the internalization effect. Hypothesis 2 summarizes the two effects.

Hypothesis 2 (H2): *Strengthening foreign PRs has two effects on the licensing strategy of a firm: (i) it increases the volume of technology licensing to both affiliated and unaffiliated parties, all else equal (i.e., the appropriability effect) and (ii) it reduces the firm's reliance on affiliated licensing as the more secure means of transfer and could motivate the firm to switch towards unaffiliated licensing (i.e., the internalization effect).*

The appropriability effect of stronger foreign PRs acts to increase the volume of technology transfer via licensing both within and outside the firm. This increase could be the result of firms switching from keeping a technology secret to marketing/licensing their technology as appropriability hazards fall. The internalization effect, on the other hand, acts to increase the firms' reliance on unaffiliated licensing while at the same time, reducing the firms' reliance on affiliated licensing as the more secure means of transfer. The underlying decision here concerns the preferred mode of control—whether to license the technology to an affiliate or unaffiliated party.

The internalization effect of stronger foreign PRs is to reduce affiliated licensing and shift the composition of licensing towards unaffiliated parties, but the appropriability effect has an opposing impact. If the appropriability effect on affiliated licensing is relatively strong, the composition of licensing could shift further towards affiliates. The overall impact of stronger PRs on licensing strategy is ambiguous and depends on the endogenous technological composition of licensing activity, as summarized by H1. The technological composition of licensing is critical for determining the overall impact of PRs because (i) the average technological complexity of the firms' products varies among firms which choose to engage in unaffiliated or affiliated licensing when the host's PRs are weak and (ii) the effectiveness of patents varies with the degree of the underlying technological complexity of the firms' products. We discuss how the licensing impact of stronger host's PR varies with technological complexity of the firm's products next.

Technological complexity differences in the licensing impact of strengthening PRs

Stronger PRs reduce the risk of imitation across all firms but the impact is strongest among low-z firms: $dm_k(z)/dPRs = (1 - z)d\mu_k/dPRs$. The technologies of low-z firms are simple enough that they can be easily communicated, misappropriated, and imitated. Consequently, low-z firms rely relatively more on strong PRs in the host country to protect their inventions and lower appropriability hazards.[17] Furthermore, patents are perceived as relatively effective means of appropriating rents from simple technological innovations, because simple technologies can be easily described in a patent and inventing around such a patent is hard. Anand and Khanna (2000), for example, argue that a pharmaceutical patent is hard to invent around "since a slight

[17]Mansfield et al. (1981) and Levin et al. (1987) found that patents raise imitation costs by 30-40 percentage points in drugs and 7-15 points in electronics.

change in the underlying gene sequence of a protein can result in very different functions."

The high-z complex-technology firms, by contrast, are less reliant on strong patent protection in the host country. The technologies of high-z firms are complex enough that they can be separated and recombined to discourage imitation and to devise alternative methods of protection in countries with weak PRs (Zhao, 2006). Moreover, patents are perceived as a relatively ineffective tool for preventing the imitation of complex technological innovations. A typical complex technological innovation has a large number of components each protected by a separate patent. The legal requirements for upholding the validity of such patents are high (Teece, 1986). Patents for one complex innovation are often owned by different firms, and the risk of patent infringement in complex technology markets is high (Grindley and Teece, 1997). Complex technology firms primarily use patents as a bargaining chip in cross-licensing negotiations, but their foreign market entry strategies are not as sensitive to country differences in the strength of PRs.

Taken together, the above arguments form the basis for hypotheses H3a-H3c:

Hypothesis 3a (H3a): *Strengthening foreign PRs increases the flow of unaffiliated licensing across all firms, but cross-product differences in the impact are relatively weak.*

The flow of unaffiliated licensing rises across all firms with stronger foreign PRs due to the combined impact of the appropriability and the internalization effects. The cross-product differences in the impact are expected to be relatively weak. This follows since from H1, unaffiliated licensing is primarily composed of complex-technology products, which have a low reliance on PRs as a means of limiting imitation and lowering appropriability hazards.

Hypothesis 3b (H3b): *Strengthening foreign PRs increases the flow of affiliated licensing relatively more among simple-technology firms, as compared to complex-technology firms.*

From H1, affiliated licensing is primarily composed of simple-technology products, which face higher risk of imitation and rely relatively more on strong host's PRs to lower appropriability hazards. The appropriability effect, which increases the flow of affiliated licensing, is expected to be relatively strong among these firms (compared to complex-technology firms). As technological complexity of firms' products rises, the appropriability effect becomes weaker, making it more likely that the internalization effect would dominate, in which case the flow of affiliated licensing will fall with strengthening host's PRs.

Hypothesis 3c (H3c): *Strengthening foreign PRs shifts the composition of licensing towards affiliated parties relatively more among simple-technology firms, as compared to complex-technology firms.*

METHODS

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:

$$T_{ijt} = \alpha + \beta_1 P_{jt} + \beta_2 X_{jt} + \beta_3 R_{it} + \beta_4 A_{it} + \beta_5 A_{it} \times P_{jt} + \alpha_j + \alpha_t + \tau_{jt} + \varepsilon_{ijt}, \tag{3}$$

where T_{ijt} is the technology transfer via the licensing of intangible assets. We consider three outcome variables (in logs): 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) to study the composition of licensing. The independent variable P_{jt} is the strength of PRs 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 number of U.S. patents granted to firm i at time t, and $A_{it} \times P_{jt}$ is the interaction of A_{it} with the host's strength of PRs. Similar to Branstetter et al. (2006), we include $A_{it} \times P_{jt}$ to allow the impact of PRs to vary with the extent to which firms utilize PRs. Next, α_j and α_t are the country and year fixed effects, and τ_{jt} the vector of country-specific linear time trends. Last, α is the constant term and ε_{ijt} the stochastic error term.

To examine the role of technological complexity, we augment the model (3) as follows:

$$T_{ijt} = \alpha + \beta_1 P_{jt} + \beta_2 X_{jt} + \beta_3 R_{it} + \beta_4 A_{it} + \beta_5 A_{it} \times P_{jt} + \beta_6 Z_p + \beta_7 Z_p \times P_{jt} + \alpha_j + \alpha_t + \tau_{jt} + \varepsilon_{ijt}, \quad (4)$$

where Z_p is the level of technological complexity of product p and $Z_p \times P_{jt}$ the interaction between the technological complexity measure and the host's PRs. By separately controlling for Z_p, we allow T_{ijt} to differ among the products for reasons other than the strength of PRs.[18]

The models (2) and (3) 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 technological complexity. Importantly, our choice of the estimator is not critical to our results. We also 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. We found that this form of endogeneity does not explain our results and the firm-by-country specific effects could be treated as random. We also employed Heckman's two-stage estimation procedure, to allow for the selection of firms into licensing, and confirmed that a selection bias does not explain our results. Last, we implemented the instrumental variable estimator using colonial origin to isolate exogenous variations in PRs, and concluded that the endogeneity of the strength of countries' PRs does not drive our results.

H1 implies a positive coefficient on Z_p in (4) when T^U or T^U/T^A is the outcome variable, and a negative coefficient on Z_p when T^A is the outcome variable. H2 further implies a positive coefficient on P_{jt} when T^U is the outcome variable. When T^A is the outcome variable, H2 implies a positive coefficient on P_{jt} if the appropriability effect is strong and a negative coefficient on P_{jt} if the internalization effect is strong. H3 discusses how the impact of PRs depends on the level of technological complexity of a firm's products. From (4), this dependence is given by $dT_{ijt}/dPR_{jt} = \beta_1 + \beta_7 Z_p$. H3a implies that the coefficient β_7 is relatively small or statistically

[18] In our data, each firm i produces within a single product category p over time.

insignificant when T^U is the outcome variable. We also expect $\beta_1 > 0$ and $\beta_7 < 0$ when T^A is the outcome variable (H3b) and $\beta_1 < 0$ and $\beta_7 > 0$ when T^U/T^A is the outcome variable provided the appropriability effect is strong (H3c).

DATA

Our data come primarily from a micro database of U.S. parent companies with foreign direct investments and operations around the world.[19] 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. We focus on technologies transferred by U.S. parent companies to 44 developing countries, where concerns about weak IP protection have been the most prominent and where access to new technologies is crucial.[20,21] 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.[22] 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.[23] In total, 1,185 U.S. firms

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

[20]The countries are listed in Appendix II. Our classification of developing countries is based on that of the United Nations (see UNCTAD, 2009). Though some of these countries (e.g., South Korea and Singapore) have exhibited rapid growth during the sample period, there had been major concerns with their IP provision and enforcement, imitative activities, and piracy during that period (see Business Software Alliance, 2002).

[21]The data show significant differences in the strength of PRs across developing countries. From Table A1 in Appendix IV, the coefficient of variation in the index of PRs is 0.39 for the sample of 44 developing countries and only 0.14 for the sample of 23 developed (OECD) countries. Table A2 further reports the average ratio of unaffiliated to affiliated licensing and shows that compared to developed countries, the ratio for developing countries is higher across complex-technology firms but lower across simple-technology firms. These patterns are consistent with the developing countries having weaker patent regimes and with simpler technologies having higher imitation risks.

[22]Although our sample ends in 2009, the BEA data collection continues beyond.

[23]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.

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.

Outcome Variables

The level of unaffiliated licensing is the sum of 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 is the sum of all the licensing fees and royalties received by the parent firm from its foreign affiliate(s) in host country j at year t. The data are in real 2005 PPP-adjusted dollars.

The analysis is performed on the flow of licensing, but we also used the stock of licensing capital as an alternative measure and confirmed that our results are not driven by our choice of the measure of licensing. We constructed the stock measure using the perpetual inventory method with a depreciation rate of 20%.[24] This 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. 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 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 PRs in a host country could affect the formation of this type of technology capital as well as impact the flow of technology transfer.

Independent Variables

[24]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.

We measure the strength of patent protection by an index of PRs (see Park, 2008). 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.[25] We also consider a patent reform dummy variable as an alternative measure 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.[26]

To explore the role of technological complexity, we employ the task-based measure from Naghavi et al. (2015). The measure is obtained at the product category level (2-digit *Nomenclature of Economic Activity*, or 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.[27] 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 average intensity of complex problem-solving tasks

[25]The sample period goes up to 2009, and the PRs index goes up to 2005. The index values follow a step function, shifting approximately every five years during the sample period.

[26]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.

[27]Complex problem-solving skills fall into the following eight categories: (1) problem identification, (2) information gathering, (3) information organization, (4) synthesis/reorganization, (5) idea generation, (6) idea evaluation, (7) implementation planning, and (8) solution appraisal.

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 technological 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.

Control Variables

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.[28] To mitigate the concern that a firm's patenting strategies may depend on its licensing and commercialization decisions, we lag the number of parent patents three years.[29]

The parent firm R&D intensity is defined as the ratio of the parent firm R&D spending to its sales. Several studies have shown that firms that heavily use research inputs and proprietary technology in their production process have strong incentives to internalize technology markets (see for example, Buckley and Pearce, 1979). 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.[30] Both of these measures come from the BEA data. 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

[28] 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.

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

[30] 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.

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.[31]

In our sensitivity analysis, we use eight additional variables: parent's capital-labor ratio (in logs); parent's assets; the share of a parent's foreign sales in its world sales; the share of a parent's unaffiliated exports in its total exports; the quality of legal institutions; the industry measure of product life-cycle length; affiliate R&D intensity; and the cost of patenting abroad per market size. The parent's capital-labor ratio is the ratio of its net property, plant, and equipment (PPE) to its employment.[32] Following Hall and Ziedonis (2001), we use the capital-labor ratio to capture the effects of sunk costs which can create patent holdup problems and so, provide incentives for firms to patent and cross-license. The parent's assets can proxy for firm size. Large firms have the resources to invest abroad and source globally.[33] The share of a parent's world sales that is foreign and the share of its exports that are unaffiliated are used to measure its foreign experience. A number of previous studies have used a company's international experience as a control variable.[34] Firms with greater foreign experience can build on existing trading relations and may therefore face lower fixed costs of foreign licensing. The data on institutional quality are from Kunčič (2014).[35] We add the measure of the quality of legal institution since our measure of PRs could

[31]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).

[32]Data on the stock of net PPE is available during the BEA's benchmark years (for example, 1989, 1994, 1999, 2004, and 2009). For the non-benchmark years, we used net expenditures on PPE to fill in the gaps.

[33]See Arora and Fosfuri (2000), Motohashi (2008), and Berry and Kaul (2015).

[34]See Oxley (1999), Hagedoorn et al. (2005), Aulakh et al. (2010, 2013), and Berry and Kaul (2015).

[35]The measure combines the information of several institutional indices from the Heritage Foundation, the Wall

be picking up the effects of broader institutional changes correlated with patent protection. Our measure of the industry product life-cycle length is binary and created using 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. We include this measure (by itself and interacted with PRs), since product life-cycle length matters for multinational activity (Bilir, 2014) and could be correlated with technological complexity. The R&D to sales ratio of the (aggregate) affiliates of the parent company enables us to see, if only tentatively, whether R&D transferred to affiliates reduces or obviates the need to transfer technologies to them via licensing. Given the potential for simultaneity between affiliate licensing and affiliate R&D, we lag this measure three years. 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), and varies by host country and year. We divided the cost of patenting by GDP to obtain the cost of patenting per market size.

Table 1 summarizes data on the three outcome variables: the flow of unaffiliated licensing, the flow of affiliated licensing, and the ratio of unaffiliated to affiliated licensing flows across all parent firms and across firms by technological complexity (below and above median). Compared to firms with a more simple technology, firms with a more complex technology 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 356.5 and -158.7. When unaffiliated licensing flow is evaluated relative to its affiliated counterpart, we see that this ratio is 0.824 points higher for firms with more complex technology. All the differences in means are highly statistically significant. Overall, these results support H1 and suggest that the technological complexity of products influences the licensing impact of PRs.

The results in Table 1 are not driven by the aggregation of product categories into two groups but

Street Journal, Freedom House, Fraser Institute, World Bank World Governance Indicators, and so forth.

also hold at the level of individual industries. Table 2 summarizes the results for eight industries. It shows that technological complexity is highest in *Machinery and equipment*, *Electronics and components*, and *Transportation*. These complex-technology 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 a more simple technology, by contrast, affiliated licensing is generally more common than its unaffiliated counterpart. The share of affiliated licensing is relatively high in all simple-technology 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 licensing flows (in thousands of real 2005 U.S. dollars) across 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 for 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 PRs. These country-level comparisons further reveal that countries with weak PRs (compared to the top third countries) obtain less affiliated and unaffiliated licensing from U.S. parent companies. The difference is particularly striking for unaffiliated licensing.

RESULTS

Table 3 shows the results of estimating the basic model (3) in columns (1)-(3) and the augmented model (4) in columns (4)-(6). In columns (1)-(3), the outcome variables are T^U, T^A, and T^U/T^A. It is apparent that the coefficient on the PRs index is positive and statistically significant at the 5% level in columns (1) and (2). Stronger host's PRs promote the licensing of innovations to both affiliated and unaffiliated parties, all else equal. These results confirm H2 and suggest that the appropriability effect is strong. We further see that the coefficient on PRs is not statistically different from zero in column (3), where T^U/T^A is the outcome variable. Thus when technological complexity is not taken into account, stronger PRs promote unaffiliated and affiliated licensing to a similar degree, leaving the composition of licensing unchanged.

In columns (4)-(6), we add the measure of technological complexity (Z_p) and its interaction with PRs ($Z_p \times P_{jt}$) to our controls. It is apparent that the coefficient on Z_p is positive and highly statistically significant in column (6). Thus, all else being equal, firms producing technologically simple products (relative to those producing technologically complex products) have a lower ratio of unaffiliated to affiliated licensing. That is, the composition of licensing is relatively more skewed towards affiliated parties among firms with more simple technology, which confirms H1. The results further show that the product difference in the composition of licensing is particularly pronounced in countries with strong PRs. The coefficient on $Z_p \times P_{jt}$ is positive and highly statistically significant in column (6). Simple-technology firms choose the more secure means of transfer via affiliates and subsidiaries, and also rely on a host's PRs to further limit the risk of imitation. Thus, technological complexity, by itself and together with patent protection, plays a key role in determining the composition of licensing.

The results in columns (4) and (5) further our understanding. In column (4), 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, firms with a more simple technology engage in unaffiliated licensing less, and the product difference in unaffiliated licensing is similar across developing countries, regardless of the level of their PRs. In column (5), 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, respectively. Thus simple-technology firms engage in affiliated licensing relatively more, and this is especially true in countries with strong PRs.

We now consider the effects of PRs and test H3a. From column (4), the elasticity of unaffiliated licensing with respect to PRs is $d \ln T^U / d \ln PRs = 0.311$, which does not depend on Z_p.[36] This

[36]The coefficients on $Z_p \times P_{jt}$ and $A_{it} \times P_{jt}$ are not statistically significant at the 5% level in column (4) and so are not taken into account.

result implies that strengthening PRs in developing countries makes the licensing of innovations to unaffiliated parties more attractive, and that this effect is equally strong across all firms, regardless of the level of technological complexity of their products. This result confirms H3a.

H3b requires a positive coefficient on P_{jt} ($\beta_1 > 0$) and a negative coefficient on $Z_p \times P_{jt}$ ($\beta_7 < 0$) in column (5), which is what we see. The results imply that the impact of stronger PRs on affiliated licensing (given by $d \ln T^A / d \ln PRs = 1.389 - 4.162 Z_p$) is positive for any $Z_p < 0.333$. In our sample, the variable Z_p ranges from a minimum of 0.1839178 to a maximum of 0.4221271. Thus it follows that when PRs are strengthened, the attractiveness of affiliated licensing rises among simple-technology firms and falls among complex-technology firms. The results in column (6) further indicate that the increase in affiliated licensing among simple-technology firms is strong enough that the entire composition of their licensing shifts towards affiliated parties, since $d \ln(T^U/T^A)/d \ln PRs = -1.068 + 3.5 Z_p < 0$ for any $Z_p < 0.305$. For complex-technology firms, by contrast, strengthening PRs reduces the attractiveness of affiliated licensing and shifts the composition of licensing further towards unaffiliated parties. These results are consistent with H3c and suggest that the appropriability effect is strong.

The coefficients on the number of U.S. patents of parent firms A_{it} and the interaction of A_{it} with the host's PRs are not statistically significant at the 5% level in columns (3) and (6). Thus we find no evidence that the composition of licensing differs with the extent to which firms utilize PRs. The coefficient on A_{it} is positive and statistically significant at the 5% level in columns (1) and (4). This result suggests that firms which utilize PRs more engage in more unaffiliated licensing, as they have more technologies, inventions, and other intangible assets to license to unrelated parties. At the same time, the coefficient on $A_{it} \times P_{jt}$ is not statistically significant at the 5% level. This result suggests that the licensing impact of stronger PRs does not vary with the number of parent patents. The coefficients on the host's relative wage and corporate income tax rate are statistically insignificant in all columns. Inward capital restrictions abroad encourage firms to access foreign markets by transacting with unaffiliated parties, as suggested by the positive and significant coefficient on capital restrictions in columns (1) and (4). Importantly, all of these factors appear to have a balanced or neutral effect on the licensing volumes so that the composition of licensing is left unchanged. The host's level of GDP and parent's R&D intensity are the only exceptions. These two variables are positively associated with both types of licensing but negatively associated with the ratio of unaffiliated to affiliated licensing. Thus consistent with the internalization literature, we find that R&D-intensive or knowledge-intensive parent firms favor affiliated over unaffiliated licensing (Henisz, 2003 and Buckley and Casson, 2009). To the extent that firms invest more heavily in their research inputs and proprietary technology, they have a greater incentive to internalize international markets.

Sensitivity Analysis

Sensitivity to additional controls

Our results in Table 3 could be driven by cross-product differences in the licensing strategies of firms, independent of PRs. Technological differences in firms' modularization strategies, for example, could influence firm licensing decisions. Complex-technology products are easier to modularize, which could explain a positive coefficient on Z_p when unaffiliated licensing is the outcome variable.[37] To check that such cross-product differences are not driving our results, we re-estimate the model (3) with product fixed effects. Column (1) in Table 4 reports the results when T^U/T^A is the outcome variable. The coefficient on Z_p is not identified in this model (since all cross-product variation is consumed by the 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), we also include eight interactions of industry indicators with the strength of PRs, since the impact of PRs could vary across industries for reasons other than differences in technological complexity. For example, we observe a lot of unaffiliated licensing in the *Electronics and components* industry because of its specific input-output structure. Components and intermediate inputs produced in this industry are used in other products or designed to work with other pieces. Often,

[37] We thank an anonymous referee for bringing this to our attention.

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 this industry. The modular, fragmentable nature of electronics products and technologies likely facilitates the external sourcing of components to countries where factor costs and access to raw materials are more advantageous (Ernst, 2005 and Ziedonis, 2004). The industry-PRs interactions 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 on $Z_p \times P_{jt}$ is still positive and highly statistically significant, but larger in magnitude.

Our results are also robust to having additional controls: the parent's capital-labor ratio; the parent's assets; the share of a parent's foreign sales in its world sales; the share of a parent's unaffiliated exports in its total exports; the quality of legal institutions; the industry measure of product life-cycle length; and affiliate R&D intensity. Table 5 shows the results. The coefficients on P_{jt}, $Z_p \times P_{jt}$ and Z_p are of the same sign and all but the coefficient on P_{jt} in column (4) are statistically significant at the 5% level. We further find that parents with a higher capital-labor ratio engage in more unaffiliated licensing (say via cross-licensing) when the host's PRs are strong. Parents with more assets also engage in unaffiliated licensing relatively more, regardless of the level of PRs. The unaffiliated licensing ratio is also high across firms with more foreign experience. We also observe more unaffiliated licensing in industries with a shorter product life-cycle. This could be because if product life-cycle is short, obsolescence is more likely to occur before imitation (Bilir, 2014). Patent protection is more effective in industries with a longer product life-cycle, where the impact of PRs is to shift the composition of licensing towards unaffiliated parties. Finally, affiliate R&D intensity is not a statistically significant factor in affiliated or unaffiliated licensing.[38]

[38]While we do not find that affiliate R&D crowds out parent company licensing to affiliates or detracts from a parent's licensing to unaffiliated parties, we cannot preclude the possibility of a more nuanced firm strategy at work in licensing decisions.

Sensitivity to model specification

The results in Table 3 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. To allow for this form of endogeneity, we re-estimate (3) using the OLS estimator with firm-by-country fixed effects. These fixed effects wipe out all cross-sectional variation in our data, leaving variation within firm-country pairs over time to identify the coefficients of interest. Since the technological complexity measure does not vary over time, the coefficient on Z_p cannot be estimated here. Table 6 shows the results, which are very similar to those in columns (4)-(6) in Table 3. The coefficients on P_{jt} and $Z_p \times P_{jt}$ have the same sign, are close in magnitude, and have similar statistical significance. The coefficient on P_{jt} is statistically significant at the 5% level in all columns, and that 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 zeros thus far but if their occurrence is non-random, our results may be biased as they do not account for the selection of firms into licensing. To address this concern, we 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 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 flow of licensing directly. In other words, patenting cost affects firms' *decisions* to protect and market an asset, but not the extent of their activity with the asset once they acquire the protection. Table 7 reports the results of Stage 1 in columns (1)-(2) and Stage 2 in column (3). The outcome variable is equal to one if the flow of unaffiliated licensing is non-zero in column (1) and if the flow of affiliated licensing is non-zero in column (2). The coefficient on the cost of patenting is highly statistically significant, indicating that the cost of patenting is an appropriate exclusion restriction. The coefficients on the inverse Mills ratios λ_1 and λ_2 are not statistically different from zero. Thus no evidence of selection bias is detected.[39]

A wide range of domestic factors may influence countries' inflows of innovative products and technologies and their implementation of patent laws.[40] 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 mitigate these concerns, but do not necessarily correct for this form of endogeneity. To estimate the causal effect of PRs, 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.[41] The resulting data are a cross-section of firms. Among 44 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 Z_p and A_{it}—as excluded instruments for the three endogenous variables—the changes in PRs (ΔP_{jt}) and the interactions of ΔP_{jt} with Z_p and A_{it}. Our IV approach is valid under the assumption that colonial origin has no effect on the outcome of interest, other than its

[39]Results are similar when the cost of patenting not scaled by GDP is used as the exclusion restriction.

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

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

effect through changes in PRs. This assumption might be too strong when growth in licensing flows is the outcome variable. 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, as it requires the colonial origin of a developing country to have no direct impact on the growth in the *composition* of licensing.

Table 8 follows. Stage 1 results are in columns (1)-(3), where each of the three endogenous variables are the outcome variables. Stage 2 results are in column (4), where $\Delta(T^U/T^A)$ is the outcome variable. 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.[42] 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 endogeneity bias. Indeed, the IV estimates are in line with those in Table 3. From column (4), the coefficient on the PRs changes is negative and the coefficient on the interaction of PRs changes with Z_p is positive. Both coefficients are highly statistically significant.

Sensitivity to measures of licensing and PRs

Our results remain qualitatively unchanged when we adopt alternative definitions of the composition of licensing, use different measures of intangible assets, or employ a different measure of patent protection. To show this, we first re-estimate (4) using the patent reform dummy variable as an alternative measure of patent protection. The patent reform dummy allows us to study changes in technology transfer that occur around the time of reform, while the PRs index allows us to study the relationship between licensing and the intensity of patent protection. Table 9 shows the results, with and without firm-by-country fixed effects. Our results are qualitatively unchanged.

We then re-estimate (4) using the stock measure of licensing. Columns (1)-(3) in Table 10 show

[42] The robust Kleibergen-Paap Wald rk F statistic equals 65.29.

the results. In the last two columns, 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 stocks and those in column (5) are for licensing flows. Again, our results are qualitatively the same.

CONCLUSION

This paper examined the impact of foreign patent protection on U.S. multinational firms' technology licensing strategy and technology transfer flows to developing countries, where the security of PRs protection has been (and still remains) a major concern. It moves beyond previous work by studying affiliated and unaffiliated licensing flows in an integrated framework, where firms decide on both the volume of licensing and the preferred mode of control, and underscoring the role of the technological complexity of firms' products in determining the impact of foreign PRs. Using a detailed firm-level dataset on U.S. multinational companies, we measured how the *volumes* and the composition of licensing respond to a strengthening of foreign PRs, and how their responses vary with the underlying technological complexity of the firms' products. Previous empirical work on multinational licensing has largely focused on one particular mode of licensing or worked with discrete dependent variables. The role of technological complexity, which plays a key role in determining the licensing impact of PRs, has also not been examined to date.

Our results show that strengthening PRs in developing countries provides all firms with a stronger incentive to increase their unaffiliated licensing (i.e., the internalization effect). The attractiveness of affiliated licensing also rises among simple-technology firms (i.e., the appropriability effect), strongly enough that the composition of their licensing shifts towards affiliated parties. For firms producing complex products, by contrast, the appropriability effect is weak and so, the composition of licensing further shifts towards unaffiliated parties. Our regression analysis picks up these compositional shifts, once we allow for variations in technological complexity.

This research has significant policy implications. One of the objectives of global IPR reforms is to provide developing countries with greater access to new technologies. This is an explicit principle embodied in the TRIPS agreement. 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. One reason is that local (arms-length) firms may not obtain crucial know-how merely by relying upon knowledge externalities from foreign affiliates. Formal licensing contracts between unaffiliated parties might be needed to convey such tacit knowledge. Policy proposals to facilitate technology diffusion in the South often call for increased industry clusters or joint ventures with local partners. These are activities where arms-length licensing may be especially necessary. We find that patent protection facilitates unaffiliated licensing; but it is primarily complex-product firms that choose to switch from intra-firm to external contracting. Among simple-product firms (e.g., in the pharmaceutical industry), even greater internal transfers and control of technology are to be expected.

For future research, it would be useful to examine how strengthening PRs impacts prices. The prices of goods and services are critical in determining whether local access to new knowledge is enhanced. Another possible direction would be to examine how other forms of IPRs, such as copyrights and trade secrecy laws, affect international knowledge transfer (see Lippoldt and Schultz, 2014). One could also incorporate R&D location decisions jointly with licensing decisions and study the strategic implications. For example, do R&D investments by local subsidiaries substitute or complement parent-affiliate technology transfers? We touched upon this issue in our paper, but clearly a more in-depth treatment is desirable. Finally, future research could measure the complexity of a technology using information from the specifications of a patent. Those specifications must be detailed enough to enable persons skilled in the art to replicate the invention, and could potentially be used to glean the types of production tasks and skills associated with the underlying product or process.

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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, Assets, Capital Employment, Exports	R&D performed by parent and data on these for the parent company (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys) and *Benchmark Surveys of USDIA* (BE-10)
Affiliate R&D, Sales	R&D performed by affiliates and total sales of affiliates (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys) and *Benchmark Surveys of USDIA* (BE-10)
Income Taxes, Net Income	Income taxes and net income of foreign affiliates (Firm level)	BEA *Annual Surveys of USDIA* (BE-11 surveys); *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)
technological 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. Technological 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: **Patent rights by country group**

	Mean	Median	Min	Max	Coefficient of Variation
Developed countries	4.12	4.33	1.67	4.67	0.14
Developing countries	2.65	2.78	0.00	4.54	0.39

Table A2: **Unaffiliated to affiliated licensing ratio by country group**

	Developed Countries	Developing Countries
All U.S. parent firms	0.408	0.569
Complex-technology firms (above median complexity)	0.708	1.104
Simple-technology firms (below median complexity)	0.321	0.280

Notes: The table shows mean ratios per group.

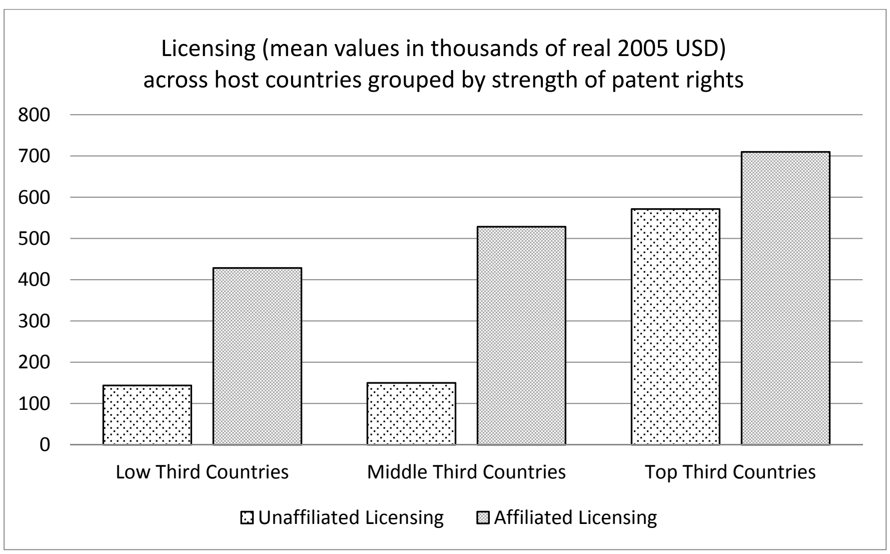

Figure 1: **U.S. licensing by destination**

Table 1: **U.S. parent firm sample statistics by technological complexity**

		Unaffil. Licensing Flows	Affil. Licensing Flows	Ratio of Unaff. to Aff. Lic.
All U.S. parent firms	Mean	329.4	578.5	0.569
	Std dev	(5311.6)	(3841.2)	
Above median complexity	Mean	536.8	486.2	1.104
	Std dev	(7939.2)	(4049.3)	
Below median complexity	Mean	180.3	644.9	0.280
	Std dev	(1774.8)	(3683.1)	
Difference in means		356.5***	-158.7***	0.824***

Notes: The licensing figures are in thousands of real 2005 U.S. dollars.
*** indicate statistical significance at the 1% level.

Table 2: **Licensing and technological complexity by industry**

	Unaffil. Lic., % Share of Manufacturing	Affil. Lic., % Share of Manufacturing	Ratio of Unaffil. to Affil. Lic.	Mean Value of Technological Complexity
Electronics and components	36.1	13.1	1.56	0.381
Machinery and equipment	32.0	13.6	1.33	0.351
Transportation	21.3	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	2.61	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	0.57	0.298

Table 3: **Aggregate and complexity results**

	Unaff. Lic. (1)	Affil. Lic. (2)	Unaff./Aff. (3)	Unaff. Lic. (4)	Affil. Lic. (5)	Unaff./Aff. (6)
log (host PRs)	0.118**	0.194**	-0.070	0.311***	1.389***	-1.068***
	(0.052)	(0.088)	(0.093)	(0.102)	(0.214)	(0.231)
Technological complexity				0.889**	-1.549**	2.498***
				(0.384)	(0.763)	(0.784)
Techn. complexity×log(host PRs)				-0.648*	-4.162***	3.500***
				(0.353)	(0.679)	(0.756)
log (parent R&D/Sales)	0.010***	0.039***	-0.031***	0.010***	0.046***	-0.038***
	(0.002)	(0.007)	(0.007)	(0.002)	(0.007)	(0.007)
log (host GDP)	0.500***	1.447***	-0.943***	0.522***	1.549***	-1.023***
	(0.163)	(0.292)	(0.342)	(0.164)	(0.294)	(0.343)
log (host/U.S. wages)	-0.081	0.012	-0.095	-0.097	-0.021	-0.080
	(0.201)	(0.350)	(0.360)	(0.202)	(0.347)	(0.360)
Capital restrictions dummy	0.063**	-0.007	0.070	0.065**	-0.008	0.072
	(0.030)	(0.057)	(0.061)	(0.030)	(0.057)	(0.060)
Host corporate income tax	-0.013	-0.043	0.030	-0.014	-0.041	0.026
	(0.047)	(0.067)	(0.070)	(0.048)	(0.064)	(0.068)
log(parent patents)	0.035**	0.034	0.003	0.036**	0.035	0.001
	(0.014)	(0.022)	(0.027)	(0.014)	(0.022)	(0.027)
log(host PRs)×log(parent patents)	-0.023*	-0.015	-0.010	-0.023*	-0.012	-0.013
	(0.013)	(0.020)	(0.024)	(0.013)	(0.021)	(0.025)
Constant	-8.415***	-22.633***	14.128**	-9.019***	-23.889***	14.756***
	(2.704)	(4.838)	(5.635)	(2.724)	(4.872)	(5.655)
Observations	29,940	29,940	29,940	29,533	29,533	29,533
R^2	0.0910	0.0242	0.0470	0.0917	0.0475	0.0663

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All outcome 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, with product fixed effects**

	Unaff./Aff. Lic. Ratio (1)	Unaff./Aff. Lic. Ratio (2)
log (host PRs)	-0.997***	
	(0.227)	
Techn. complexity×log(host PRs)	3.281***	3.778***
	(0.746)	(1.030)
log (parent R&D/Sales)	-0.020***	-0.024***
	(0.007)	(0.007)
log (host GDP)	-1.042***	-0.987***
	(0.337)	(0.332)
log (host/U.S. wages)	-0.078	-0.047
	(0.363)	(0.362)
Capital restrictions dummy	0.072	0.074
	(0.060)	(0.060)
Host corporate income tax	0.026	0.026
	(0.068)	(0.067)
log(parent patents)	-0.000	-0.008
	(0.027)	(0.028)
log(host PRs)×log(parent patents)	-0.019	-0.010
	(0.025)	(0.026)
Pharmaceuticals×log (host PRs)		-0.435
		(0.288)
Non-pharmac. chemicals×log(host PRs)		-1.227***
		(0.289)
Energy×log(host PRs)		-0.697**
		(0.306)
Metals×log(host PRs)		-1.303***
		(0.319)
Transportation×log(host PRs)		-1.702***
		(0.343)
Machinery & equipment×log(host PRs)		-0.985***
		(0.362)
Electronics & components×log(host PRs)		-1.366***
		(0.378)
Other manufacturing×log(host PRs)		-1.165***
		(0.248)
Product fixed effects	Yes	Yes
Constant	15.675***	14.744***
	(5.551)	(5.473)
Observations	29,533	29,533
R^2	0.123	0.134

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All outcome 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: **Additional controls**

	Unaff./Aff. (1)	Unaff./Aff. (2)	Unaff./Aff. (3)	Unaff./Aff. (4)	Unaff./Aff. (5)
log (host PRs)	-1.063***	-1.278**	-1.596**	-1.222*	-2.394***
	(0.231)	(0.635)	(0.630)	(0.728)	(0.823)
Technological complexity	2.903***	3.166***	3.924***	4.423***	4.680***
	(0.776)	(0.978)	(0.965)	(1.001)	(1.207)
Techn. complexity×log(host PRs)	3.502***	3.858***	3.597***	3.574***	4.497***
	(0.755)	(0.903)	(0.924)	(0.977)	(1.286)
log (parent R&D/Sales)	-0.044***	-0.048***	-0.046***	-0.042***	-0.040***
	(0.007)	(0.008)	(0.008)	(0.010)	(0.012)
log (host GDP)	-1.031***	-1.206***	-1.353***	-1.676***	-1.705***
	(0.345)	(0.398)	(0.443)	(0.445)	(0.477)
log (host/U.S. wages)	-0.081	-0.290	-0.465	0.553	0.884
	(0.362)	(0.416)	(0.495)	(0.539)	(0.607)
Capital restrictions dummy	0.072	0.035	0.043	0.090	0.118
	(0.061)	(0.074)	(0.074)	(0.085)	(0.094)
Host corporate income tax	0.028	0.096	0.099	0.129	0.204**
	(0.068)	(0.080)	(0.080)	(0.087)	(0.088)
log(parent patents)	-0.001	-0.043	-0.040	-0.012	0.009
	(0.027)	(0.028)	(0.028)	(0.030)	(0.036)
log(host PRs)×log(parent patents)	-0.015	0.013	0.009	-0.013	-0.024
	(0.025)	(0.027)	(0.027)	(0.029)	(0.034)
log(parent assets)	0.092***	0.161***	0.154***	0.236***	0.222***
	(0.021)	(0.051)	(0.051)	(0.049)	(0.056)
log(host PRs)×log(parent assets)		-0.040	-0.037	-0.068	-0.035
		(0.042)	(0.042)	(0.042)	(0.046)
log (parent K/L)		-0.175***	-0.245***	-0.285***	-0.337***
		(0.057)	(0.060)	(0.074)	(0.092)
log(host PRs)×log(parent K/L)		0.164***	0.200***	0.208***	0.260***
		(0.050)	(0.052)	(0.065)	(0.080)
Product life-cycle length			-0.367***	-0.494***	-0.530***
			(0.066)	(0.083)	(0.106)
Product life-cycle l.×log(host PRs)			0.135**	0.205***	0.257***
			(0.066)	(0.075)	(0.093)
Quality of legal institutions			-0.056	0.151	0.429**
			(0.143)	(0.175)	(0.207)
Share of foreign in world sales				0.539***	0.460***
				(0.135)	(0.167)
Share of unaff. exports in total exports				0.506***	0.317***
				(0.075)	(0.088)
log (affil. R&D intensity)					0.020
					(0.013)
Constant	13.134**	15.725**	19.335**	20.745***	20.257**
	(5.753)	(6.562)	(7.540)	(7.624)	(8.314)
Observations	29,530	23,491	22,576	19,831	15,361
R^2	0.0764	0.0723	0.0750	0.0850	0.0798

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All outcome 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 6: **OLS with firm-by-country fixed effects**

	Unaff. Lic.	Affil. Lic.	Unaff./Aff.
	(1)	(2)	(3)
log (host PRs)	0.298**	1.498***	-1.200***
	(0.141)	(0.236)	(0.277)
Techn. complexity×log(host PRs)	-0.539	-4.431***	3.892***
	(0.480)	(0.810)	(0.960)
log (parent R&D/Sales)	-0.001	0.031***	-0.033***
	(0.003)	(0.008)	(0.009)
log (host GDP)	0.508***	1.593***	-1.085***
	(0.161)	(0.292)	(0.340)
log (host/U.S. wages)	-0.029	-0.100	0.071
	(0.226)	(0.338)	(0.374)
Capital restrictions dummy	0.057*	-0.011	0.067
	(0.031)	(0.053)	(0.061)
Host corporate income tax	-0.015	-0.037	0.022
	(0.046)	(0.063)	(0.072)
log(parent patents)	0.052***	0.020	0.031
	(0.016)	(0.028)	(0.032)
log(host PRs)×log(parent patents)	-0.036**	-0.016	-0.021
	(0.014)	(0.024)	(0.028)
Constant	-9.227***	-25.799***	16.571***
	(2.903)	(5.470)	(6.277)
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 outcome 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 7: **Two-stage selection model**

	Stage 1		**Stage 2**
	Unaff. Licen.	Aff. Licen.	Unaff./Aff. ratio
	(1)	(2)	(3)
log (host PRs)	0.486**	1.278***	-2.500**
	(0.219)	(0.171)	(1.243)
Technological complexity	0.750	-1.379**	3.101**
	(0.865)	(0.692)	(1.448)
Techn. complexity×log(host PRs)	-1.363*	-3.547***	7.449**
	(0.730)	(0.577)	(3.334)
log (parent R&D/Sales)	0.014	0.027***	-0.070**
	(0.010)	(0.007)	(0.029)
log (host GDP)	0.170***	-0.117**	-1.387*
	(0.063)	(0.049)	(0.744)
log (host/U.S. wages)	-1.630***	-1.655***	0.869
	(0.463)	(0.365)	(1.524)
Capital restrictions dummy	0.119*	0.086*	-0.059
	(0.066)	(0.051)	(0.133)
Host corporate income tax	-0.003	-0.001	0.003
	(0.078)	(0.057)	(0.091)
log(parent patents)	0.065**	0.012	-0.032
	(0.028)	(0.022)	(0.053)
log(host PRs)×log(parent patents)	-0.047*	0.003	-0.002
	(0.026)	(0.021)	(0.036)
Patenting cost per market size	0.177***	-0.157***	
	(0.068)	(0.053)	
The log of the variance $ln(\sigma_v^2)$	0.992***	0.780***	
	(0.055)	(0.040)	
Mills ratio λ_1			-1.135
			(2.175)
Mills ratio λ_2			-1.157
			(0.956)
Constant	-3.203***	2.525***	22.622
	(1.139)	(0.899)	(13.982)
Observations	32,238	32,238	29,408

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 8: **IV estimation**

	Stage 1			Stage 2
	PRs Changes	PRs Changes ×Techn. Complexity	PRs Changes ×Parent patents	T^U/T^A Changes
	(1)	(2)	(3)	(4)
Non-colony dummy	0.027***	-0.009***	-0.438**	
	0.005)	(0.002)	(0.175)	
Techn. complexity×Non-colony	-0.019	0.051***	-0.344	
	(0.016)	(0.006)	(0.410)	
Parent patents×Non-colony	-0.000	-0.000	0.0506***	
	(0.000)	(0.000)	(0.005)	
PRs changes				-1.251***
				(0.269)
Techn. complexity×PRs Changes				3.449***
				(0.640)
Parent patents×PRs Changes				0.002
				(0.001)
Parent R&D/Sales changes	-0.008	-0.001	0.351	-0.163***
	(0.008)	(0.002)	(0.424)	(0.042)
Host GDP changes	-0.015	0.020	8.005	0.449
	(0.160)	(0.053)	(7.865)	(0.455)
Host/U.S. wage changes	1.550***	0.447***	25.97	1.679**
	(0.361)	(0.123)	(29.813)	(0.803)
Capital restrictions changes	-0.225***	-0.056**	-1.948	-0.269
	(0.071)	(0.022)	(4.353)	(0.160)
Host corporate income tax changes	0.556***	0.175***	8.911	-0.573
	(0.144)	(0.044)	(4.608)	(0.295)
Constant	0.043***	0.013***	0.713***	-0.008
	(0.002)	(0.001)	(0.175)	(0.012)

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=66.47, p-value=0.000
Weak identification test (Kleibergen-Paap Wald rk F statistic): 26.60
Endogeneity test of endogenous regressors: χ^2=3.127, p-value=0.373

Table 9: **Sensitivity test: Measure of PRs**

	Unaff. Lic. (1)	Affil. Lic. (2)	Unaff./Aff. (3)	Unaff. Lic. (4)	Affil. Lic. (5)	Unaff./Aff. (6)
Patent reform dummy	0.335***	1.065***	-0.735***	0.353***	0.999***	-0.646***
	(0.080)	(0.142)	(0.162)	(0.097)	(0.154)	(0.181)
Technological complexity	0.732***	-3.814***	4.577***			
	(0.247)	(0.483)	(0.506)			
Techn. complexity×log(patent reform)	-0.763***	-2.793***	2.052***	-0.783***	-2.577***	1.794***
	(0.260)	(0.450)	(0.515)	(0.302)	(0.502)	(0.594)
log (parent R&D/Sales)	0.010***	0.045***	-0.037***	-0.001	0.030***	-0.030***
	(0.002)	(0.007)	(0.007)	(0.003)	(0.008)	(0.009)
log (host GDP)	0.525***	1.370***	-0.841***	0.509***	1.422***	-0.913***
	(0.152)	(0.270)	(0.325)	(0.146)	(0.272)	(0.326)
log (host/U.S. wages)	-0.007	0.111	-0.122	0.068	0.035	0.033
	(0.191)	(0.343)	(0.367)	(0.211)	(0.332)	(0.382)
Capital restrictions dummy	0.060**	-0.011	0.071	0.052*	-0.009	0.061
	(0.027)	(0.056)	(0.059)	(0.029)	(0.053)	(0.060)
Host corporate income tax	-0.003	0.002	-0.005	-0.001	0.006	-0.007
	(0.038)	(0.059)	(0.069)	(0.037)	(0.059)	(0.072)
log(parent patents)	0.022**	0.035**	-0.014	0.029**	0.021	0.008
	(0.010)	(0.016)	(0.019)	(0.012)	(0.021)	(0.024)
Patent reform×log(parent patents)	-0.011	-0.013	0.001	-0.016	-0.015	-0.001
	(0.011)	(0.015)	(0.019)	(0.012)	(0.017)	(0.021)
Firm-by-country fixed effects				yes	yes	yes
Constant	-9.148***	-20.518***	11.275**	-9.355***	-22.847***	13.493**
	(2.504)	(4.447)	(5.353)	(2.619)	(5.101)	(6.023)
Observations	30,001	30,001	30,001	30,001	30,001	30,001
R^2				0.665	0.658	0.642

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 outcome 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 10: **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 PRs)	0.594***	2.013***	-1.419***	-1.149***	-0.830***
	(0.090)	(0.219)	(0.234)	(0.208)	(0.199)
Technological complexity	0.685*	-2.389**	3.102***	4.256***	3.313***
	(0.390)	(0.952)	(0.975)	(0.837)	(0.651)
Techn. complexity×log(host PRs)	-1.528***	-6.491***	4.964***	3.695***	2.177***
	(0.300)	(0.623)	(0.715)	(0.619)	(0.620)
log (parent R&D/Sales)	0.007***	0.036***	-0.030***	-0.031***	-0.045***
	(0.002)	(0.006)	(0.006)	(0.006)	(0.006)
log (host GDP)	0.030	0.490	-0.460*	-0.545**	-1.421***
	(0.121)	(0.310)	(0.265)	(0.275)	(0.279)
log (host/U.S. wages)	0.051	-0.455	0.507	0.374	-0.068
	(0.162)	(0.361)	(0.313)	(0.311)	(0.310)
Capital restrictions dummy	0.056***	0.069	-0.013	-0.036	-0.003
	(0.021)	(0.062)	(0.057)	(0.057)	(0.055)
Host corporate income tax	-0.029	0.001	-0.030	-0.010	0.033
	(0.038)	(0.081)	(0.064)	(0.063)	(0.055)
log(parent patents)	0.051***	0.079***	-0.029	-0.070***	-0.046**
	(0.012)	(0.021)	(0.023)	(0.020)	(0.022)
log(host PRs)×log(parent patents)	-0.039***	-0.020	-0.019	0.008	0.033
	(0.010)	(0.016)	(0.018)	(0.015)	(0.020)
Constant	-0.900	-2.508	1.599	2.958	21.374***
	(2.028)	(5.306)	(4.542)	(4.732)	(4.639)
Observations	33,784	33,784	33,784	33,784	29,533
R^2	0.0393	0.0669	0.0542	0.0617	0.0449

Notes: Random effects estimator. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All outcome 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.