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Not with my own: Long-term effects of cross-country collaboration on subsidiary innovation in emerging economies versus advanced economies

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Not with my own: Long-term effects of cross-country collaboration on subsidiary innovation in emerging economies

Abstract

Prior literature has established that international collaboration on R&D is an important means for generating new and impactful ideas through the cross-border integration of knowledge. We show that cross-country collaboration improves not just the resulting inventions, but also has a long-term benefit for the involved inventors in terms of continuing to generate higher-impact patents in the future. However, our results also show that the improved performance of specific inventors in an MNC subsidiary does not translate to broader subsidiary-level capabilities at innovation. One possible explanation might be that inventors obtaining international exposure often do not develop collaborative ties with other inventors in the subsidiary, favoring instead to collaborate internationally on subsequent R&D projects.

1. Introduction

In recent decades, we have observed significant changes to the global landscape of innovation. Owing to the increasing number of countries which possess innovative capabilities, strong national innovation systems, and unique resources, knowledge for innovation has become globally dispersed. Leveraging knowledge from the dispersed locations has, therefore, become a salient source of competitive advantage for the firm (Dunning, 1998). In this context, the multinational corporation (MNC) has a unique advantage, since it can more easily transfer knowledge between countries, and build on knowledge that is distant. Indeed, empirical evidence has supported the view that MNCs are superior to other governance structures, like markets and alliances, when it comes to mobilizing knowledge across large geographic distances (Almeida, Song and Grant, 2002). In part, this is due to the tacit nature of much of the knowledge required for innovation, which makes it more difficult to transfer between firms than within firm boundaries—even when these boundaries span geographic regions (Kogut and Zander, 1993).

This advantage of the MNC does not relieve it from the many challenges of distant knowledge sharing. Typically, a subsidiary's knowledge stock is tacit and context-specific because its creation is highly influenced by its surrounding business environment (Riusala and Suutari, 2004). As a result, other subsidiaries which were not involved in the process of creating that knowledge may not comprehend its value, nor realize how it could be useful to them (Kogut and Zander, 1992). But even if a subsidiary can locate valuable knowledge within the MNC, a number of different costs can be accrued when long-distance knowledge transfer takes place. For example, it may need to invest in an shared electronic knowledge repository. Additionally, a prerequisite for the individuals involved is the dedication of time towards coordinating activities and generating shared norms such that the knowledge can be transferred in high-fidelity (e.g. Kogut and Zander, 1992; Lane, Salk and Lyles, 2001; Srikanth and Puranam, 2010). These costs are expected to be higher when the knowledge is more complex (Sorenson, Rivkin and Fleming, 2006), as well as when larger distances separate the subsidiaries (Srikanth and Puranam, 2010), since, in both these cases, the sender and the recipient are required to be more involved in the process of knowledge transmittal. For these reasons, inter-subsidiary knowledge transfer does not happen haphazardly.

Previous literature that has examined the factors which facilitate inter-subsidiary knowledge sharing has emphasized the importance of interpersonal relationships (e.g., Ghoshal, Korine and Szulanski, 1994; Frost and Zhou, 2005). The characteristics of interpersonal ties are highly diverse. For instance, they can be formal or informal, strong or weak, and can remain active over a long or a short time period. In this study, interpersonal ties represent collaborative R&D relations between inventors from different subsidiaries. Because these are activities that lead to the production of patents, which are non-trivial events, the inter-unit ties are expected to be strong and evolve over an extended period of time.

Cross-country collaboration on R&D has been established as a valid mechanism for transferring knowledge across large distances (Frost and Zhou, 2005; Singh, 2005) even when the knowledge is complex (Sorenson et al., 2006). In a patent-level study, Singh (2008) showed that merely having geographically dispersed R&D operations, with no mechanism for integrating the distant knowledge, does not improve the value of innovations that are generated by an MNC. However, when inventors from distant subsidiaries collaborate internationally, they are then able to integrate geographically dispersed knowledge with more ease, which ultimately helps with the creation of higher impact innovations. In a similar study conducted at the firm-level, Lahiri (2010) showed that an increase in the share of an MNC's patents which involved cross-country collaboration substantially improved its ability to generate valuable patents through the integration of geographically dispersed knowledge.

The rich, empirical studies on cross-country collaboration within the MNC have mostly focused on describing the benefits that result directly from these endeavors. There is very little evidence on whether or not the benefits are long-term. Our study questions if the high-impact patents that are generated through cross-country collaboration are merely a series of "one-off successes" for foreign subsidiaries. Or, alternatively, can this type of collaboration aid with the construction of new internal capabilities which support future growth? We explore this question in two ways. Firstly, we examine the long-term benefit of cross-country collaboration on the inventors that were involved in this activity by testing if the inventors who have collaborated internationally in the past can continue to create high-impact R&D on their own. Secondly, and more generally, we examine if knowledge from these collaborative activities can be later internalized by the foreign subsidiaries, and used to create new inventions.

To explore the potential of an enduring effect of cross-country collaboration on the inventors and their respective subsidiaries, we rely on patent data assigned to foreign subsidiaries of 238 US semiconductor multinational corporations (MNCs) over a 26 year time period. The data covers subsidiaries in 43 countries, of which 16 are emerging economies. Emerging market economies are by no means identical to one another, but in comparison to many advanced economies, their country resources and institutions are less developed (Wan, 2005). This can lead to systemic differences in the type of R&D that is offshored to emerging and advanced economies. To account for such differences, we repeat our empirical analyses to explore the effect of cross-country collaboration independently for the sample of emerging economy and advanced economy patents. Since the emerging and advanced economy categories are broad, and, within each category countries can differ substantially, all empirical models account for country-level heterogeneity. Our results show that there is a long-term effect of cross-country collaboration, but only for the inventors that were involved in this activity. The subsidiaries, on the other hand were less likely to internalize knowledge from cross-country collaboration.

2. International R&D collaboration in foreign subsidiaries

The creation of novel innovations hinges on knowledge and resources that are already in existence, as they are often an outcome of recombining elements that are available and accessible (Kogut and Zander, 1992; Hargadon and Sutton, 1997; George, Kotha and Zheng, 2008; Kotha, Zheng and George, 2011). Innovation is therefore a function of the resource endowment of a firm. If the firm is resource constrained, the number of unique combinations that are possible will inevitably be limited, curbing its ability to solve problems that it may face and capitalize on opportunities that become available. In order to become better positioned for R&D, these firms are required to leverage their capabilities, which can be achieved either organically, or by integrating external capabilities through mergers and acquisitions (Walter and Barney, 1990). Whether the search for new elements that would supplement an existing knowledge base takes place internally or externally,this search takes place locally, within a terrain that is familiar to the pursuer (Cyert and March, 1963). To do otherwise and engage in a distant search incurs a higher search cost, but is at times necessary as it enhances the diversity of an existing knowledge stock, creating more opportunities for new and impactful innovations (Arora and Gambardella, 1990; Ahuja and Lampert, 2001; Cohen and Malerba, 2001; Fleming, 2001).

For a single-location firm, the distant knowledge is more likely to reside outside the firm’s boundaries, rendering it difficult and costly to obtain and, more importantly, to absorb since it often entrenched within complex organizational routines (Zack, 1999). Faced with this constraint, the single-location firm would require an effective strategy to overcome the challenges associated with searching for complementary knowledge that is external, and ensure that the profits yielded after integrating it compensate for the costs associated with obtaining it. In comparison to a single-location firm, an MNC enjoys an advantage across two fronts. First, the MNC is composed of multiple geographically dispersed entities that are inter-linked through certain relationships (e.g. Hedlund, 1986; Prahalad and Doz, 1987; Bartlett and Ghoshal, 1989; Ghoshal and Nohria, 1993). To transmit knowledge between the affiliated units, even if they are spatially separated, is often easier than transmitting knowledge between firms (Kogut and Zander, 1993). Second, subsidiaries that are embedded in their respective host-countries, develop, over time, capabilities that resonate with those of other firms in their locales and which consequently diverge from the capabilities of their affiliates (Taggart and Hood, 1999; Andersson, Forsgren and Holm, 2001; Andersson, Bjorkman and Forsgren, 2005). Thus, having subsidiaries in multiple locations could be an efficient mechanism for searching for distinctive but complementary knowledge across large spatial distances.

Within an MNC, the opportunity to enhance capabilities in this way is contingent on the subsidiary's ability to absorb external knowledge in the host-country (Cohen and Levinthal, 1990; Zahra and George, 2002). If the subsidiary is able to do so, and is then able to share the location-specific knowledge across the MNC network, new opportunities for innovation are generated (Zander, 1997; Nobel and Birkinshaw, 1998). Yet, even affiliated can find it challenging at times to share knowledge due to the large geographic and cultural distances that separate them (Hansen and Lovas, 2004; Ambos and Ambos, 2009). Therefore, encompassing diverse knowledge in the affiliated subsidiaries is, on its own, not sufficient to achieve novel combinations for subsequent innovation. It is only when the affiliated subsidiaries are capable of integrating the distant knowledge does it become a source of competitive advantage (Grant, 1996).

The transmittal of knowledge that is tacit or complex across large distances can be achieved through the creation of strong interpersonal ties between distant subsidiaries (; Hansen, 1999; Hansen and Lovas, 2004; Singh, 2005; Sorenson et al., 2006). There are at least three reasons why the cross-regional setting makes fostering such collaborative ties particularly important. First, interpersonal ties occur more abundantly within a region rather than across regions (Almeida and Kogut, 1999; Breschi and Lissoni, 2009). In the sporadic occasions when they do occur, cross-regional ties can essentially act as structural bridges which introduce non-redundant knowledge (Burt, 1992). Second, the differences in the knowledge encompassed by different regions means that cross-regional ties are more likely to transfer knowledge that is heterogeneous, creating richer possibilities of novel combinations (Reagans and Zuckerman, 2001; Cummings, 2004; Rodan and Galunic, 2004). Lastly, the transfer of high-fidelity knowledge across subsidiaries is only possible if the motivational disposition to share knowledge exists (Szulanski, 1996; Gupta and Govindarajan, 2000). Because they reduce transaction costs like opportunism (Williamson, 1985; Teece, 1986), interpersonal ties incentivize subsidiaries to share knowledge.

The discussion so far highlights the importance of interpersonal ties for the transfer of knowledge between subsidiaries. It is worthwhile to note that these ties occur between individuals and not directly between subsidiaries. In other words, the effect of these ties on the individuals involved will likely differ from their effect on the respective subsidiaries. Therefore, in the following two subsections, we first discuss the direct effect of interpersonal ties on the innovative performance of the individuals involved, and then describe how this individual-level effect translates to a higher level which, in this study, is the level of a subsidiary.

2.1 Cross-country collaboration and inventor performance

Prior literature has already established that working with a team of inventors yields higher impact inventions than working individually (Singh and Fleming, 2010), and working in a team composed of multinational inventors yields an even higher impact (Singh, 2008). What these analyses do not disentangle is whether the breadth of experiences that are gained through collaboration or, more prominently through international collaboration can enhance each of the collaborator's abilities to later apply this knowledge to generate impactful innovations on their own. The probable scenario is that collaboration does indeed have an enduring effect that is positive, and which is more prominent when the inventors collaborate internationally.

Since prior experiences, personality traits, and familiarity guide how people perceive new knowledge that they are exposed to, it is highly unlikely that two individuals will conceptualize and embody knowledge in exactly the same way. What is likely, however, is that if the two individuals shared the same experiences and were exposed to the same resources during their careers, their knowledge bases would begin to depict more similarities than if their experiences vastly differed. Thus, teams of inventors can collectively bring together a wider set of solutions in comparison to an inventor who works in solitude. All else being equal, when the inventors reside in dispersed geographic locations, the diversity of the collective knowledge and the range of possible solutions become even grander. Over time, subsidiaries become host-country oriented, and the inventors employed by these subsidiaries begin to accumulate experiences that are unique to that subsidiary. Therefore, even if the skills and expertise of inventors employed in different subsidiaries are comparable; their experiences are likely to depict more disparities than co-located inventors.

The discussion so far reveals why international collaboration on R&D can positively impact the inventions that are a result. Yet, to have an enduring effect on the participating inventors, they each need to disclose their own knowledge and internalize one another's. In some situations, knowledge sharing may not occur. For example, if the knowledge elements that were combined to create an invention are perfectly modular, and required no trial-and-error period before the final combination was achieved, then extensive interaction is not a prerequisite for the individuals associated with that particular project. Although possible, this is not likely to be the case because patented inventions are often complex and require intensive collaboration over a long period of time (Fleming, King and Juda, 2007). It is therefore likely that when inventors collaborate, knowledge will be shared, even after the formal collaborative relationship ends (Agrawal, Cockburn and McHale, 2006).

Even if the success of an invention requires knowledge elements from all team members, this still does not imply that each of the co-inventors will share equally. Some inventors may deliberately avoid sharing because they lack the motivation to do so, particularly if their knowledge stock is what gives them competitive advantage over their colleagues. Alternatively, some inventors may be incapable of teaching others what they know; or, in other cases, a specific invention may call for some inventors' knowledge more than others. It is therefore likely that knowledge will flow disproportionately within a team of inventors. But even if we assume that each inventor contributes equally to an invention, individuals differ in their abilities to perceive the value in the available knowledge, and use it to broaden their skills. Thus, each of these inventors may integrate the new ideas to create vastly distinct combinations, which ultimately have different outcomes and impacts. In other words, the subsequent performance of each inventor on that team may vary. However, in conducting this activity, these inventors are more likely to encounter diverse knowledge than inventors who did not collaborate internationally; which, in turn, this allows for richer opportunities for creating high-impact innovation (Arora and Gambardella, 1990; Ahuja and

Lampert, 2001; Cohen and Malerba, 2001; Kotha, Zheng and George, 2011). The discussion so far leads to the following hypothesis:

> ***Hypothesis 1:*** *Prior cross-country collaboration by one or more of the inventors will positively influence patent impact.*

2.2 Cross-country collaboration and subsidiary knowledge internalization

Apart from the anticipated positive effect of cross-country collaboration on the inventors, we also expect for cross-country collaboration to have a positive effect on the subsidiaries. A subsidiary which relies solely on its internal knowledge base for innovative endeavours risks exhausting all of the useful combinations. In such a case, a distant search for new knowledge could serve as a springboard for novel combinations (Fleming, 2001; Fleming and Sorenson, 2004). In an MNC, this is possible when a subsidiary forms ties across geographical boundaries, which can help them to access new capabilities (Boschma, 2005; Phene et al., 2006). Cross-country ties have been shown to improve knowledge transmission (Frost and Zhou, 2005), but also enhance the value of innovations by facilitating the integration of globally dispersed knowledge (Singh, 2008; Lahiri, 2010).

Being exposed to new knowledge does not automatically lead to its internalization. It depends on factors such as the subsidiary's absorptive capacity, and its openness to the new, foreign ideas. Typically, strong ties which facilitate knowledge transfers, such as cross-cross collaboration on R&D, are likely to lead to further interactions at a later date (Monteiro, Arvidsson and Birkinshaw, 2008). These interactions can create a pool of shared knowledge and norms between the collaborating subsidiaries, which would allow them to internalize one another's knowledge with more ease (Frost and Zhou, 2005). What is more, the inventors will be more disposed to interacting with colleagues from the subsidiaries which they previously shared ties with (Monteiro et al., 2008). Therefore, if a subsidiary cannot fully comprehend the knowledge that it was exposed to through cross-country collaboration, further information on how to internalize it could be made available to them. For these reasons, we expect that:

> ***Hypothesis 2:*** *New knowledge that a subsidiary is exposed to through cross-country collaboration will appear on more of its subsequent inventive activities.*

3. Data construction

The dataset used for the empirical analyses consists of successful patent applications published by the US Patent and Trademark Office (USPTO). Information contained in patent data makes it ideal for tracking the impact of inventive activities, indicating the location or locations in which these activities took place, as well as gauging the extent to which they resulted from collaborative efforts between inventors from the same or different regions. All these features regarding the R&D activities of firms have been extensively studied using patent data (e.g. Jaffe, Trajtenberg and Henderson, 1993; Agrawal et al.,2006; Breschi and Lissoni, 2009; Nicholas, 2009).

The sample is composed of patents assigned to US MNCs whose main line of business falls in the semiconductor and related devices industry (SIC code = 3674). We focus on the semiconductor industry for several reasons. The semiconductor industry has evolved to become one that is highly globalized, particularly in recent decades (Phene and Almeida, 2008) and is therefore an appropriate context for examining how a firm's R&D characteristics vary across globally dispersed subsidiaries. Second, it has been noted that US semiconductor firms have high rates of technological innovation (Stuart, 2000), as well as high propensities to patent their technologies (Hall and Ziedonis, 2001). Therefore, patent data more comprehensively covers the innovative activities of firms in the semiconductor industry than in other industries where patenting is not a chief activity, and is a better proxy for innovation in this context.

The main sample covers 238 semiconductor MNCs headquartered in the US. These were selected using the following steps. First, we populated a list of US semiconductor firms using several sources. The first is the list of firms used in Hall and Ziedonis (2001) which investigates the drivers of the patenting trend in the US semiconductor industry between 1975 and 1995. This set consisted of patents assigned to 95 publicly traded firms who have a COMPUSTAT record and their respective subsidiaries, according to the Who Owns Whom directory. Because our study also includes firms that were not publicly traded and those that may have begun patenting after 1995--which were not covered by Hall and Ziedonis (2001)--two additional sources are relied upon. The Directory of American Firms Operating in Foreign Countries[1] contains the list of US firms who have substantial capital investments in foreign countries, and provides information that includes the company's main industry, the name and address of the US parent firm, and the names and addresses of its foreign subsidiaries and affiliates. This directory contained a list of 502 US semiconductor firms with 2544 subsidiaries in the US and 5728 subsidiaries abroad. Finally, the rankings of semiconductors firms that are published annually by iSuppli Corporation from the year 2000 onwards are used to ensure that no major corporation is missing from the list of firms. These methods resulted in the construction of a list containing 550 unique semiconductor firms that are headquartered in the US.

A major challenge that confronts research that utilizes patent data is matching each firm to all the patents it applied for. This is due to the absence of a unique assignee identifier in the USPTO database. Instead, a firm's name can appear in full (e.g. International Business Machines), with an alternative spelling (e.g. International Business Machines Corp.), as an acronym (e.g. IBM) or even as the name of one of its foreign subsidiaries. As is the case with other studies (e.g. Hall and Ziedonis, 2001; Hall, Jaffe and Trajtenberg, 2005), a number of

[1] Directory of American Firms Operating in Foreign Countries, Uniworld Business Publication, Inc., New York, NY. Web site: http://www.uniworldbp.com/

steps are used to clean the data, whereby obtaining a more accurate account of all the patents that are assigned to each unique firm. First, data that is made available from the NBER patent project is used to match USPTO assignees with a unique numerical identifier[2]. Second, each variation in the names of the 8,272 subsidiaries of the 502 semiconductor firms retrieved from the Directory of American Firms Operating in Foreign Countries is compared against the names of the 247,309 assignees that were granted a USPTO patent during the time-period 1975-2008. Lastly, for companies where a match was unattainable using the mentioned steps, company websites and industry publications were used to manually check for any other variations in the names.

Following the above steps, we identified 463 firms that had been granted at least one USPTO patent between 1975 and 2008. Since a patent's application year is a more accurate reflection than grant year for the time when an invention took place, all analysis reported in the paper is based on the application year of these patents. We excluded application years prior to 1980 from our sample in order to have a historical account for previous tie formation through international collaboration. Likewise, the sample ends at application year 2005 so that there is a large enough subsequent time window to make sure that patents applied by then have truly been granted and also we get a chance to observe future impact of these patents on subsequent inventions. The future citation impact is measured until patents granted as recently as 2010. [3]

During the time period between 1980 and 2005, 246 of the 463 semiconductor firms mentioned above applied for at least one patent, with the total number of resulting patents

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2 This data is available from two sources: https://sites.google.com/site/patentdataproject/Home and http://www.nber.org/patents/. The first source is used for the purpose of this research as it is a more up to date version.

3 We supplemented our core dataset with patent data that was made available by Lai, D'Amour, Yu, Sun and Fleming (2011) which is available on
http://dvn.iq.harvard.edu/dvn/dv/patent/faces/study/StudyPage.xhtml?studyId=70546&versionNumber=1

from these being 207,824. Since we are interested in inventions resulting from the foreign subsidiaries of these firms, we dropped all purely home country (i.e., US) patents. Similar to other studies (e.g. Stolpe, 2002; Frost and Zhou, 2005), we define a patent as being developed at least partially in a foreign subsidiary if at least one of the inventors had a foreign address at the time the of patent application. We also drop the countries where the number of patents arising is too trivial to be statistically meaningful, keeping only those countries where at least 10 patents originated over the time period 1980-2005. For the relatively rare cases where a patent involves inventors located in multiple foreign subsidiaries of a firm, we assign a unit value to each of the foreign locations in order to not miss the contribution of any of the foreign subsidiaries. Following these steps, we end up with a final dataset comprising of 26,708 patents from 1,022 foreign subsidiaries belonging to one of 238 firms now left in the sample.

Insert Table 1 here

Table 1 summarizes the data across the 42 foreign countries where subsidiaries in our sample are located. The table shows the number of distinct subsidiaries from which the patents in our sample originated, and the number of patents by inventors from each of these subsidiaries. The table is separated into two sections in order to distinguish between emerging economies and relatively advanced economies. We categorize countries as emerging or relatively advanced economies based on their average gross domestic product (GDP) per capita. [4] Countries with an average GDP per capita during 1980-2005 that is less than 10,000 USD, as per the World Development Indicators & Global Development Finance database

[4] Our categorization of emerging and advanced economies is also comparable to frequently used indices that have been used to identify emerging economies such as the Morgan Stanley Capital International (MSCI) Emerging Markets Indices, the Standard and Poor's list on emerging markets, and the FTSE list on advanced and secondary emerging markets.

from the World Bank, were classified as emerging economies, as there seemed to a natural gap in the distribution of different countries' incomes at this point.

Insert Figure 1 here

As a part of the data construction exercise, we also classify each observation as being the result of either an international collaboration or a completely local effort within the subsidiary. This is done by examining information on the country of residence for each of the inventors. If a patent involves inventors from a given country as well as at least one other country (which in 89% of such instances is the home country, i.e., the US), it is classified as a patent involving an international collaboration. However, if all inventors have the subsidiary country listed as their place of location, then it is considered a purely domestic patent. Figure 1 illustrates the extent of international collaboration for the different countries in our sample. Overall, about 35% of observations in our sample demonstrate international collaboration, with a slight upward trend over years. As shown in Figure 1, more than 50% of the patents in the majority of countries in our sample are a result of international collaboration.

3.1 Variable definitions and empirical methodology

Our objectives are twofold. First, we examine whether cross-country collaboration improves an inventor's ability to generate better innovations in the future, even if those are purely local innovations that do not depend on foreign collaboration. To examine this issue, we define a dependent variable, Impact, which captures the value of patents that these inventors develop. Patents vary quite substantially in their value, where the majority is worth very little (Jaffe and Trajtenberg, 2002). Therefore, rather than just focusing on patent counts, recent literature has tried to measure the economic and technological importance of patents. In particular, the number of citations a patent receives has been shown to be correlated with several direct measures of patent value, including the consumer-surplus generated

(Trajtenberg, 1990), expert evaluation of patent value (Albert, Avery and Narin, 1991), patent renewal rates (Harhoff, Narin, Scherer and Vopel, 1999) and contribution to a firm's market value (Hall et al., 2005). It follows that citation-based measures of invention value have been used in several studies. In an analogous manner, we also define value of innovation as the number of forward citations received by a patent.[5]

The second objective is to examine the extent to which offshore subsidiaries internalize new knowledge that was introduced to them through cross-country collaboration. To construct this variable, we isolate patents containing components that are new to the subsidiary. These are patents with a subclass that has not been used in recent years by a subsidiary (Fleming, 2001). We define a patent as containing a new component if the patent's technological subclass did not appear on any of a subsidiary's patents that were applied for in the previous five years. A five-year time frame is used because prior knowledge for new inventions drops considerably after this period of time (Griliches, 1984). For these patents, the variable *Internalization* counts the number of times that a subsidiary develops patents with the same technological subclass as the focal patent in the next five years. For example, for a patent with subclass s which was applied for in year t, *Internalization* is calculated as the number of times that a subsidiary develops a patent with the same subclass (s) during year t+1 to t+5. Higher values would mean that a subsidiary was able to familiarize itself with the new component (Fleming, 2001).

Two explanatory variables are included to examine the long term effect of cross-country collaboration. The first is *Cross-country*, which is a binary variable that takes a value of 1 if the inventors who developed the focal patent had addresses in different countries at the

[5] This is consistent with USPTO's view: "If a single document is cited in numerous patents, the technology revealed in that document is apparently involved in many developmental efforts. Thus, the number of times a patent document is cited may be a measure of its technological significance (Office of Technology Assessment and Forecast, Sixth Report, 1976, p. 167). Our citation-based measure includes both self-citations by the owner firm and citations made by others, since both are signals of patent value: while a self-citation signals that the patent may have helped internal innovation, an outside citation suggests the patent to be a potential source of licensing revenue.

time that the patent was applied for, and 0 otherwise. The second variable is *Prior cross-country* which takes a value of 1 if any of the inventors listed on the focal patent had collaborated internationally on a prior patent, and a value of 0 otherwise. The effect of *Prior cross-country* is examined in two ways. First, its effect is examined in the sample of patents which depicted no cross-country collaboration. A positive and significant coefficient would indicate that patents by inventors with prior international experience are more valuable, and that there is an enduring effect of cross-country collaboration. Second, the moderating effect of *Prior cross-country* on current *Cross-country* collaboration is examined in the full sample, which is composed of both collaborative and non-collaborative patents. A positive and significant interaction term would mean that the two variables complement one another. In contrast, a negative interaction effect between the two variables would mean that building upon knowledge previously acquired through international collaboration is an effective substitute for knowledge integration through direct international collaboration.

We also include several control variables which may drive the impact of inventions. It has been well-documented that larger teams lead to better innovations, and we need to make sure our findings are not driven just by this. We therefore include *Team size*, which is a categorical variable that takes a value of 1 for a sole inventor; a value of 2 if an inventor is part of a small team of two to three inventors; a value of 3 if an inventor was part of a team of four to six inventors, and a value of 4, otherwise. Four other team-level variables, based on the track records of the inventors, are included in the models to account for inventor-level heterogeneity which may drive the impact of patents. Previous literature has shown that the professional experience of the inventors can influence not only the impact of their patents, but also, their propensity to form new collaborative ties (Lee, 2010). We therefore control for the experiences of the inventors listed on each patent, in terms of average number of years that have elapsed since each of the team member's first USPTO patent (*Inventor age*) and the average number of patents that they have cumulatively earned during this time (*Inventor experience*). The third variable, *Collaborators*, counts of the average number of distinct inventors that had previously collaborated with the focal inventor. It is included as a control because this variable has also been shown to affect the impact of patents (Lee, 2010). The last inventor-level variable controls for the breadth of the team of inventors previous patents, which can influence their ability to capture knowledge that diverges from what they already know (Banerjee and Campbell, 2009). We operationalize this variable by first defining pi as the proportion of the team's previous patents that were in the three-digit technological class i. *Portfolio diversity* is then calculated as follows:

$$1-\sum_{i} p_i^{\,2}$$

At the subsidiary-level, two control variables are included to account for differences between subsidiaries of the same MNC. These capture the subsidiary's experience in terms of number years it was active in R&D (*Subsidiary age*) and the number of patents cumulatively earned by the subsidiaries during this time (*Subsidiary experience*). These subsidiary differences are important to control for because they have been shown to vary the impact of patents (Phene and Almeida, 2003). Additionally, over time, the mandate of subsidiaries could change, which may ultimately influence the type of R&D that is conducted.

Other variables that can also influence the forward citations that a patent receives are as follows. Firstly, the number of *Claims* in a patent is related to the number of novel features contained in the patented invention, which reflects the scope or breadth of protection. As the number of claims has been shown to be highly correlated with a patent's impact (Lanjouw and Schankerman, 2004), it is included as a control variable. Secondly, we also control for the differences in citation propensities across different technological classes using the variables *Mean technology* and *Variance technology* (Fleming, 2001). For each patent in technological class C, and which was applied for in year y, *Mean technology* is defined as the average number of forward citations that all USPTO patents with technological class c and which were applied for in year y received, and *Variance technology* is the variance of these citations. Finally, two sets of dummy variables are included to account for differences across time and geographies. Since, younger patents have a shorter time frame during which they can accumulate citations, year dummies are included in all models. Secondly, although we separate the sample of emerging economy patents and advanced economy patents, substantial differences between countries categorized by these broad groups are anticipated. Hence, all the regressions include country dummies. The descriptive statistics and correlation matrix are presented in Table 2.

Insert Table 2 about here

Both dependent variables, Impact and Internalization, are count variables. A count model, such as a Poisson regression, should be appropriate. However, Poisson regressions assume that the variance and the mean of the dependent variable are equal, whereas citation data is usually over-dispersed. We therefore implement quasi-maximum Poisson regressions with firm fixed-effects, which allow for over-dispersion, and also overcome the limitations of other count models, such as the conditional fixed-effects negative binomial regression (Allison and Waterman, 2002). In all the models, standard errors are clustered by firm.

4. The enduring effect of international collaboration on the impact of innovations by foreign inventors

4.1 The effect of cross-country collaboration on the impact of patents

We begin our empirical analysis of direct and long-term effects of cross-country collaboration on the impact of patents by employing the full sample of patents assigned to the 238 MNCs. The results of the quasi-maximum likelihood Poisson regression are displayed in Table 3. Column 1 examines the extent to which patents resulting directly from cross-country collaboration are of superior quality. This is a question that has been studied before, but serves as a useful benchmark against which we then compare our subsequent results. As column 1 in Table 3 demonstrates, we find strong evidence ($b = 0.194$, $p < 0.001$) that patents which feature inventors from multiple countries have a higher impact than patents where the inventors are all located in the same subsidiary. In this column, 50 observations pertaining to 50 MNCs were dropped because there was only a single observation per firm, and a further 8 observations pertaining to 3 MNCs were dropped because all of the outcomes of each firm were zero. To account for the dropped observations, the analysis was repeated using an unconditional fixed effects negative binomial regression (Allison and Waterman, 2002). The results, which are not displayed in Table 3, remained overall consistent with those presented.

Insert Table 3 about here

The more novel question is not whether international collaboration leads directly to better innovations, but whether it also improves an inventor's ability to generate better innovations in the future, even if those are purely local innovations that do not depend on foreign collaboration. Column 2 isolates the 17,321 patents which were developed wholly in the subsidiaries (i.e., *Cross-country* =0), of which 17,269 are retained in the regression. The positive and significant ($p < 0.001$) coefficient on *Prior cross-country* indicates that domestic patents by a team containing at least one inventor that has collaborated internationally in the past are expected to receive 11.74% more citations than teams without this experience. Thus, inventors from foreign subsidiaries who collaborated internationally in the past are still capable of creating more valuable patents even when they join a local team.

To examine the moderating effect of *Prior cross-country* on *Cross-country* collaboration, we go back to our original sample which is composed of both of collaborative and non-collaborative patents. Column 3 shows that there is indeed a strong negative interaction effect between the two variables. In other words, indigenously building upon knowledge previously acquired through international collaboration is an effective substitute for knowledge integration through direct international collaboration. For example, when *Prior cross-country* = 0, patents that are developed by cross-country teams are expected to receive 28.02% more citations. In contrast, if at least one of the inventors collaborated internationally in the past, the positive effect of cross-country collaboration reduces, although it still remains positive. In this case (i.e., *Prior cross-country* = 1), patents with cross-county teams are expected to receive 7.57% more citations. Taken together, these results corroborate Hypothesis 1.

4.2 Examining the impact of patents by emerging and advanced economy inventors

In Table 4, we examine the effect of current and prior cross-country collaboration on the impact of patents. The table is separated into 6 columns, where the first 3 columns present these effects for the sample of emerging economy patents, and the latter 3 columns for the sample of advanced economy patents. All six columns are estimated using quasi-maximum likelihood Poisson regressions, with standard errors clustered at the firm level. Column 1 examines how cross-country collaboration between emerging economy inventors and inventors from other subsidiaries influences a patent's impact. We test this effect on the full sample of emerging economy patents. The emerging economy sample comprises of 2595 patents that are assigned to 83 MNCs. In Column 1, 25 MNCs with single observations are automatically dropped from the, and a further 5 MNCs with a total of 13 patents are also dropped because of all zero outcomes. The coefficient on Cross-country is insignificant in this model.

Next, in Column 2, we isolate patents which were conducted wholly in emerging economies (i.e., patents which feature no cross-country collaboration). We do so in order to test whether inventors who have collaborated internationally in the past are capable of creating high-impact patents if they join domestic teams. In other words, we are essentially testing whether or not there is an enduring positive effect of cross-country collaboration. In our sample, there are a total of 1264 emerging economy patents assigned to subsidiaries of 46 MNCs which are developed wholly in the emerging economy subsidiaries. Of these, 1248 patents assigned to 31 MNCs are retained in the regression. The results in Column 2 indicate that emerging economy patents which were developed by at least one inventor who had collaborated internationally in the patents are expected to have an impact that is 36.75% higher; a result which is significant at the alpha-level of 0.05.

Finally, we examine the interaction effect between prior and current cross-country collaboration. It is possible for the positive effect of cross-country collaboration to decrease if the emerging economy inventors collaborated internationally before, since prior experience with cross-country collaboration allows inventors to continue to conduct higher quality inventions on their own. In this case, we would expect the interaction term to be negative. To examine the moderating effect of prior cross-country ties on cross-country collaboration, we revert back to our original sample that comprises both collaborative and non-collaborative patents. The results, in Column 3, show that there is indeed a negative and significant interaction effect between the two variables ($p < 0.001$).

Insert Table 4 about here

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In column 4-6 of Table 4, we repeat the same analysis for the sample of advanced economy patents. First, Column 4 examines the effect of cross-country collaboration for the full sample of patents. The advanced economy sample comprises of 24,112 patents assigned to 226 MNCs; of which 24,061 patents are retained in the regression in Column 4. The coefficient on Cross-country in Column 4 is positive and significant ($b= 0.191$, $p < 0.001$).

Column 5 examines the effect of prior cross-country collaboration for the sample of 16,057 advanced economy patents— assigned to subsidiaries of 189 MNC – in which inventors from these subsidiaries do not collaborate internationally. A total of 49 patents assigned to 47 MNCs are dropped from the specification because of either all zero outcomes or single observations per firm. The coefficient on prior cross-country in Column 5 indicates that domestic teams with at least one inventor who had collaborated internationally in the past generate patents that receive 10.74% more citations ($p < 0.01$). Put differently, focusing solely on the direct outcomes of cross-border collaboration underemphasizes its long-term benefits, as these inventors more markedly enhance the performance of inventions created by domestic teams. Lastly, the negative coefficient on the interaction term in Column 6 suggests that prior cross-country collaboration negatively moderates current cross-country collaboration, an effect which is significant at $p < 0.05$.

5. International collaboration as a means of knowledge internalization

Table 5 reports the effect of cross-country collaboration on *Internalization*. Only patents with components that a subsidiary is unfamiliar with are retained in these regressions in order to analyse the extent to which a subsidiary is able to internalize new knowledge. We find that 79.11% of the patents in our sample are in technological subclasses that have not been previously used by the subsidiary. The regression models also include an additional control variable, *Subsequent patents*, which is a dummy variable that takes a value of 1 if the subsidiary applied for at least 1 patent in the five years following the focal patent's application date, and zero otherwise. This is an important control variable because the dependent variable can take a value of zero if the subsidiary did not develop any patents, which is different from a subsidiary being unable to internalize new knowledge. A final important difference is that this part of the analysis also includes technology dummies, which are based on the two-digit technological subcategory of each patent (Hall et al., 2001, Jaffe and Trajtenberg, 2002). Technology dummies are included in this model to account for the differences in patenting propensities across different technologies. This was unnecessary in the previous specifications where the dependent variable was Impact, since *Mean technology* and *Variance technology* accounted for the differences in citation propensities across technologies (Fleming, 2001).

Insert Table 5 about here

Table 5 is separated into three columns, where the first column examines the effect of cross-country collaboration for the sample of patents, and the next two columns examine its effect for the emerging and advanced economy patents, respectively. In Column 1, a total of 364 patents were dropped because of either all zero outcomes, or single observations per MNC. The results suggest that the expected value for *Internalization* is 9.43% ($p < 0.05$) less when patents feature cross-country collaboration. This negative relationship between cross-country collaboration and internalization is the opposite of the relationship postulated in Hypothesis 2. The relationship remains negative and significant ($p < 0.05$) in Columns 2 and 3 where we examine the effect of cross-country collaboration separately for the emerging economy sample and the advanced economy sample.

6. Further analysis

6.1 The propensity of domestic tie formation

The results so far have indicated that international collaboration has a lasting positive effect on inventors from the foreign subsidiaries. However, the same effects do not translate to innovations that are conducted by domestic teams in the subsidiaries. In this section, we provide one explanation for why this could be the case. Specifically, we examine if inventors who collaborated internationally in the past are more likely to collaborate internationally again in current innovations. To implement this analysis, we expand our focal dataset such that there is one observation per patent per foreign inventor. Therefore, unit of analysis is the patent-inventor which yields 53,046 observations.

The dependent variable, *domestic team*, is a binary integer that takes a value of 1 if all the inventors that are listed on a patent were from the same subsidiary and takes a value of 0 otherwise. The main explanatory variable is *prior foreign tie*, which takes a value of 1 if an inventor collaborated internationally on a previous patent and a value of 0 otherwise. We use historical data on the inventor to look at the relationship between prior international collaboration and current collaboration to account for right-censoring in our data. An additional control variable is included in these regressions to account for the number of co-inventors that the focal inventor has collaborated with in the past.

Insert Table 6 here

The results, which are displayed in Table 6, are separated into 3 columns. Column 1 depicts the full sample, and shows that inventors from foreign subsidiaries who have collaborated internationally in the past are 79.61% less likely to conduct R&D with domestic-only team. Next, Columns 2 and 3 separate the emerging economy and the advanced economy patents, respectively. The results show that the likelihood of joining a domestic-only team decreases by 61.13% and 80.64% for inventors from emerging economy and advanced economy subsidiary who have formed an international tie in the past. Several of the control variables are also noteworthy in distinguishing between inventors who are more likely to join domestic teams. For example, foreign inventors who have more patenting experience and those who have collaborated more extensively are more likely to join a domestic team.

6.2 Instrumental variable regressions

International teams could be assigned to some projects that are perceived to generate higher returns in comparison to others. In these cases, international collaboration would not lead to high impact patents, but rather, they will be the outcome of inventions that are anticipated to be valuable. We examine the direction of causation between cross-country collaboration and the impact of patents using a two-stage regression. In the first equation, the potentially endogenous variable (i.e., *Cross-country*) is the dependent variable in a regression which contains the instrumental variables and all other independent (control) variables. In the second equation, the predicted value of cross-country collaboration, along with all other control variables, are placed in a regression, where the dependent variable measures the patent's impact.

Two instrumental variables are developed. The first variable is the share of inventors, located in other subsidiaries, who have patented in the same three-digit technological class as the focal patent during the past five years. This variable is expected to be highly correlated with Cross-country collaboration, but have no influence on the outcome of the R&D endeavour. Cuijpers, Guenter and Hussinger (2011) use the share of R&D employees outside the R&D department as an instrument for collaboration because the allocation of R&D employees across different departments is assumed to foster inter-departmental innovation collaboration, but to not influence project delays and project terminations. The second instrumental variable is the propensity to collaborate internationally, and is measured as the frequency probability that a patent assigned to any firm headquartered in the U.S involves cross-country collaboration. It is calculated as follows. For each patent in our sample in technological class *i*, and which was applied for in year *j*, we retrieve all patents that are applied for by US firms that have the same class (*i*), and which were applied for in the previous year (*j-1*). The variable is then measured as percentage of these patents which involve cross-country collaboration. We expect that patents in our dataset with technological classes that generally depict higher collaboration propensities will more likely feature cross-country teams than other patents.

Insert Table 7 about here

Table 7 displays the results of a two-stage least square regression (Wooldridge, 2002). Since *Impact* is a count variable, which may be inappropriate for an OLS regression, we standardize the variable based on the citation counts of all USPTO patents, and not just those in our dataset; taking a normal distribution within any year-technology combination in the patent database. A unique advantage of normalizing *Impact* in this way is that it allows one to compare patents from different years. We measure technology at the level of two-digit technology subcategory as defined by Jaffe and Trajtenberg (2002). In the table, Column 1 displays the results of first-stage regression, where the dependent variable is *Cross-country*. The coefficients on the two instruments are both positive and significant ($p < 0.001$). Several key statistics confirm the validity of the instruments. First, the F-test for the joint significance of the excluded instruments is significant at $p < 0.001$, rejecting the hypothesis that the instruments are weak. Second, the Sargan test is insignificant ($p > 0.4$), which verifies that the excluded instruments used are valid in that they do not correlate with the error term. The coefficient on Cross-country in Columns 2, which presents the second stage results, is positive and significant ($p < 0.01$). Finally, we repeat the instrumental variable regression by including *Prior cross-country* collaboration into the model as an exogenous variable, and its interaction with *Cross-country* as a second endogenous variable. The results, presented in Column 3, are consistent with our main findings.

In our analysis, we do not use instrumental variables to predict *Prior cross-country* as there is a time lag between when that activity took place and the patents that we observe; which minimizes the need for a two-stage regression in order to establish causality. For similar reasons, we do not use an instrumental variable regression to predict the effect of *Cross-country* on *Internalization* because the dependent variable in this case is calculated based on subsequent patenting.

7. Conclusions

Previous literature on MNCs has extensively discussed the importance of the firm's internal structure for the development of new capabilities (e.g., Bartlett and Ghoshal, 1989; Gupta and Govindarajan, 1991; Goold, Campbell and Alexander, 1994). In this paper, we also focus on the MNC's internal structure to examine if cross-country ties between geographically dispersed subsidiaries can improve inventor performance in the long-term, and if these ties can also promote the internalization of new capabilities by the subsidiaries. The results of our empirical analyses suggest that inventors who have collaborated internationally in the past can continue to generate high impact innovations subsequently, even if they later join a domestic team. An interesting question-- and potential avenue for future research-- that spawns from our findings is whether or not the positive affect of prior international collaboration decays over time. In other words, do inventors need to refresh cross-country ties after a certain period of time in order to keep generating valuable innovations?

To the extent that international collaboration on R&D builds new capabilities at the level of the individual, these are unlikely to branch out and broaden the capabilities at the level of the subsidiaries. In stark contrast, new technologies that a subsidiary is exposed to when its inventors collaborate internationally are less likely than new technologies that were initially developed by domestic teams to be internalized by the subsidiary indigenously. A possible explanation that we find empirical support for is that inventors who have previously collaborated internationally are less likely to join domestic teams during subsequent R&D activities, which can constrain knowledge that they accumulate from flowing within the subsidiary. As knowledge creation and sharing across regional boundaries is of central importance for MNCs (Bartlett and Ghoshal, 1989), it would be interesting for future studies to examine the relationship between the overall structure of the MNC and the long-term benefits. For example, is there a difference between MNCs that feature a decentralized corporate structure versus those with a centralized structure in the extent to which their subsidiaries can internalize new knowledge that is generated through cross-country collaboration?

One could not neglect that there could be other viable explanations for why we do not observe the integration of new capabilities that are introduced by certain inventors. For instance, domestic teams in foreign subsidiaries may have a different mandate than teams who collaborate internationally, differentiating the type of R&D that they each conduct. However, if these subsidiaries were to construct new capabilities, they could possibly do so internally, by assigning inventors with foreign experience to domestic teams. Prior empirical studies have already shown that firms can create new capabilities not only by reallocating resources, but by also reallocating human capital (e.g. Banerjee and Campbell, 2009). While the focus of this paper was on how new capabilities can be developed internally within the MNC, external inter-organizational relationships, such as mergers and acquisitions are also important mechanisms for capability building (Makri, Hitt and Lane, 2010).

By employing data on subsidiaries of US MNCs in 43 countries, our study also articulates the variance in the effect of international collaboration in different locations. We pondered whether cross-country collaboration can yield the same benefits for emerging economy subsidiaries as it does for advanced economy subsidiaries. On the one hand, prior literature has shown that international collaboration can overcome the larger geographic and cultural distances that separate emerging economies from the mass of their affiliates, which are often located in the Western nations (Flores and Aguilera, 2007). On the other hand, emerging economy subsidiaries are typically younger, and may have not yet accumulated the knowledge stock nor shared sufficient past experiences with their affiliates that would allow them to absorb geographically distant knowledge. By distinguishing between emerging economy subsidiaries and advanced economy subsidiaries, we were able to show that the effect international collaboration was similar in both contexts. Specifically, there was a long-term effect cross-country collaboration on inventors from both subsidiaries, but the knowledge that was generated during these endeavours was less likely to be internalized by the subsidiaries. This finding has important implications for managers and policy-makers. Establishing R&D subsidiaries in foreign countries requires the subsidiaries have sufficient capabilities to innovate. One mechanism that can help subsidiaries – and particularly emerging economy subsidiaries – construct new capabilities is international collaboration. However, simply investing in costly inter-unit ties does not, on its own, suffice. To take full advantage of the new capabilities that they are exposed to, and to translate them into subsidiary-level capabilities, the foreign subsidiaries need to devise a way to internalize and build on the knowledge.

Finally, in all our empirical models, we controlled for differences between subsidiaries by including country-fixed effects. We did so in order to assess unambiguously the long-term effects of cross-country collaboration on inventive performance in the same subsidiary that instigated these ties. Future research may wish to relax this control variable in order to examine how unique characteristics of different subsidiaries in an MNC affect capability development. An interesting question that builds on our study would be to examine how different modes of international expansion, like greenfield entries versus acquisitions, affect subsidiary performance (Vermeulen and Barkema, 2001).

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Table 1: Patenting trends by foreign subsidiaries of US semiconductor MNCs

Emerging Economies				Advanced Economies			
	Subsidiaries	Patents	% Cross-country		Subsidiaries	Patents	% Cross-country
India	34	1158	51%	Japan	65	5013	20%
Malaysia	22	476	39%	France	58	3518	24%
China	38	260	61%	UK	101	3145	33%
Philippines	7	155	54%	Germany	82	2995	35%
Russia	10	115	67%	Israel	48	2090	34%
Hungary	1	86	34%	Canada	74	1887	43%
Thailand	7	70	29%	Switzerland	30	826	50%
Czech Rep.	8	53	55%	Netherlands	37	758	54%
Brazil	8	39	72%	Singapore	39	656	39%
Mexico	11	37	62%	Italy	37	628	40%
Poland	4	35	49%	Taiwan	49	490	42%
Ukraine	4	26	62%	S. Korea	24	405	43%
Argentina	7	22	73%	Ireland	25	367	37%
Romania	5	19	89%	Belgium	24	249	71%
Egypt	5	14	64%	Denmark	15	206	39%
				Australia	22	204	53%
				Sweden	21	149	50%
				Spain	14	130	61%
				Hong Kong	23	101	60%
				Norway	12	93	60%
				Iceland	6	54	54%
				New	10	45	56%
				Austria	10	40	65%
				Finland	13	38	47%
				Greece	5	15	93%
				UAE	2	10	100%

Table 2: Correlation matrix and descriptive statistics

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Impact	1														
2	Internalize (Subclass)	0.05	1													
3	Internalize (Class)	0.05	0.43	1												
4	Cross-country	0.09	-0.04	-0.1	1											
5	Prior cross country	0.01	0.01	-0.02	0.35	1										
6	Team	0.05	0.03	0.02	0.5	0.19	1									
7	Log (Inventor age)	-0.03	0.03	0.03	0.19	0.36	0.19	1								
8	Log (Inventor experience)	-0.05	0.02	0.06	0.01	0.53	0	0.61	1							
9	Log (Collaborators)	-0.07	0.12	0.16	-0.06	0.34	0.17	0.45	0.55	1						
10	Portfolio diversity	-0.05	0.06	0.04	-0.02	0.33	0	0.41	0.55	0.67	1					
11	Log (Subsidiary age)	-0.05	0.23	0.23	-0.03	0.07	0.1	0.15	0.09	0.28	0.2	1				
12	Log (Subsidiary experience)	-0.08	0.32	0.38	-0.18	-0.01	0.03	0.15	0.15	0.35	0.25	0.78	1			
13	Log (Claims)	-0.01	0.04	0	0.14	0.08	0.09	0.01	0.04	0.01	0.02	-0.05	-0.06	1		
14	Mean technology	0.44	0.02	0.08	0	-0.06	-0.03	-0.09	-0.1	-0.13	-0.11	-0.08	-0.1	-0.21	1	
15	Variance technology	0.35	0.02	0.06	0.01	-0.03	0	-0.06	-0.08	-0.08	-0.07	-0.03	-0.04	-0.14	0.84	1
	Mean	8.05	2.2	16.36	0.35	0.33	2.31	1.32	1.18	0.94	0.17	1.98	1.9	2.72	4.86	118.37
	S.D.	15.82	4.7	28.61	0.48	0.47	0.89	0.89	1.13	0.86	0.23	0.99	0.81	0.65	6.62	324.43
	Min	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Max	435	56	246	1	1	4	3.58	6.12	4.03	0.9	3.26	3.31	5.3	67.44	8395

Table 3: Quasi Maximum-Likelihood Poisson estimates of the effect of cross-country collaboration on Impact

	(1) Full Sample	(2) Domestic Sample	(3) Full Sample
Cross-country	0.194***		0.247***
	(0.037)		(0.029)
Prior cross-country		0.111***	0.130**
		(0.033)	(0.042)
Cross-country *x* Prior cross-country			-0.174**
			(0.067)
Team size	0.052***	0.033*	0.053***
	(0.014)	(0.014)	(0.014)
Log(Inventor age)	-0.007	-0.015	-0.013
	(0.014)	(0.017)	(0.016)
Log(Inventor experience)	0.003	-0.005	-0.001
	(0.024)	(0.030)	(0.026)
Collaborators	-0.016	0.001	-0.016
	(0.017)	(0.013)	(0.018)
Portfolio diversity	-0.015	-0.029	-0.026
	(0.063)	(0.079)	(0.063)
Log (Subsidiary age)	-0.001	0.026	-0.002
	(0.022)	(0.031)	(0.023)
Log (Subsidiary experience)	-0.120**	-0.112*	-0.115**
	(0.040)	(0.057)	(0.040)
Log(Claims)	0.241***	0.241***	0.240***
	(0.016)	(0.021)	(0.016)
Mean technology	0.055***	0.050***	0.055***
	(0.004)	(0.006)	(0.004)
Variance technology (/100)	-0.026***	-0.020***	-0.027***
	(0.003)	(0.004)	(0.003)
Year dummies	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes
Observations	26647	17269	26647
MNCs	185	145	185
Log-Likelihood	-151015.029	-87670.623	-150844.012

Notes: Standard errors in parentheses + p<0.10, * p<0.05, ** p<0.01, *** p<0.001. Year and country fixed-effects included in all models.

Table 4: QML Poisson estimates of the effect of cross-country collaboration in Emerging and Advanced economy subsidiaries.

	(1)	(2)	(3)	(4)	(5)	(6)
	Emerging economy patents			Advanced economy patents		
	Full	Domestic	Full	Full	Domestic	Full Sample
Cross-country	0.149		0.257+	0.191***		0.241***
	(0.119)		(0.133)	(0.037)		(0.030)
Prior cross-country		0.313*	0.315**		0.102**	0.120**
		(0.150)	(0.120)		(0.034)	(0.044)
Cross-country x Prior cross-country			-0.380**			-0.161*
			(0.137)			(0.067)
Team size	0.075	0.117*	0.074	0.050***	0.032*	0.052***
	(0.066)	(0.057)	(0.067)	(0.014)	(0.015)	(0.015)
Log(Inventor age)	0.024	0.241	0.010	-0.007	-0.016	-0.012
	(0.065)	(0.148)	(0.062)	(0.015)	(0.017)	(0.017)
Log(Inventor experience)	0.004	-0.077	0.007	0.001	-0.004	-0.003
	(0.031)	(0.116)	(0.045)	(0.027)	(0.031)	(0.028)
Collaborators	-0.089	0.020	-0.108	-0.016	-0.004	-0.016
	(0.090)	(0.122)	(0.098)	(0.018)	(0.014)	(0.018)
Portfolio diversity	-0.280	-0.311	-0.245	-0.004	-0.023	-0.016
	(0.246)	(0.304)	(0.247)	(0.073)	(0.079)	(0.073)
Log (Subsidiary age)	-0.065	-0.101	-0.063	-0.004	0.026	-0.005
	(0.063)	(0.067)	(0.064)	(0.026)	(0.036)	(0.027)
Log (Subsidiary experience)	0.038	-0.232	0.034	-0.112**	-0.096	-0.107**
	(0.155)	(0.208)	(0.162)	(0.041)	(0.060)	(0.041)
Log(Claims)	0.232***	0.379**	0.233***	0.240***	0.239***	0.240***
	(0.062)	(0.116)	(0.062)	(0.017)	(0.020)	(0.017)
Mean technology	0.095***	0.048	0.094***	0.055***	0.050***	0.055***
	(0.020)	(0.045)	(0.020)	(0.004)	(0.006)	(0.004)
Variance technology (/100)	-0.079***	0.024	-0.080***	-0.026***	-0.020***	-0.026***
	(0.015)	(0.104)	(0.015)	(0.003)	(0.004)	(0.003)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2557	1248	2557	24061	16008	24061
MNCs	52	31	52	178	142	178
Log-likelihood	-9561.934	-3526.950	-9530.142	-140366.671	-83493.479	-140227.278

Notes: Standard errors in parentheses: + p< 0.10, * p< 0.05, ** p< 0.01, *** p< 0.001

Table 5: Quasi maximum-likelihood Poisson regressions estimating the effect of cross-country collaboration on internalization

	Full Sample	Emerging economy patents	Advanced economy patents
Cross-country	-0.099*	-0.184*	-0.083*
	(0.046)	(0.081)	(0.039)
Team size	0.020	-0.005	0.021
	(0.019)	(0.050)	(0.019)
Log(Inventor age)	-0.025	-0.039	-0.025
	(0.025)	(0.099)	(0.026)
Log(Inventor experience)	-0.005	0.027	0.000
	(0.029)	(0.068)	(0.029)
Log(Collaborators)	0.102**	0.072	0.096*
	(0.039)	(0.086)	(0.041)
Portfolio diversity	-0.133	-0.128	-0.111
	(0.149)	(0.412)	(0.146)
Log (Subsidiary age)	-0.091+	0.082	-0.098*
	(0.047)	(0.127)	(0.045)
Log (Subsidiary experience)	0.853***	-0.050	0.836***
	(0.077)	(0.162)	(0.084)
Log(Claims)	0.118***	-0.101+	0.130***
	(0.028)	(0.053)	(0.031)
Mean technology	0.052***	0.166+	0.051***
	(0.007)	(0.095)	(0.007)
Variance technology (/100)	-0.028***	-0.810***	-0.028**
	(0.008)	(0.234)	(0.010)
Subsequent patents	26.574***	18.342***	28.720***
	(1.044)	(0.553)	(1.217)
Technology dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes
Observations	20765	2283	18382
MNCs	126	36	120
Log-likelihood	-37210.055	-3360.580	-33565.409

Notes: Standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 6: Logistic regressions estimating the likelihood of joining a domestic team

	(1) Full Sample	(2) Emerging Economy	(3) Advanced Economy
Prior Cross Country	-1.590***	-0.945***	-1.642***
	(0.030)	(0.111)	(0.032)
Team size	-1.591***	-1.871***	-1.583***
	(0.023)	(0.094)	(0.025)
Log(Inventor age)	-0.791***	-2.611***	-0.654***
	(0.022)	(0.102)	(0.023)
Log(Inventor experience)	0.156***	0.357***	0.129***
	(0.016)	(0.074)	(0.017)
Log(Collaborators)	0.874***	1.123***	0.869***
	(0.024)	(0.092)	(0.026)
Portfolio diversity	-0.619***	-0.729*	-0.655***
	(0.090)	(0.359)	(0.095)
Log (Subsidiary age)	0.194***	0.215*	0.163***
	(0.029)	(0.094)	(0.032)
Log (Subsidiary experience)	0.557***	0.505**	0.572***
	(0.041)	(0.194)	(0.045)
Log(Claims)	-0.350***	-0.299***	-0.354***
	(0.021)	(0.085)	(0.023)
Mean technology	-0.055***	-0.134+	-0.053***
	(0.007)	(0.074)	(0.007)
Variance technology (/100)	0.038***	-0.008	0.037***
	(0.009)	(0.218)	(0.009)
Year dummies	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes
Observations	52330	4870	47039
MNCs	238	82	226
Log-Likelihood	-19804.251	-1636.692	-17423.823

Standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 7: Two-Stage OLS estimating the effect of Cross-country collaboration on Normalized Impact

	(1) First Stage	(2) Second Stage	(3) Second Stage
Cross-country		1.371**	2.986**
		(0.446)	(1.127)
Prior cross-country			0.787**
			(0.283)
Cross-country *x* Prior cross-country			-2.754*
			(1.086)
Team size	0.242***	-0.212+	-0.264+
	(0.003)	(0.110)	(0.139)
Log(Inventor age)	0.108***	-0.062	-0.209+
	(0.003)	(0.052)	(0.113)
Log(Inventor experience)	-0.001	-0.008	0.149*
	(0.003)	(0.018)	(0.072)
Log(Collaborators)	-0.116***	0.123*	0.213*
	(0.004)	(0.057)	(0.097)
Portfolio diversity	0.122***	-0.327**	-0.487**
	(0.014)	(0.100)	(0.150)
Log (Subsidiary age)	0.021***	0.016	0.008
	(0.005)	(0.031)	(0.034)
Log (Subsidiary experience)	-0.123***	0.086	0.141
	(0.007)	(0.076)	(0.099)
Log(Claims)	0.047***	0.194***	0.149**
	(0.004)	(0.032)	(0.048)
Mean technology	-0.000	0.006	0.008
	(0.001)	(0.005)	(0.005)
Variance technology	0.001	0.014+	0.008
	(0.001)	(0.008)	(0.009)
Instrumental variables:			
Share of inventors outside the subsidiary	0.094***		
	(0.009)		
Collaboration propensity	0.867***		
	(0.113)		
Country dummies	Yes	Yes	Yes
Constant	-0.335***	0.481**	0.316*
	(0.020)	(0.159)	(0.131)
Observations	26707	26707	26707
MNCs	238	238	238
R^2	0.331	0.012	0.007

Notes: Standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Figure 1: Patterns of international collaboration across countries