Strategic Management Journal
Strat. Mgmt. J., **37**: 1715–1733 (2016)
Published online EarlyView 6 September 2015 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/smj.2418
Received 17 January 2014; *Final revision received 26 June 2015*

RIGHT PERSON IN THE RIGHT PLACE: HOW THE HOST COUNTRY IPR INFLUENCES THE DISTRIBUTION OF INVENTORS IN OFFSHORE R&D PROJECTS OF MULTINATIONAL ENTERPRISES

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Research summary: *Prior work has shown that the strength of the intellectual property regime (IPR) in a host country influences offshore R&D to that country. Building on this work we propose that the strength of the IPR in a host country differentially influences the threat of knowledge leakage on projects that are produced for the location where the multinational firm is headquartered (home) versus the offshore location to which the R&D project is sent (host). We argue and show that when the host location has a weak IPR, fewer host inventors are involved in host R&D projects when compared to home R&D projects. We test our hypotheses using a dataset of patents held by US assignees, but coinvented in 43 host locations with differing IPR strength.*

Managerial summary: *Multinational enterprises often cite the weak IPRs at emerging economy host destinations as a significant impediment to offshore R&D activities in those countries, despite the abundant supply of inexpensive scientific talent there. We find that the weak IPR at the host destination is a greater impediment to offshore R&D that is aimed for end use at the host market than for R&D that is aimed for end use globally or in the home market. Since IPRs are local, a weaker IPR at the host location does not protect IP that is relevant to the host market. Since the IPR at the home country is more relevant for technologies aimed at the home market, the IPR at the host country is irrelevant for such R&D projects.*

INTRODUCTION

The internationalization of R&D activity of multinational enterprises (MNEs) is an important and growing phenomenon. The increasing offshore R&D activities by MNEs to emerging economies such as India and China, which have a weak intellectual property regime (IPR), however, poses the question of how such offshore R&D is protected from imitation. We argue that R&D projects that are relevant to the offshore location (host market) have a relatively higher threat of intellectual property (IP) leakage than R&D projects relevant to the location where the MNE is headquartered (home market). Therefore, somewhat surprisingly, the MNE is likely to involve more host inventors from weak IPR locations in R&D projects relevant to the home market than in projects relevant to the host market. Our findings contribute to the literature on understanding how IPRs at the host location influence MNE R&D (Branstetter, Fisman, and Foley, 2006; Yang and Maskus, 2001; Zhao, 2006) by showing how differences in leakage risks inherent in host versus home R&D projects moderate

Keywords: intellectual property regime; R&D offshoring; multinational R&D strategy; global organization of work; knowledge spillover
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the relation between the strength of the IPR at the host location and the extent of involvement of host inventors in MNE R&D projects.

A large body of work suggests that MNEs locate R&D units internationally to take advantage of the available knowledge (Chung and Yeaple, 2008; Feinberg and Gupta, 2004; Kogut and Chang, 1991). A few studies explicitly argue that spillover benefits that emanate from R&D conducted by other firms at the host location is an important consideration for MNEs deciding where to locate their foreign R&D centers (Almeida, 1996; Chung and Yeaple, 2008; Feinberg and Gupta, 2004). The strength of the IPR at the host location presumably influences the extent to which a firm can utilize knowledge spillovers, as well as whether a firm can appropriate value from its IP. Therefore the strength of the IPR at a location is likely to be an important consideration in a MNE's decision regarding whether and to what extent to perform a specific R&D project at any given host location. This is because the MNE is likely to balance R&D production considerations, such as factor prices and access to knowledge at the host location, against the cost of likely IP leakage in deciding the extent of host versus home inventor participation in R&D projects at a given location. However, there is surprisingly little work on how the strength of the IPR at the *host location* influences the *extent* to which host inventors are involved in MNEs' R&D projects.

The closest work to ours is that of Zhao (2006), who investigates how MNEs protect the IP that is created in their captive centers located in countries with weak IPRs. Zhao (2006) argues that MNEs disaggregate projects into components, with some components performed at offshore R&D centers in locations with weak IPRs and others performed at home. The IP generated in the weak IPR location is protected because it is of little value unless combined with the IP that is generated at home, which is protected by the strong IPR at home. Zhao (2006)calls this mechanism "strong internal linkages" between the subsidiary and the headquarters. She empirically shows that US patents developed in weak IPR locations have higher forward self-citations than those developed in strong IPR locations, which she argues is evidence of strong internal linkages. We build on this work by considering whether different types of R&D projects conducted by the MNE at the host location have different IP leakage threats.

MNEs perform R&D in international locations to customize their products and services for the host market, which we call *host projects*, and/or to utilize the talent and knowledge available at the host location to create products and services for the home market, which we call *home projects* (Kuemmerle, 1999). We argue that the strength of the host location's IPR is likely to matter crucially for *host projects* since they are commercialized in that location. However, *home projects* are likely protected by the strong IPR at home and therefore the extent to which the host location IPR matters for value appropriation is unclear. We extend Zhao's work by considering how the strength of the IPR at the host location and the nature of the R&D project *jointly* influence the level of involvement of host inventors in an offshore R&D project.

The differential influence of IPRs on home versus host projects has not been explicitly tested in the international economics literature either. Branstetter *et al.* (2006) show that host subsidiaries pay higher royalties to headquarters after the host IPR has been strengthened and argue that MNEs transfer more technology to host countries with a stronger IPR. They also show that MNEs file more patents in the host country after its IPR is strengthened. While this work implies that stronger IPRs stimulate technology transfer and production of R&D that is more applicable to the host country, they do not explicitly differentiate between the leakage threats on home versus host projects. Moreover, it is also unclear whether the additional host country patents were generated by headquarters, the subsidiary, or in collaboration. In sum, prior work does not examine how changes in the IPR in the host location influence the participation of host inventors on innovations relevant to the home versus host locations differentially. Our effort is directed precisely at this question.

We test our hypotheses using a novel dataset consisting of a matched sample of patents that belong to MNEs headquartered in the United States. Our dataset includes patents invented in the United States and patents that are coinvented or fully invented in 43 host countries with a strong or a weak IPR. We also distinguish between home and host projects based on the location in which the patent was filed and compare the involvement of host inventors in these patents. This empirical strategy is similar to recent work that compares the influence of IPRs across countries (Branstetter *et al.*, 2006; Lerner, 2009; Zhao, 2006) and several other studies on comparative institutional economics. We also perform several robustness tests that increase our confidence that the results may not be merely driven by just the differences between host locations, technologies or time trends.

Our key contribution is to highlight the *joint* role of the strength of the IPR in the host country and the location of its intended use (home vs. host project) in the involvement of host inventors in an R&D project. Although MNE R&D strategy starkly illustrates this phenomenon, our theory is also applicable to a multi-unit R&D setting in which different R&D locations vary in the extent of spillover risks, such as, for example, the influence of differences in trade secrecy laws in different US states (Marx, Singh, and Fleming, 2015; Png, 2011) or the presence of direct competitors at a location (Alcácer and Zhao, 2012).

CONCEPTUAL FRAMEWORK AND HYPOTHESES

When choosing offshore R&D, ideally, MNE managers make decisions on staffing R&D projects at different locations based on production considerations such as differences in scientists' wages or the knowledge available at the different locations. Weak IPRs at the host location will likely impede such efficient resource allocation since MNE managers must now also take into account the cost of IP leakage, which will therefore influence the extent to which an R&D project is committed to a specific offshore location.

Consider a scenario in which an R&D manager at an MNE has to allocate two types of labor input to an R&D project: that from an inventor located at MNE headquarters (home inventor) and that from an inventor located at the host facility (host inventor). Both these inputs are owned by the same focal MNE and are imperfectly substitutable. We assume that the cost of generating an innovation consists primarily of the labor costs of the home and host country inventors. We also assume that in the absence of knowledge leakage, employing host country inventors is cheaper than employing home country inventors, either because host inventors have lower wage rates or possess specialized expertise that reduces the number of man–hours spent on the project. We also assume that the home location has a strong IPR, whereas the host country may have a strong or a weak IPR. Therefore, offshore R&D may pose an equivalent or greater threat of IP leakage compared to that at the home location.

In our framework, the threat of IP leakage arises from employing host inventors in an R&D project who can be hired away by competitors. Prior work has shown that employee mobility is a significant source of knowledge transfer between firms and that such spillovers tend to be geographically localized (Agrawal, Cockburn, and McHale, 2006; Rosenkopf and Almeida, 2003). Such employee "poaching" impacts the focal MNE in two ways. First, competitors can utilize employees' tacit knowledge, such as knowhow, to infringe existing patents or even invent workarounds. Second, competitors may access and utilize proprietary knowledge related to a MNE's current (unpatented) projects and leapfrog it.

We assume that a weak IPR at a host location implies that both its patent and trade secrecy laws are weak, so that an IP holder has very few legal remedies when its IP is expropriated. A weak IPR facilitates the leakage of an MNE's proprietary IP to a competitor more easily for at least two reasons: first, a weak patent regime presents few remedies for the innovator whose patent has been infringed, which consequently incentivizes the infringement of patents. Second, weak trade secrecy protection provides limited remedies for the MNE that seeks to prevent its employees from using its proprietary IP for private gain. For instance, when trade secrecy laws are weak, nondisclosure and noncompete agreements are virtually unenforceable, allowing imitators to rely on employee mobility to access proprietary knowledge. Weak trade secrecy laws, especially the restricted use of noncompete agreements, incentivizes employee mobility (Gilson, 1999), which in turn increases the possibility of knowledge leakage.

Finally, we assume that the greater the number of host country inventors involved in an R&D project, the greater the probability that one of them will leak proprietary knowledge to a competitor. We can think of host country inventors as the weaker links in a chain—since they are more likely to lead to IP leakage than home country inventors. As the number of weaker links in a chain increases, the more likely the chain breaks. Thus, in sum, involving host country inventors can reduce costs, but can also increase IP leakage. The goal of an MNE R&D manager is to minimize the total cost of an innovation by optimally choosing the number of host and home country inventors for a focal R&D project.

This is a significant concern for MNE managers considering offshore R&D activities. For example, a manager of a large global pharmaceutical company suggested that, with sensitive technologies like sensors and wearables, fewer inventors are involved from Asia compared to established R&D hubs in the US because confidentiality and nondisclosure agreements are relied upon more in the US than in places like India or China. Another senior executive of a cloud software-based startup headquartered in the US suggested that "IP maturity" at host locations is a very prominent consideration when the technology in question is "highly competitive" (i.e., is also of value to a competitor).

Since our goal is to examine how the extent of involvement of host versus home inventors varies with the strength of the IPR at the host location, we state all our hypotheses in terms of the share of host country inventors (*Share*), which is the number of host inventors divided by the total number of inventors, in an R&D project. This choice reflects what we had discovered in our field work.

Effect of the strength of the IPR at the host location on the share of host inventors

Consider an innovation that features a mix of home and host country inventors. If personnel employed by the focal MNE are hired away by competitors, the focal MNE will likely risk losing two types of knowledge: (1) competitors can expropriate the focal MNE's proprietary IP held as trade secrets, and (2) employees hired away by competitors can facilitate imitation by inventing around the MNE's patents by leaking proprietary tacit knowledge. Strong IPRs constrain employee mobility and also provide better legal recourse to prevent competitors from infringing patents, thereby protecting both patents and trade secrets from expropriation. In contrast, host locations with a weak IPR protect neither patents nor trade secrets.

Therefore, all else being equal, a weaker IPR at the host location increases the likelihood of knowledge leakage and therefore increases the cost of involving host inventors in an R&D project. At partial equilibrium, this should result in a decrease in the number of host scientists involved in an R&D project, consequently increasing the number of home scientists. In essence, this implies that the proportion of host scientists in a patent should be lower when IPRs are weaker at the host location. We formally state this as the following baseline hypothesis.

Hypothesis 1: The share of host inventors in an R&D project is lower when the strength of the IPR at the host location is weak than when it is strong.

Joint effect of host location IPR and innovation's intended end-use location

The literature suggests two broad objectives for MNEs in offshore R&D. The first is to explore new growth opportunities in host markets (Mansfield, Teece, and Romero, 1979). The second is to produce inexpensively innovations for the home market (Kumar and Puranam, 2012; Zhao, 2006). We refer to a project that is mainly relevant to the host location as a *host R&D project* and a project that is mainly relevant for the MNE's home market as a *home R&D project.* We now investigate whether the focal project being a home versus a host R&D project modifies the effect of the strength of the IPR at the host location on host inventor participation.

Exploiting growth opportunities in host markets requires an MNE to invest in R&D that tailors its existing products or creates new products that cater to the preferences of the customers in the host market. Appropriating value from these innovations mainly depends on the strength of the IPR at the host location. A stronger IPR in the host location enables the MNE to reduce competition for this innovation in the host market. Recall that the weaker the IPR at the host location, the greater the risk of IP leakage there. All else being equal, this means that employing additional host inventors from a weak IPR host country becomes more expensive when compared to employing additional host inventors from a strong IPR host country. Therefore, the focal MNE is likely to involve fewer host inventors from weak IPR host locations and consequently more home inventors in projects aimed at that host market than comparable projects conducted in strong IPR locations. Therefore, we propose the following hypothesis.

Hypothesis 2: The share of host inventors in a host R&D project is lower when the host location has a weak IPR than when it has a strong IPR.

The subsidiaries of MNEs in host countries perform R&D for the home market as well as for the host market. In a home R&D project, an MNE's proprietary IP that is patented at home is protected by the home country's strong IPR. Thus, even if an MNE employee at the host location defects to a competitor, the strong IPR in the home country enables the MNE to seek redress against the infringement of patented knowledge. Patent rights are territorial and are normally confined to the country in which the patent is filed. Therefore, the strength of the host country's IPR is unlikely to have a significant impact on protecting patented innovations at home.

However, this does not imply that the threat of leakage in a home R&D project is zero. The strength of patents is only one aspect of an IPR, the other being the strength of trade secrets. When the host destination IPR does not protect unpatented knowledge, competitors can hire away employees to work around the focal firm's patents or leapfrog it, which can affect the focal MNE's ability to appropriate value from its IP.

Leakage of tacit knowledge in a weak IPR host location is a more severe problem for value appropriation in host projects than in home projects for two reasons. First, knowledge relevant to the host market is likely to be of interest to domestic firms as well as other MNEs that compete in that market. In contrast, knowledge that is relevant to the home market is likely to be of interest only to firms that are present in the host location but compete in the home market. There are likely to be many more firms present in the host location that compete in the host market than those that can compete in the home market. In addition, in order to compete effectively in the home market, these competitors, especially emerging market multinationals, need to overcome their liability of foreignness in the focal MNE's home market. In contrast, it is the focal MNE that needs to overcome the liability of foreignness in the host market.

Therefore, ceteris paribus, fewer host inventors from a weak IPR location are likely to be involved in projects aimed at the host market than in projects aimed at the home market.

Hypothesis 3a: In a host location with a weak IPR, the share of host inventors is lower in a host R&D project than in a home R&D project.

In contrast to a host location with a weak IPR, a host location with a strong IPR provides safeguards against the leakage of both patented and unpatented knowledge. Consequently, we argue in Hypothesis 2 above that the involvement of host inventors in a host R&D project is likely to be higher in strong IPR locations than in weak IPR locations. In addition, the arguments above for Hypothesis 3a suggest that the relative expropriation threat for a home R&D project is lower than for a host R&D project. This is true regardless of whether the host country has a strong or a weak IPR, because the protection of home R&D projects depends primarily on the home country's IPR and the strength of the host country's IPR plays a smaller role in whether home R&D projects are expropriated. Combining the arguments from Hypotheses 2 and 3a suggests that, relative to a weak IPR host location, in a strong IPR host location, the difference in expropriation threat for a home R&D project versus that for a host R&D project is unlikely to be very large. This suggests the following differences-in-differences hypothesis.

Hypothesis 3b: The relative reduction in the share of host inventors in a host R&D project compared to that in a home R&D project is greater when the R&D project is performed in a weak IPR host location than in a strong IPR host location.

DATA AND MEASURES

We test our hypotheses using a sample of patents assigned to MNEs headquartered in the United States (US assignees) but with at least one patent invented either exclusively or partially outside of the United States (in 1 of the 43 host countries listed in Table 1). Our unit of observation is a patent. In order to identify foreign invented patents, we used the same criteria as Zhao (2006); i.e., we include only host countries that have more than 2 million residents, more than one percent tertiary school enrollment rates, and greater than five patents filed with the United States Patent and Trademark Office (USPTO) in the 1990s. For a US assignee to be in our sample, it must have at least one granted patent in the USPTO that was exclusively invented or coinvented in 1 of these 43 countries between 1974 and 2009. Similar to Zhao (2006), patents held by local subsidiaries are aggregated up to the headquarters. We assembled our sample from two sources: from

Table 1. Details of the sample used in this study

Description	N
Total patents held by US assignees that had at least one offshore patent between 1974 and 2009	7,126,632
Total patents after matching offshore and nonoffshore patents	5,062,701
Total patents after matching patents coinvented in a weak IPR with those that were coinvented in a strong IPR (final sample)	2,915,144
Total offshore patents	838,160
Total nonoffshore patents	2,076,984

Notes: The host countries in our sample include the following 43 countries: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, Denmark, Egypt, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korean Republic, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovak Republic, South Africa, Spain, Sweden, Taiwan, Turkey, U.K., Ukraine. The unmatched sample additionally includes the following four host countries that our matching procedure eliminated: Thailand, Peru, Pakistan and Venezuela.

the PATSTAT database (Wagner, Hoisl, and Thoma, 2014), we assembled all patents that belonged to US assignees that satisfied our sampling criteria. Second, we used COMPUSTAT to gather time varying firm attributes for the US assignees in our sample.

We use two sources of variation to test our hypotheses. The first is variation in the strength of IPR in the host country in which a patent was invented. We classified these 43 offshore destinations at which a patent was coinvented as having either a weak IPR or a strong IPR based on table 1 of Zhao (2006: 1189). We compared patents produced wholly or partially by inventors residing in a weak IPR host country with similar patents that were wholly or partially produced by inventors residing in a strong IPR host country.

The second is the country in which the patent was filed. Here we compare *home patents*—patents filed in the USA—with *host patents*—patents filed in the same host country in which they were exclusively or jointly produced. Since most patenting is driven by trade or competition considerations, the patent filing location is a good proxy for whether the R&D project is relevant to the home market or the host market (Yang and Nai-Fong, 2008). When the same patent was filed in multiple countries, we included the patent only once and classified it as described above.

Offshore patents can vary systematically in a variety of dimensions from patents that are not offshore. Moreover, patents coinvented in a host country with a weak IPR can differ systematically from those coinvented in a host country with a strong IPR. To minimize the possibility that our results are driven by differences between patents that are unrelated to our hypotheses, we construct a matched sample of patents based on a set of observable patent characteristics. For this purpose, we use coarsened exact matching (CEM) technique to construct a matched sample of patents. CEM is useful for minimizing any sample selection bias and also reduces the sensitivity of the regression results to specific functional form assumptions (Azoulay, Graf-Zivin, and Wang, 2010; Iacus, King, and Porro, 2012; Singh and Agrawal, 2011).

We implement CEM at two levels. First, for every offshore patent (i.e., coinvented or fully invented in a host country), we find an equivalent nonoffshore (i.e., exclusively US-invented) patent. We match these patents based on assignee, application year, and main IPC class and use coarsened matching on observable characteristics, including the number of inventors, the ratio of backward self-citations of patents produced at the MNE's headquarters to total backward citations (*backward ratio*), the ratio of forward self-citations of patents produced at the MNE's headquarters to total forward citations (*forward ratio)* and the number of claims. We used this subsample to match patents invented in a host country with a strong IPR with patents invented in a host country with a weak IPR using the same criteria.[1]

As shown in Table 1, we start with 7,126,632 patents held by US assignees that meet our sampling criteria, which we then match in two steps, as described above. Descriptive statistics suggest that the differences in observable characteristics are significantly reduced after matching. However, in addition to matching, we further control for any remaining differences by adding the observable patent characteristics as controls in our regressions. Table 2 shows our final sample's composition by inventor country and filing country IPR strength.

[1] We are mindful that matching between the treatment and control groups is based only on observable characteristics and therefore does not fully eliminate endogeneity concerns. However, to the extent that unobservable and observable parameters are correlated with each other, matching enables us to minimize the possibility that our results are driven by unobservable differences between patents (Iacus *et al.*, 2012). We thank a reviewer for pointing out this shortcoming of the matching procedure.

Table 2. Patents, by offshore and filing locations

	Offshore location				
	Weak	Strong	Offshore total	Not offshore	Total
Filed only in the US	195,940	191,718	387,658	1,121,113	1,508,771
Filed only in Host	40,446	152,484	192,930	131,109	324,039
Filed at Both	24,959	91,294	116,253	775,020	891,273
Filed at Neither	89,851	51,468	141,319	49,742	191,061
Total patents	351,196	486,964	838,160	2,076,984	2,915,144

Notes: Offshore location weak includes patents that have one or more inventors residing at a weak IPR location. Offshore location strong includes patents that have one or more inventors residing at a strong IPR location.
Not offshore patents only have inventors residing in the US. A total of 35,511 patents were produced in a weak as well as a strong host. In this case, we classify the host country as either strong or weak based on whether the maximum number of inventors on the patent was from a host country with a strong or a weak IPR. There were 5,669 patents in which there was a tie in number of inventors from host locations with a weak and a strong IPR. We considered such patents as having been invented in a host location with a weak IPR. Alternatively, dropping these 30,511 patents that were produced in a weak and a strong host country does not qualitatively alter our results.
The *filed in host* category comprises patents that were filed exclusively at the offshore location. The category *Filed at both* comprises patents that were filed both in the US and at the offshore location and the *Filed at Neither* category comprises patents that were filed neither in the US nor at the offshore location but elsewhere.
Weak IPR host destinations include the following 27 countries: Argentina, Brazil, Bulgaria, Chile, China, Czech Republic, Egypt, Greece, Hong Kong, Hungary, India, Indonesia, Israel, Korean Republic, Malaysia, Mexico, Philippines, Poland, Portugal, Romania, Russia, Slovak Republic, South Africa, Spain, Taiwan, Turkey, Ukraine. Strong IPR host destinations include the following 16 countries: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Singapore, Sweden, U.K.

Table 1 provides the details of the sample used in this study. Table 2, shows that 58.1 percent of the offshore patents were filed in a host location with a strong IPR. Moreover, in our sample, more offshore patents were filed at home than at the host location, especially when developed in weak IPR locations. For patents developed in a strong IPR location, 39.4 percent were filed at home whereas 31.3 percent were filed at host; for patents developed at a weak IPR location, 55.8 percent were filed at home whereas 11.5 percent were filed at host.

Dependent variable

Share of host inventors

The key dependent variable is the proportion of host inventors in a focal patent, *Share*, which is measured as the number of inventors from the host location divided by the total number of inventors listed in the patent. If these counts—namely, the number of host or total number of inventors for the same patent—vary across patent offices in which they were filed, we take the maximum. However, it is plausible that the effect of the IPR on the participation of host inventors is not a continuum. We check our results in the robustness section by redefining our different dependent variable based on different thresholds.

Independent variables

Strength of the IPR at the host location

It is difficult to devise a perfect measure of the strength of a country's IPR (Arora, 2009). Since there is no perfect measure, we test our hypotheses using a variety of proxies for the strength of the IPR in the host country.

Our primary method to identify the strength of the IPR is through the use of the variation in the location of an offshore patent. To this end, we follow the classification provided by Zhao (2006: 1189). We create two dummy variables, *weak,* which equals 1 if the offshore patent was produced in a host country with a weak IPR and 0 otherwise. Similarly, we use another dummy variable, *strong*, which equals 1 if the offshore patent was produced in a host country with a strong IPR and 0 otherwise. Following the literature, we classify patents as originating from weak or strong IPR locations depending on whether the maximum number of inventors is from a weak or strong IPR country.

However, since this source of variation exclusively relies on differences between host countries, this empirical strategy can potentially pick up other unobserved differences between host countries that are orthogonal to differences in IPR strength. As an alternative, we test the robustness of our principal

DOI: 10.1002/smj

results using a standardized measure of the IPR index of Ginarte and Park (1997), which varies by both country and time (*index* henceforth) and is measured over five-year intervals (Park, 2008). This allows us to control additionally for other unobserved differences between host countries in our regressions.[2]

Location for which the invention is relevant

We use the variation in filing location as a proxy for the country in which the focal patent is relevant. Conditional on a patent being offshore, we define four dummy variables to classify a patent into four mutually exclusive categories. To proxy for a home R&D project, we use *Filed only in the US,* which equals 1 if the patent was filed exclusively with the US patent office and was produced in a host country. The proxy for a host R&D project is *Filed only in Host,* which equals 1 if the patent was only filed in the same host country in which it was produced or coproduced. *Filed in Both* equals 1 if the patent was produced in the host location and filed in both the home and host locations. *Filed in Neither* equals 1 if the patent was coproduced in the host location, but was filed neither at home nor at the host location.[3]

Control variables

R&D intensity

We control for the R&D intensity of the assignee firm of the focal patent measured as the firm's R&D budget divided by its total sales for that year. We lack this measure for about 4.9 percent of the sample since the relevant data are not available. We control for missing values by using *R&D not reported dummy*, which equals 1 if the data is missing.

Size

We control for the size of the assignee firm using the number of employees (as a log, henceforth *log size*) of the focal MNE. Similar to R&D intensity, we lack this measure for about 4.9 percent of our sample, which we control for by using *R&D not reported dummy*.

Innovation complexity

We control for an innovation's complexity by using the number of claims on the focal patent (as a log, henceforth, *log claims*). In our regressions, we control for missing data using *claims not found dummy*, which equals 1 when claims for the patent are missing.[4]

Forward ratio

We control for the extent to which the focal innovation is useful to the innovating firm by using the ratio of the number of forward self-citations by patents produced at the headquarters to the total number of forward citations of the focal patent (*forward ratio*).[5]

Backward ratio

We control for the extent to which the focal patent uses prior knowledge from the MNE by using the ratio of backward self-citations to patents produced at the headquarters to the total number of backward citations of each patent *(backward ratio).*

Originality and generality

We control for a patent's originality and generality, using the patent measures of originality and generality.

[2] Consistent with our scheme of classifying offshore patents as invented in either a *weak* or a *strong* host country, when a patent is offshore in multiple countries, the value that *index* takes for that patent is the value that relates to the host country with the highest number of inventors. When there was a tie between two or more countries in the number of inventors, we assigned the weighted (by the number of inventors from that country) average of the *index* for those countries.

[3] These classifications take into account all subsequent filings of a Patent Cooperation Treaty patent until 2012. Our sample also includes patents that are filed at the host location but have no host inventors. They are part of the omitted category of patents produced exclusively in the US. Our results are unchanged if we redefine these categories purely based on filing location, regardless of whether they were offshore.

[4] We were unable to collect the number of claims for 9.5 percent of the sample because they were missing in the PATSTAT database. Most of these patents (about 56%) were filed before 1990. In cases in which the same patent was filed in different countries with a differing number of claims, we took the maximum number of claims across the filing countries as the number of claims for that patent.

[5] When the patent was filed in multiple countries, we collected the total number of unique citations made to and by the patent in all the filing countries. However, not all countries make the citation details available to the general public. When the focal patent was filed only in a country that does not publicly disclose citation data, we assigned that focal patent the average forward and backward ratios that is relevant to the focal patent's grant year and main technology class cohort. This constitutes about 3.9 percent of the data.

Industry dummies

The utility of patents and the propensity to file them can vary across industries (Cohen, Nelson, and Walsh, 2000). We control for such industry-specific effects using industry dummies constructed by mapping each patent to a three-digit SIC code using the 2005 IPC–SIC concordance of the USPTO (available at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/brochure.htm, last accessed June 15, 2015). Using this classification, we include 28 two-digit SIC code fixed effects to control for any industry effects.

Time dummies

We control for filing year effects using 35 dummies, one each for 1974–2009.

Firm dummies

We control for firm-specific effects using 58,811 firm fixed effects.

Table 3 shows the descriptive statistics for all of the independent variables.

EMPIRICAL ANALYSIS

We begin with a nonparametric analysis of the data. In Table 4, we analyze how the share of host inventors in a patent (*Share*) varies with the filing location and the location in which the patent was coinvented. In line with Hypothesis 1, regardless of filing location, patents that were coinvented in a host country with a weak IPR, have a lower *Share* than patents coinvented in a host country with a strong IPR. We also see that, among patents filed in the same host location as they were invented, *Share* is lower for patents that were coinvented and filed in that host location ("*filed only in host*") with a weak IPR relative to patents coinvented and filed in a host location that has a stronger IPR (diff. -0.33, p-value <0.01), supporting Hypothesis 2. In addition, we see that the *Share* on a "*filed in both*" category patent is lower than that of the other two categories. Thus, to the extent that *filed in both* encompasses the IPR threat for both home and host R&D projects, *Share* in this category of patents is likely to be the lower than *filed only in the US* or *filed only in host* patents. Among patents coinvented in a host country with a weak IPR, those filed only in the host country have a lower *share* than those filed in home (diff. -0.28, p-value <0.01), supporting Hypothesis 3a. In contrast, this difference in *share* between host and home patents coinvented in a country with a strong IPR is only -0.06. Supporting Hypothesis 3b, we also find that the difference in *Share* between "*filed only in host*" and "*filed only in the US*" patents is higher for patents coinvented in a host country with a weak IPR than for patents coinvented in a host country with a strong IPR (diff. −0.22, p-value <0.01). The nonparametric analysis does not control for various other factors that might influence these differences. Accordingly, we turn to regressions.

In Table 5, we start by exploring how the strength of the IPR at a host location influences *Share*. To identify this effect, we estimate fixed effects specifications by including the dummies that identify patents invented in a host country that has a weak IPR (*weak dummy*) and patents invented in a host country that has a strong IPR (*strong dummy*). The omitted category comprises patents that were invented exclusively in the USA, for which the *Share* is zero by definition. Thus, we estimate how the *Share* on a patent p that belongs to an i offshore assignee to a host location type m filed at location type k at time t in technological class j varies by the location type at which the focal patent was coinvented as follows:

$$Share_{ijmktp} = \beta_0 + \alpha_1 Weak_m + \alpha_2 Strong_m + \theta_i X_i + \theta_j Y_j + \theta_t \tau_t + \theta_p \lambda_p + \varepsilon_{ijmktp} \qquad (1)$$

where X_i is a vector of assignee characteristics that include assignee fixed effects; Y_j is a vector of technology characteristics that include industry fixed effects; τ_t is a vector of time effects that include filing year dummies; and λ_p includes a vector of other patent characteristics such as the number of claims, originality, generality and forward and backward ratios. Our dependent variable is a proportion, which varies between zero and one. We use, a fixed effects specification and estimate how changes in host IPR across patents within a firm influences changes the *Share*.

In Table 5, specification 1, along with the main independent variables of interest, we include 35 filing year dummies, 58,811 assignee fixed effects, and 28 two-digit SIC code dummies. In addition, we include controls that vary by both

DOI: 10.1002/smj

Table 3. Descriptions of measures

Variable	Description	Source of variation	N	Mean	Std. dev.
Share	Number of offshore inventors divided by total number of inventors	Patent, firm, offshore location, filing location, technological class, industry, and filing year	2,915,144	0.11	0.29
Weak	= 1 if the focal patent was filed to a host country with a weak IPR and 0 otherwise	Host location	2,915,144	0.11	0.24
Strong	= 1 if the focal patent was filed to a host country with a strong IPR and 0 otherwise	Host location	2,915,144	0.17	0.28
Filed only in US	= 1 if the patent was coinvented in a host country and filed exclusively in the US and 0 otherwise	Filing location	2,915,144	0.11	0.29
Filed only in Host	= 1 if a patent was coinvented in a host country and filed exclusively in the same host country, and 0 otherwise	Filing location	2,915,144	0.07	0.23
Filed in Both (US and Host)	= 1 if the patent was coinvented in a host country and filed both in the US and at the host destination, and 0 otherwise	Filing location	2,915,144	0.06	0.21
Filed in Neither (US or Host)	= 1 if the focal patent was coinvented in host country and filed neither in the US nor at the host destination, and 0 otherwise	Filing location	2,915,144	0.05	0.25
Backward ratio	Number of backward self-citations divided by the total number of backward citations	Patent	2,801,531[a]	0.36	0.55
Forward ratio	Number of forward self-citations divided by the total number of forward citations	Patent	2,801,531[a]	0.47	0.57
Industry dummies	28 three-digit SIC code dummy variables	Industry	-		
Filing year dummy	35 dummies, 1 for each year between 1974 and 2009	Filing year	-		
Firm fixed effects	58,811 firm fixed effects	Firm	-		
Originality	Originality of a patent	Patent	2,801,531[a]	0.57	0.51
Generality	Generality of a patent	Patent	2,801,531[a]	0.55	0.49
Log claims	Natural log of the number of claims on a patent	Patent	2,772,302[b]	2.31	2.91
R&D over sales	Yearly assignee R&D divided by sales	Firm, year	2,772,302[c]	0.03	0.79
Log(employees)	Number of assignee employees in a year	Firm, year	2,772,302[c]	1.91	2.28

[a] We were not able to calculate the forward and backward ratios for 3.9% of the sample. For these patents, we assigned the average ratio relating to Indian patents for the filing year cohort.
[b] We were unable to obtain the number of claims for 9.5% of the observations. In regressions, we control for missing values using a dummy that equals 1 when the number of claims was missing for the patent.
[c] For 4.9% of the sample, we were unable to obtain R&D expenditure and employees. In our regressions we control for the missing values that occur in both these cases using a dummy that equals 1 when the R&D or employees was missing for the patent.

Table 4. Comparison of shares, by filing location and by offshore inventor location

		Filing location			
		Filed only in US	Filed only in Host	Filed in both	Diff. (FiledHost – FiledUS)
Offshore inventor location	*Weak*	0.80	0.52	0.49	−0.28*** (H3a)
		(0.00)	(0.00)	(0.00)	(0.00)
	Strong	0.91	0.85	0.79	−0.06***
		(0.00)	(0.00)	(0.00)	(0.00)
	Diff (invented in weak−invented in strong)	−0.11*** (H1)	−0.33*** (H1, H2)	−0.30***	−0.22*** (H3b)
		(0.00)	(0.00)	(0.00)	(0.00)

***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively
Standard errors are in parentheses.

assignees and time, using *R&D over sales* and *log size* along with our control for missing data. In specification 2, we further control for patent characteristics using *forward ratio, backward ratio,* and *log claims*. In specification 3, we additionally control for a patent's *originality* and *generality*.

Hypothesis 1 argues that more host inventors from strong IPR locations are likely to be involved than host inventors from weak IPR locations in otherwise similar R&D projects, or $\alpha_1 - \alpha_2 < 0$. From Table 5, specification 1, we see that, the difference in coefficients for *weak* and *strong* is about -0.11 (p-value <0.01). Specifications 2 and 3 suggest that further controlling for other observable patent characteristics does not change our results much. Table 5 suggests that the reduction in the number of host inventors on an offshore R&D project to host locations with a weak IPR when compared to a similar offshore R&D project at host locations with a strong IPR is between 13 and 15 percent.[6] These results support Hypothesis 1.

To test Hypotheses 2, 3a, and 3b, we utilize variation in location at which the focal patent was coinvented as well as the location(s) at which the patent was filed. We estimate

$$\begin{aligned} Share_{ijkmtp} = {} & \beta_0 + \alpha_1 Weak_m + \beta_1 Weak_m XFiledUS_k \\ & + \beta_2 Weak_m XFiledHost_k \\ & + \beta_3 FiledUS_k + \beta_4 FiledHost_k \\ & + \beta_5 FiledBoth_k + \beta_6 FiledNeither_k \\ & + \theta_i X_i + \theta_j Y_j + \theta_t \tau_t + \theta_p \lambda_p + \varepsilon_{ijkmtp} \end{aligned} \qquad (2)$$

The omitted category comprises patents that were not filed offshore, in which, by definition, the proportion of host inventors is zero. Recall that we defined the categories *Filed only in the US, Filed only in Host, Filed in Both,* and *Filed in Neither* conditional on an offshore patent. Therefore, the interaction effects $Weak_m \times FiledUS_k$ and $Weak_m \times FiledHost_k$ identify the additional influence of a host country with a weak IPR over and above that of a host country with a strong IPR on patents that are *Filed only in the US* and on patents *Filed only in Host*, respectively. In Equation 2 above, β_3 estimates the *Share* on home R&D projects and β_4 estimates the *Share* on host R&D projects for offshore projects in a host country with a strong IPR. When the IPR is weak at the host location, $\alpha_1 + \beta_1 + \beta_3$ estimates *share* on a home R&D project and $\alpha_1 + \beta_2 + \beta_4$ estimates *share* on a host R&D project. The results are shown in specification 4 of Table 5.

Hypothesis 2 suggests that *share* for a host R&D project is lower when the IPR at the host location is weak than when it is strong; given that the *share*

[6] Calculated as follows: From Spec. 1, a share of 0.71 for an offshore patent invented in a weak IPR host location implies that the total number of host inventors are about $0.71 \times 2.63 = 1.87$, where 2.63 is the average number of inventors in an offshore patent. Similarly a share of 0.82 on strong IPR offshore patents implies that the total number of host inventors are about 2.16. Thus the difference is about 0.29 or 13 percent ($0.29/2.16 \times 100$).

DOI: 10.1002/smj

Table 5. Effect of IPR strength at the host location on the share of host inventors using Equations 1 and 2

		Spec.1	Spec. 2	Spec. 3	Spec. 4
Weak	α_1	0.71 (0.00)***	0.68 (0.00)***	0.66 (0.00)***	−0.05 (0.00)***
Weak × filed only in US	β_1				−0.09 (0.00)***
Weak × filed only in Host	β_2				−0.30 (0.00)***
Strong	α_2	0.82 (0.00)***	0.79 (0.00)***	0.78 (0.00)***	
Filed only in the US	β_3				0.83 (0.00)***
Filed only in Host	β_4				0.79 (0.00)***
Filed in Both (US and Host)	β_5				0.73 (0.00)***
Filed in Neither (US or Host)	β_6				0.84 (0.00)***
Forward ratio			0.01 (0.00)***	0.01 (0.00)***	0.02 (0.00)***
Backward ratio			−0.02 (0.00)***	−0.01 (0.00)***	−0.03 (0.00)***
(1-no claims) × log claims		−0.05 (0.00)***	−0.04 (0.00)***	−0.03 (0.00)***	−0.02 (0.00)***
Claims not found dummy		0.01 (0.00)*	0.01 (0.00)*	0.01 (0.00)*	0.02 (0.01)*
Originality				−0.02 (0.00)***	−0.02 (0.00)***
Generality				−0.02 (0.00)***	−0.03 (0.00)***
R&D over sales				0.01 (0.01)***	0.02 (0.00)***
R&D not found dummy				−0.01 (0.02)	−0.01 (0.02)
Log (employees)				−0.02 (0.00)***	−0.01 (0.01)**
Constant		0.01 (0.04)	0.00 (0.03)	0.02 (0.02)	0.01 (0.05)
N		2,915,144	2,915,144	2,915,144	2,915,144
Assignee fixed effects (58,811)		Y	Y	Y	Y
Two-digit SIC code dummies (28)		Y	Y	Y	Y
Filing year dummies (35)		Y	Y	Y	Y
Within R-squared		0.54	0.55	0.56	0.57
Test for H1: $(\alpha_1 - \alpha_2)$		**−0.11 (0.00)*** **	**−0.11 (0.00)*** **	**−0.12 (0.00)*** **	
Test for H2: $\alpha_1 + \beta_2$					**−0.35 (0.00)*** **
Test for H3a: $(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3)$					**−0.25 (0.01)*** **
Test for H3b: $(\beta_2 - \beta_1)$					**−0.21 (0.01)*** **

***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively

Standard errors are in parentheses. Patents that are exclusively invented in the United States are the omitted category. Test for H3b: $\{[(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3)] - (\beta_4 - \beta_3)\} = (\beta_2 - \beta_1)$.

on a host R&D project when the IPR at the host location is weak is $\alpha_1 + \beta_2 + \beta_4$ and *share* when the IPR at the host location is strong is just β_4, that difference is $\alpha_1 + \beta_2 < 0$. From specification 4 in Table 5, we find that this difference is -0.35 (std. err. 0.00, p-value <0.01) supporting Hypothesis 2. This suggests that the number of host inventors on host R&D offshore projects to weak IPR host locations is about 44 percent lower than in similar R&D offshore projects to host locations with a strong IPR.

Similarly, Hypothesis 3a suggests that when the IPR is weak at a host location, the *share* is lower on a host R&D project than on a home R&D project. In Equation 2 above, as noted earlier, when $Weak_m = 1$, *share* for a host R&D project is $\alpha_1 + \beta_2 + \beta_4$. From spec 4 in Table 5, we see that this is 0.34 (std. err. 0.00). When $Weak_m = 1$, *Share* for a home R&D project is $\alpha_1 + \beta_1 + \beta_3$, which is 0.69 (std. err. 0.00). The difference $(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3) =$ -0.35 (std. err. 0.00, p-value <0.01), or about 36 percent. This supports Hypothesis 3a.

Hypothesis 3b argues that the relative reduction in *share* between a host R&D project and a home R&D project when $Weak_m = 1$ is greater than a similar reduction when $Weak_m = 0$. Stated otherwise, the test for Hypothesis 3b is $\{(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3)\} - (\beta_4 - \beta_3) < 0$, or just $(\beta_2 - \beta_1) < 0$. Table 5 suggests that $\beta_2 - \beta_1 =$ -0.21 (std. err. 0.02, p-value <0.01), supporting Hypothesis 3b. The relative reduction in host vs. home projects is about 31 percent when $Weak = 1$. However the reduction in the number of host inventors in host vs. home patents when $Weak = 0$ is only five percent. Thus the relative reduction in the number of host inventors between a host and a home R&D project is about 26 percent higher at a host location with a weak IPR when compared to a host location with a strong IPR.

Hypotheses 3a–b are the key hypotheses that test our contribution. Specifically, we argue for the counterintuitive proposition that when a host country's IPR is weak, the share of host inventors is likely to be lower in a host R&D project compared to a home R&D project, even though the host inventors are likely to know more about the host market. Similar to Singh and Agrawal (2011), we also matched patents across countries on observables. To the extent that observable and unobservable characteristics correlate, which is the principle underlying the coarsened exact matching (CEM) approach (Iacus *et al.*, 2012), it is unlikely that our results are exclusively driven by unobserved differences between patents produced in host countries with a weak IPR versus strong IPR.

In addition, our key hypotheses do not rely on a direct comparison between patents produced in weak IPR versus strong IPR countries. Hypotheses 3a–b, are differences-in-differences tests that compare *share* on patents invented by host country inventors belonging to the same assignee from the same location type (*weak* versus *strong*), in the same year and technology class, but are filed at home (the USA) as opposed to being filed at the host location. Therefore, to the extent that host location type-specific effects, firm-specific effects or temporal dynamics affect offshore patents in a host destination in a similar manner, differencing these coefficients should remove these unobservable differences that persist even after matching. This provides us some confidence that the identified effects relate to our hypotheses rather than being driven by unobservable differences between patents, host countries or filing year cohorts, although we cannot rule out these possibilities.

Robustness checks

Controlling for unobserved differences between countries—results using index

As argued above, it is plausible that our results are merely picking up other differences between host countries with weak and strong IPR. We hence replicate our results using an alternative measure of the IPR. For this purpose, we use "*index*," the measure of strength of IPR provided on a five-yearly basis in Park (2008). Since *index* varies by both host location and time, we now control for unobserved differences between host countries by using 43 host country dummies. Specification 1, of Table 6 estimates $Share_{ijkmtp} = \alpha_0 + \lambda_1 Index_{mt} + \theta_i X_i + \theta_j Y_j + \theta_t \tau_t + \theta_p \lambda_p + \theta_m K_m + \varepsilon_{ijkmtp}$ where θ_{m} denotes host country fixed effects while the other parameters are as described in Equation 1. Our results show that one standard deviation increase in *index* (increasing IPR strength) is associated with about nine percent more host inventors, supporting Hypothesis 1.

Specification 2 of Table 6 estimates $Share_{ijkmtp} = \alpha_0 + \lambda_1 Index_{mt} + \gamma_2 Index * FiledUS_k + \gamma_3 Index_{mt} * FiledHost_k + \beta_4 FiledUS_k + \beta_5 FiledHost_k + \beta_6 FiledBoth_k + \beta_7 FiledNeither_k + \theta_i X_i + \theta_j Y_j + \theta_t \tau_t + \theta_p \lambda_p + \theta_m K_m + \varepsilon_{ijkmtp}$ to test Hypotheses 2–3b. Hypothesis 2 is also supported: the number of host inventors on a host R&D project is about 48 percent more when conducted at a host location with a strong IPR compared to a weak IPR. Moreover, the number of host inventors for host R&D projects is about 31 percent lower than for home R&D projects, when the IPR at the host location is weak, supporting Hypothesis 3a. Finally, the increase in *index* increases the number of host inventors by about 19 percent more for host R&D projects relative to home R&D projects, supporting Hypothesis 3b.

Results using the number of offshore inventors as the dependent variable

We defined our dependent variable as the share of host inventors in a patent, taking the approach that the greater the share of knowledge for a given innovation available in the host country, the greater the likely loss from leakage. However, it is plausible that the absolute level of involvement of host inventors rather than the relative level may better capture the leakage threat. To check this, we redefine our dependent variable as the log of 1 plus the number of host inventors involved in a patent. We run two specifications, with and without controlling for the inventing team's size. Table 7 shows that all our hypotheses are supported.

Results using other dependent variables to proxy the extent to which a patent is offshore

We also checked if our results are sensitive to the fact that the effect of the IPR on *share* may not be a continuum. For this purpose, we tested our results by dichotomizing our dependent variable based on different kinds of thresholds, such as whether the patent is exclusively invented offshore, or whether

DOI: 10.1002/smj

Table 6. Replicating results using *Index* as a time-varying measure of IPR strength in the host destinations

		Spec. 1	Spec. 2
Index	λ_1	**0.08 (0.00)*****	**0.16 (0.00)*****
Index × filed only in the US	γ_2		**0.01 (0.00)*****
Index × filed only in Host	γ_3		**0.22 (0.01)*****
Filed only in the US	β_4		0.73 (0.00)***
Filed only in Host	β_5		0.69 (0.00)***
Filed in Both (US and Host)	β_6		0.68 (0.00)***
Filed in Neither	β_7		0.82 (0.00)***
Forward ratio		0.01 (0.00)***	0.01 (0.00)***
Backward ratio		−0.03 (0.00)***	−0.03 (0.00)***
(1-no claims) × log claims		−0.02 (0.00)***	−0.02 (0.00)***
Claims not found dummy		0.01 (0.00)*	0.01 (0.00)*
Originality		−0.02 (0.00)***	−0.02 (0.00)***
Generality		−0.02 (0.00)***	−0.01 (0.00)***
R&D over sales		0.01 (0.01)***	0.01 (0.01)***
R&D not found dummy		−0.01 (0.02)	−0.01 (0.02)
Log(employees)		−0.02 (0.00)***	−0.02 (0.00)***
Constant		0.02 (0.02)	0.00 (0.01)
N		2,915,144	2,915,144
Host country dummies		**43**	**43**
Assignee fixed effects (58,811)		Y	Y
Two-digit SIC code dummies (28)		Y	Y
Filing year dummies (35)		Y	Y
Within R-squared		0.78	0.79
Test for H1: $\lambda_1 > 0$		**0.08 (0.00)*****	
Test for H2: $\gamma_3 > 0$			**0.22 (0.01)*****
Test for H3a: $(\beta_5 - \beta_4) < 0$			**−0.04 (0.01)*****
Test for H3b: $(\gamma_3 - \gamma_2) > 0$			**0.21 (0.02)*****

***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively
Standard errors are in parentheses. Note that index at home country only varies with filing year and hence is omitted given that filing year dummies have been included in the regressions. Patents that are exclusively invented in the US are the omitted category.

the patent has a higher number of offshore inventors than the sample median. Finally, we also estimated a tobit specification that allows the distribution of *Share* to be concentrated around 0 and 1, while the rest of it is assumed to be distributed normally. All our hypotheses are supported in these tests.[7]

Results using an alternative sample

In addition, all our hypotheses held when we tested the robustness of our results by relying on the recently implemented patent reforms in India to redefine whether the patent is invented in host location with a strong or a weak IPR. This specification has a few advantages: it includes patents from the Indian patent office that are not included in the PATSTAT dataset, for which we have more in-depth information. For example, in this sample, claims are missing for only about three percent of the patents. Moreover, India strengthened the patent law for agricultural and pharmaceutical patents in 1994 and for other sectors in 2004, which provides us with an alternate, possibly exogenous measure to capture the strength of patents in a host country. This alternate sample comprised of 53,320 matched patents that belong to US-based assignees that were produced either exclusively in the US or offshore in the UK or India. We tested our hypotheses by using patents invented in India post-reform as the strong IPR sample, and those invented pre-reform as the weak IPR sample. We follow Lerner (2009) and Branstetter *et al.* (2006) and use UK-invented patents as a control sample since the UK has had a strong and stable IP regime for a long period of time. We use a differences-in-differences estimation to test our hypotheses in which we compare the difference in *Share* on Indian-invented patents between pre- and post-reform periods with the

[7] The results for these and subsequent robustness checks are reported in the Appendix S1.

Table 7. Replication of the results using the level of offshore inventor involvement - ln(1 + num of offshore inventors) as the dependent variable (DV)

		Without controls for team size		With control for team size	
		Spec 1	Spec 2	Spec 3	Spec 4
Weak	α_1	0.78 (0.00)***	−0.16 (0.00)***	0.78 (0.00)***	−0.19 (0.00)***
Weak × filed only in US	β_1		−0.10 (0.00)***		−0.12 (0.00)***
Weak × filed only in Host	β_2		−0.25 (0.00)***		−0.22 (0.00)***
Strong	α_2	0.91 (0.00)***		0.92 (0.00)***	
Filed only in the US	β_3		0.96 (0.00)***		0.95 (0.00)***
Filed only in Host	β_4		0.91 (0.01)***		0.91 (0.01)***
Filed at Both (US and Host)	β_5		0.88 (0.00)***		0.86 (0.00)***
Filed Neither	β_6		0.90 (0.00)***		0.88 (0.00)***
Forward ratio		0.01 (0.00)**	0.01 (0.00)***	0.01 (0.00)**	0.01 (0.00)***
Backward ratio		−0.02 (0.00)***	−0.02 (0.00)***	−0.03 (0.00)***	−0.01 (0.00)***
(1-no claims) × log claims		−0.02 (0.00)***	−0.01 (0.00)*	−0.02 (0.00)***	−0.02 (0.00)***
Claims not found dummy		0.02 (0.01)**	0.01 (0.00)***	0.03 (0.01)***	0.03 (0.01)***
Originality		−0.01 (0.00)***	−0.01 (0.00)***	−0.02 (0.00)***	−0.02 (0.00)***
Generality		−0.00 (0.00)***	−0.00 (0.00)***	−0.01 (0.00)***	−0.01 (0.00)***
R&D over sales		0.01 (0.00)***	0.01 (0.00)***	0.01 (0.00)***	0.01 (0.00)***
R&D not found dummy		−0.01 (0.00)	−0.01 (0.02)	−0.01 (0.00)	−0.01 (0.02)
Log(employees)		−0.01 (0.00)***	−0.01 (0.00)***	−0.01 (0.00)***	−0.02 (0.00)***
Log(1 + total inventors)				**0.09 (0.00)*****	**0.10 (0.00)*****
Constant		−0.03 (0.10)	−0.01 (0.10)	−0.06 (0.11)	−0.00 (0.10)
N		2,915,144	2,915,144	2,915,144	2,915,144
Assignee fixed effects (58,811)		Y	Y	Y	Y
Two-digit SIC code dummies (28)		Y	Y	Y	Y
Filing year dummies (35)		Y	Y	Y	Y
Within R-squared		0.54	0.55	0.56	0.57
Test for H1: $(\alpha_1 - \alpha_2)$		**−0.13 (0.00)*****		**−0.14 (0.00)*****	
Test for H2: $(\alpha_1 + \beta_2)$			**−0.41 (0.00)*****		**−0.41 (0.00)*****
Test for H3a: $(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3)$			**−0.20 (0.01)*****		**−0.14 (0.01)*****
Test for H3b: $(\beta_2 - \beta_1)$			**−0.15 (0.00)*****		**−0.10 (0.00)*****

***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively
Standard errors are in parentheses. Test for H3b: $\{[(\alpha_1 + \beta_2 + \beta_4) - (\alpha_1 + \beta_1 + \beta_3)] - (\beta_4 - \beta_3)\} = (\beta_2 - \beta_1)$.

similar difference on UK-invented patents. All our hypotheses are supported even in this sample.

Alternate method of classifying patents based on their filing location

We tested whether our results are sensitive to our classification of patents based on whether they were offshore and their filing location. We also checked whether the propensity to assign an offshore project to weak vs. strong IPR host location is dependent on the location of its end use or where the patent is filed. For this purpose, we redefined the categories filed only in USA, filed only in host, filed in both and filed in neither unconditionally based only on where the patent was filed. Using three dependent variables based on whether a patent filed in an offshore destination with a weak IPR (*weak*), or a location with a strong IPR (*strong*) or whether they were produced exclusively in the USA, we implemented a set of seemingly unrelated regressions with the patent filing locations as the main explanatory variables. We find support for all our hypotheses.

Other potential sources of bias

Our results, especially for Hypotheses 1 and 2, rely on comparing the share for patents coinvented in *weak* host locations versus the share for patents coinvented in *strong* host location. It is plausible that differences in *share* are driven by factors other than the strength of the IPR at the host location. For example, the differences in *share* may just reflect the differential levels of integration of the subsidiary with headquarters and subsidiaries located in strong IPR countries may be more integrated in the MNE's knowledge network relative to those in weak IPR countries or that R&D collaboration with the subsidiaries located in some countries could be in different technological areas relative to others. Through matching patents we have attempted to mitigate these concerns. A related issue is that our results may also reflect the changing ability of subsidiaries to take on more complex projects over time. Like much of the prior work (Alnuaimi, George, and Puranam, 2012; Lahiri, 2010; Singh, 2008), we do not control for time-varying subsidiary-specific effects. However, as discussed earlier, Hypotheses 3a–b rely on the difference between patents filed at home versus host locations from within a host type and filing year cohort. It is unlikely that the subsidiary's ability at an instance in time would differentially impact home versus host R&D projects. This helps us mitigate the likelihood of alternative explanations that suggest that our results derive from systematic differences in patents.

DISCUSSION

The internationalization of R&D activity by MNEs has been an active topic of research for the past 50 years, with the pace of scholarly interest picking up in the past 20 years, given the significant increase in foreign R&D conducted by MNEs. Whereas much prior work has discussed R&D internationalization in the context of the most developed countries, such as the United States, Canada, Western European countries, and Japan (Kuemmerle, 1999; Rugman, Verbeke, and Nguyen, 2011), the most recent and exciting trend is the growing presence of emerging economies, such as China and India, on the MNE R&D map (Alnuaimi *et al.*, 2012; Zhao, 2006). This recent trend presents MNE managers with a trade-off. Whereas relatively inexpensive labor costs at these destinations provide opportunities for cost arbitrage, the weak IPRs at these destinations also makes the appropriability of IP a challenge. It is from this perspective that our study makes novel contributions.

We ask how the relative participation of inventors from headquarters and the foreign subsidiary of an MNE changes with the changing strength of the IPR at the host location. Early studies argue that R&D centers in host locations customize technologies developed at home to suit local market needs (Mansfield *et al.*, 1979). Later studies argue that MNEs may also establish foreign R&D centers to access specialized skills and technologies available there that are perhaps not readily available at home (Almeida, 1996; Kuemmerle, 1999). Understanding the relative involvement of host inventors versus headquarters inventors is important to understand how MNE's organize R&D internationally.

Our empirical investigation leads to two conclusions. First, on average, fewer host inventors from locations with a weaker IPR are involved in MNE R&D projects. Second, the influence of the strength of the host country's IPR on the involvement of host inventors is greater when the R&D is aimed at the host market than when aimed at the home market.

Our results refine the findings from prior studies on the influence of IPR strength on offshore R&D. Unlike prior work, we show that the extent to which a weak IPR in the host country imposes an appropriability threat to an MNE depends on where the output of the R&D project is used. Innovations produced for the host market entail the risk of the expropriation of both patented and unpatented knowledge, whereas inventions produced for the home market, which has a strong IPR, entail the risk of expropriation of only unpatented knowledge. Consequently, innovations intended for host markets with a weak IPR have lower levels of host inventor participation compared to those aimed at the home market. This finding adds to prior work on offshore R&D in weak IPR locations by Branstetter *et al.* (2006) and Zhao (2006). Since Zhao (2006) uses patents filed at the US.PTO to test her hypotheses, although she implicitly alludes to the fact that many patents that are invented in host countries with a weak IPR are for global use, she does not test the relative differential in host inventor involvement across home and host patents. Branstetter *et al.* (2006) show that royalty payments as well as patents filed by nonresidents in the host country increase with stronger IPRs in the host country. Thus, they implicitly suggest that stronger IPR at host countries may matter for host R&D projects, but they do not consider the influence of host IPRs on home projects developed offshore at that host location. We explicitly test how the strength of the IPR at the host location and the nature of the R&D project *jointly* influence the level of involvement of host inventors in an offshore R&D project. Our results are consistent with the intuition derived from prior studies.

Our results also have significant managerial implications, especially for MNE managers looking to capitalize on the relatively cheap innovation talent available in weak IPR countries. Our results suggest that the strength of the IPR matters differently depending on whether the fruits of the R&D are utilized at home or in offshore markets. Thus, our paper provides guidance for MNE managers in deciding upon the extent of offshore R&D and other considerations to bear in mind when selecting projects for outsourcing to weak IPR locations.

Our results have interesting policy implications as well. A country's IPR is a significant component of its national innovation system (Pavitt and Patel, 1999) and although MNE R&D has globalized, national innovation systems, especially IPRs, remain local (Carlsson, 2006). Our findings suggest that IPRs seem to act mainly as a deterrent to MNEs' working on technologies that are particularly relevant to that host country. Grossman and Helpman (1993) suggest that a weak IPR may impede technology transfer and therefore the economic growth of the offshore country. Consistent with their work, our results suggest that when IPR is weak, although the host location may work on cutting-edge technology, it may not benefit from such activity since the technology may more relevant to the home market.

As with most work, ours also has limitations, many of which we discussed and attempted to mitigate in the section on robustness checks. Our main limitations arise from two sources imposed by the nature of the data, mainly because we lack the details on the actual characteristics of the R&D project, as well as the details of all the R&D personnel involved in it.

The first relates to our proxy for the nature of the offshore R&D project (home versus host). We base our analysis on the country or countries in which the patent assignee(s) opted to file, which is assumed to be indicative of the market in which the patent is largely relevant. In relation to the hypotheses that we test in this paper, this assumption is relevant only for patents that are filed in only one location; that is, for *Filed only in the US* and *Filed only in Host* patents. Our supplementary interviews and data validation efforts largely support this assumption. Moreover, to the extent that firms file patents in the host location to prevent local competitors from entering the home country, rather than because the host country is a target market, these patents will be classified as *Filed in Both,* and therefore are unlikely to influence our results in our regressions. In addition, it is plausible that the staffing of an R&D project may not happen with the all the end-use locations in mind. For example, a home patent may be filed later at the host location, when the host market has become more mature. In this scenario as before, we are likely to classify the patent as *Filed in Both.* In addition, this scenario is less likely because patents filed under the Patent Cooperation Treaty have relatively less time for follow-on filings in different countries, and therefore these patents may indeed be staffed with the specific markets in mind.

The second limitation relates to the measures we use to proxy for the strength of IPR. It is plausible that both our proxies for the strength of IPR pick up other time varying differences between host countries or subsidiaries. We acknowledge that this cannot be perfectly identified simply because it is difficult to devise a perfect measure of the strength of the IPR in a country (cf. Arora, 2009). Prior studies that analyze how institutional differences between countries influence firm strategies, also face the same problem in identifying the effect of the institution apart from other unobserved differences between the countries studied. In this respect, our work is in line with prior work in comparative institutional economics, such as those by Zhao (2006); Branstetter *et al.* (2006); Lerner (2009); Mahmood and Mitchell (2004); Chang, Chung, and Mahmood (2006); Chacar and Vissa (2005), and Chari and David (2012).

We attempted to address these limitations in two ways: (1) by matching offshore patents with those produced in the home country and in addition matching offshore patents invented at host countries with a strong IPR with those with a weak IPR (2) by estimating a set of regressions where our results rely on a set of differences-in-differences thereby avoiding direct comparisons of patents invented across the different types of locations. In other words, even if offshore patents to strong versus weak IPR locations are systematically different, our results pertain to differences in the involvement of host country inventors in weak IPR destinations, but are filed in the home country versus in the host country. However, they may not account for all unobserved differences, a limitation we share with most prior work in this area.

Despite these limitations, we believe the paper contributes in a novel way to understanding how MNE's organize their R&D activities across geographies. We investigate how IPRs influence decisions regarding staffing R&D projects at home and at offshore locations and show that, when an MNE's talent base is scattered across geographies that vary in IPR strength, the involvement of offshore inventors is sensitive not just to the strength of the IPR at the host location, but also to the nature of the R&D project. In fact, the influence of the IPR strength is high enough to counter the intuitive notion that host inventors are more likely work on host R&D projects and home investors are more likely to work on home R&D projects. We thus hope that our paper inspires more such work to provide deeper insight into the implications of how MNEs manage institutional voids (such as a poor IPR) across countries to create competitive advantage.

ACKNOWLEDGEMENTS

The authors thank the Associate Editor Kulwant Singh and two anonymous referees for helpful comments to refine this paper. The authors also thank Gautam Ahuja, Jay Anand, Ashish Arora, Sea-Jin Chang, Sendil Ethiraj, Reddi Kotha, Anita McGahan, Phanish Puranam, Nandini Rajagopalan, Markus Reitzig, Jasjit Singh, Stefan Wagner and seminar participants at ESMT and INSEAD for helpful comments on this paper. Anand Nandkumar thanks Vikram for the help in assembling the dataset used in this paper. Kannan Srikanth acknowledges support from the Strategic Organization Design Unit, University of Southern Denmark.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix S1. Additional robustness checks.