# INNOVATION NETWORKS IN PERIPHERAL ECONOMIES


## Abstract

This paper explores a topic that has not received much attention in the literature - the global connectivity of peripheral economy innovation systems. Innovation networks encompass two different levels of analysis: the organizational level (e.g. firms and research organizations) and the individual level (i.e. inventors). Exploring the global connections of both firms and individual inventors, we disentangle both levels and challenge the assumption that innovation networks at the level of the organization and at the level of the individual have similar properties. Our results suggest that there are fundamental differences between these two networks, at least for peripheral economies. At the organizational level, we found that subsidiaries with parents in highly innovative core economies may provide the local economy with limited connectivity benefits. Conversely, at the personal level, innovative interactions with inventors based in highly innovative core economies may provide the local economy with substantial connectivity benefits to global innovation networks. We believe these insights may be relevant to other peripheral contexts, and may shed light on the little known topic of how firms from peripheral economies source their knowledge and what are the collaborative patterns of local inventors.

# INNOVATION NETWORKS IN PERIPHERAL ECONOMIES

## INTRODUCTION

As more firms disaggregate their value chains across borders, including R&D activities, national systems of innovation (NSI) are increasingly interconnected in global innovation networks (Narula & Guimón, 2010). Locations outside core OECD countries, trying to catch-up technologically with more developed countries, seek to attract R&D-performing MNEs to their territories, as a gap-bridging mechanism. Simultaneously, domestic firms from non-core locations have been pursuing internationalization, often beginning their expansion in regions with historical and cultural ties to their home countries (Guillén, 2005; Jaklić & Svetličič, 2003).

The concept of "peripheral" economy is not new but gained traction in recent literature, filling an intermediate category (J. Molero, 1995) in the rigid developed vs. developing economy dichotomy. Molero (1998) defines such group as displaying less developed productive structures than the core, less internationalization via outward FDI, modest patenting and innovation systems marked by medium-low R&D effort. Benito and Narula (2008) provide a complementary definition - peripheral economies: are not significant destinations for or home to many MNEs; engage in relatively little trade in intermediate and manufactured goods; contribute relatively little to innovation/scientific progress; are weakly linked or accessible physically to the core; do not play significant decision-making roles in supranational organizations; and do not share a significant number of formal institutions with core countries. In parallel, these are relatively affluent economies, with per capita incomes significantly higher than emerging countries, but below the most developed ones. Some southern and eastern European countries are good examples (Benito and Narula, 2008; Liagouras, 2010; Narula and Guimón, 2010). We prefer peripheral "economy" to "country", as peripheral economies can exist within countries, when uneven levels of development occur across regions (e.g. Italy has a core north and a peripheral south).

Although this paper uses Portugal as an European peripheral economy example (Benito & Narula, 2008; Narula & Guimón, 2010), our sample includes firms and inventors in 35 countries (i.e. every patent linked to the Portuguese NSI through either one inventor or one assignee). By understanding the specificities of the Portuguese NSI, we highlight characteristics typical of other peripheral economies. NSI of peripheral economies are landscapes composed of a mix of domestic and multinational firms, drawing knowledge from both local and foreign inventors. Yet not much is known about the characteristics of those networks. Specifically, little work has been done to understand where firms from peripheral economies source their knowledge and how their innovation networks differ from those of MNEs from core economies. The differences between the activities of inventors in peripheral and leading economies also remains underexplored, especially concerning their degree of network connectivity with other inventors, in the same or other countries. This is the gap this paper tries to fill. Innovation networks include two levels of analysis: the networks of individual inventors and those of organizations (firms, universities, etc). The two levels are commingled because most commercial inventors are employed by and operate within organizations. This paper disentangles these two levels to examine how innovation networks in a peripheral economy differ from those in core economies.

The rest of the paper is structured as follows. Next, we review relevant literature. Then, the theoretical bases of our analysis and the hypotheses derived are developed. Subsequently, data and empirical methods are described. Finally, results and implications are discussed.

## LITERATURE REVIEW

### Peripheral Economies

MNEs spread their value adding activities geographically to take advantage of market opportunities and to exploit resources and capabilities specific to different locations (McCann & Mudambi, 2005; Mudambi, 2008). However, some countries that are spatially or economically on the periphery are less attractive destinations either due to their small market size or to scarce location advantages (Benito & Narula, 2008). Hence, the activities MNEs locate in peripheral regions are different and usually less integrated into their global operations (Manolopoulos, 2010; Manolopoulos, Papanastassiou, & Pearce, 2007; Tavares-Lehmann, 2008). As these authors note, "peripheral" does not mean "developing". The disadvantages of being peripheral apply to some "developed" countries whose characteristics result in them exhibiting lower levels of engagement in international business, when compared to "core" countries.

Periphery is not a new concept. Its roots can be traced to early works on the foundations of capitalism (Wallerstein, 1974) and dependency theory (Prebisch, 1962), which addressed the challenges of economic and technological catch-up for peripheral countries. Much of this early work involved a rather crude definition of the periphery, basing it on the realities of imperialism from the nineteenth century and earlier. By the last decades of the twentieth century, this research became outmoded and no longer useful to understand the nature of global interactions.

Although the criteria to label a country "peripheral" are broad, Benito and Narula (2008) emphasize the role of interdependence. For them, the critical difference between core and periphery is the degree of social, political and economic international integration in the world economy. Cross-border activity (like international trade) or vertical cross-border linkages do not necessarily qualify as interdependence; they are mere internationalization. The key to interdependence is reciprocity, which involves ongoing, mutual relationships between economic actors; the more unequal the relationships, the weaker the integration, and hence the peripheral status. Peripherality plays a role in determining the distribution of tasks between core and peripheral locations. For instance, the European automotive industry has a clear task distribution pattern. Central functions (R&D, global management, planning, marketing) and the production of luxury cars are located in the core European region that extends from England to northern Italy. The production of lower-end vehicles occurs usually in peripheral regions, like the Iberian Peninsula, Eastern Europe and Turkey (Evren, 2002).

**Peripheral regions and knowledge networks**

One way to reduce peripherality is to attract and embed MNEs' R&D activity. Since MNEs form internationally integrated networks within firms (Cantwell & Piscitello, 2000; McCann & Mudambi, 2005), the more MNE activity in the economy, the more integrated the economy is likely to be in different global networks. However, peripheral economies are not very attractive locations for MNE R&D activities, because their location advantages and absorptive capacity (Cohen & Levinthal, 1990) tend to be low. Entry of MNEs can also lead to 'crowding-out' or displacement of local firms' innovation activity and higher dependency on external players for technology development (Narula & Guimón, 2010). Recent literature implicitly or explicitly recognizes that the potential benefits derived from MNEs' innovative activities outweigh the costs. The current environment is one where governments try and attract MNEs (McCann & Mudambi, 2004). The most direct benefits are the creation of high-skill jobs and the increase in the innovation output of the country (although this will depend on the type of mandate of the subsidiary). There are also indirect benefits (Narula & Guimón, 2010), such as opening markets for domestic suppliers, spurring local companies to improve their productivity given increased competition (Liu, Siler, Wang, & Wei, 2000; Wei & Liu, 2006), and knowledge and technology spillovers. However, the types of R&D activities MNEs perform in peripheral locations are generally different from those performed in core locations (Pearce, 1999). Håkanson and Nobel (1993a, 1993b) identify five main motivations for MNE subsidiary location: market-driven, research-driven, politically motivated, production-support driven, and multi-motive. Other authors (Ambos, 2005; Ambos & Schlegelmilch, 2004; Chiesa, 1996) summarize these into two basic strategic motivations: demand-driven, leading to the establishment of "capability/knowledge-exploiting" R&D activities (e.g. adaptation of products/services to new markets), and supply-driven, leading to "capability/knowledge-augmenting" R&D activities (which seek to tap into sources of knowledge and resources available at a certain location). These motivations are summarized as competence-creating vs. competence-exploiting (Cantwell & Mudambi, 2005).

Though MNE subsidiaries with strong R&D mandates are the most attractive, they usually require locations with a rich resource base (Cantwell & Mudambi, 2000). Due to their disadvantage in technological capabilities *vis-à-vis* the core, peripheral economies tend to attract competence-exploiting, demand-driven R&D activities (Cantwell & Mudambi, 2000; Narula & Guimón, 2010). In line with this, Ambos and Ambos (2009) explored the location of R&D laboratories and found that out of 25 labs in non-core locations, only 5 had a capability-creating mandate. Competence-exploiting subsidiaries - the dominant type in Greece and in Portugal, according to Manolopoulos (2010) and Tavares-Lehmann (2008) - focus on routine replication and local adaptation, being thus unlikely to spark much innovation applicable beyond the local milieu (Cantwell and Mudambi, 2005). Hence, attracting MNEs to peripheral economies may have a limited impact on sparking high quality innovative activity in those economies.

This study is interested in revealing where firms source their knowledge in peripheral economies and how inventor networks in these economies differ from those in core locations. At the firm level there are, *a priori*, clear differences in knowledge-sourcing patterns between MNEs and purely local firms. MNEs are characterized by "multiple embeddedness" (Meyer, Mudambi, & Narula, 2011), being embedded in their home country contexts and in the context of each of their subsidiaries (Andersson & Forsgren, 1996). And their subsidiaries are, simultaneously, externally embedded in their host milieu and internally embedded within their parent organization network. This multiple embeddedness allows MNEs to integrate diverse knowledge sources and create value through "knowledge arbitrage". Henderson (2003) found that single-plant firms benefit more than multi-unit firms from local information spillovers derived from local concentration of other plants in the same industry. This implies that local and external environments are more important for domestic firms; MNEs can source knowledge from remote units and within the organization. It follows that the innovative activity of domestic firms is likely to rely more on local networks of inventors, while the networks of inventors of MNEs tend to be less local. Cantwell and Mudambi (2011) found that the propensity of MNE subsidiaries to source knowledge locally is even lower when the industry is locally concentrated, as this creates less opportunities for foreigners to find complementary knowledge in the local landscape.

Knowledge sourcing and collaboration patterns may vary also depending on regional characteristics. Munificent regions, with high levels of innovation, favor local collaboration, given the availability of local knowledge; conversely, firms in less-favorable locations may be compelled to source knowledge from more remote sources. Bathelt et al. (2004) launched the argument of "local buzz, global pipelines" to discuss the complementarity of tacit knowledge flows confined to the local milieu (the "buzz") and the extra-local exchange of codified knowledge (the "pipelines"). They argue that the availability of both (high levels of buzz and many pipelines) in a certain location provides firms with particular advantages. Other authors talk about "geographical proximity" and "organized proximity" (Torre & Rallet, 2005); as knowledge circulates through networks, firms do not necessarily require permanent co-location (geographical proximity) for interactive learning to occur. The existence of knowledge networks across regions or countries (organized proximity) allows firms to search non-locally for knowledge that is not available in their home region. Belussi et al. (2010) explored research networks in one of the most innovative regions of Italy and found a high propensity to establish local or national ties rather than transnational linkages to source knowledge. In turn, Boschma and Ter Wal (2007) explored the knowledge network of firms from a cluster located in a peripheral region (southern Italy) and found that firms having knowledge linkages with non-local firms had better innovation performance than those relying only on local relationships. This implies that firms in peripheral regions benefit from searching knowledge beyond the local milieu, even if they are located in a specialized cluster. Asheim and Isaksen (2002) found that external contacts, outside the local industrial milieu, are crucial for the innovation process of SMEs; too much reliance on local knowledge sources seems to be harmful for innovative capacity and can lead to a “technology trap” (Giuliani, 2010).

Specialized knowledge doesn’t flow freely, rather circulating within “epistemic communities”, networks of specialized individuals spanning different organizations; firms are excluded from important knowledge-sharing if they don’t belong to these knowledge networks (Lissoni, 2001). Lorenzen and Mudambi (2013) refer to pipelines as “organization-based linkages”, to distinguish them from “person-based linkages”. Incorporating a social network view, they argue that the impact of global linkages on the catch-up ability of clusters in emerging regions depends on those linkages’ network structure. Regarding motivations for collaborative R&D (an important part of these global linkages), they can be summarized into two main arguments: cost economizing/avoiding duplication of efforts, and engaging in R&D projects not related to core activities (Cantner & Graf, 2006; Hagedoorn, 1993; Teece, 1986). Hagedoorn and Wang (2012) explored the existence of complementarity or substitutability between internal and external R&D. The authors found complementarity at higher levels of in-house R&D investments, and substitutability at lower levels of in-house R&D. If firms in peripheral economies are expected to be less R&D intensive than core-region firms, the substitutability mechanism will operate; they are likely to choose either internal or external R&D, but rarely both. If they have shallow knowledge bases, it makes sense for them to contract-out R&D; it follows that peripheral region firms should have more linkages with non-local inventors than core region firms. The reversal of this argument is that inventors from core regions will have more non-local connectivity, since they will work both locally and collaborating with inventors in other countries.

## THEORY AND HYPOTHESES

As discussed in the literature review, multinationals are embedded in multiple contexts (Andersson & Forsgren, 1996; Meyer, et al., 2011), while domestic firms tend to rely more on the local context for knowledge sourcing (Henderson, 2003). MNEs have the ability to locate R&D activities in multiple locations, in order to tap into local pools of knowledge. Therefore they are less dependent on any single location. Although some MNEs may centralize their R&D laboratories in one place, it is reasonable to expect that MNEs will tend to have networks of inventors with larger geographical dispersion than purely domestic firms (see Image 1). In less developed cluster districts, pipelines to global production and innovation systems are typically built and maintained by MNE subsidiaries rather than domestic players (Lorenzen & Mudambi, 2013). We argue the same is true for peripheral regions. Relative to MNEs, domestic firms are likely to face significantly bigger obstacles to creating linkages to inventors in foreign locations. Based on the literature, we state the following as our baseline hypothesis:

*Hypothesis 1: In peripheral economies, MNEs' networks of inventors are more internationally dispersed than the networks of purely domestic firms.*

Innovation networks in clusters have been argued to be the outcome of both local exchange and global linkages. The local exchange of knowledge, tacit and otherwise, has long been documented (Jaffe, Trajtenberg, & Henderson, 1993). Additionally, there is evidence that innovation in firms as well as regions is stimulated by global linkages operationalized by "global networks held together by travel and virtual communications" (Amin & Cohendet, 2004). Integrating these two perspectives, it follows that both local "buzz" and global pipelines provide firms with an advantage in innovation (Bathelt, et al., 2004; Lorenzen & Mudambi, 2013).

MNEs headquartered in advanced market economies are likely to view peripheral economies from two perspectives. First, in the traditional international business view, they are locations where advanced-economy MNEs can exploit their home-base advantages (Kuemmerle, 1999). Second, they are likely to function as suppliers of lower-order "standardized" inputs into the larger innovative systems of their parents (Cantwell & Mudambi, 2011). This is because the innovation system in the peripheral economy is unlikely to have knowledge resources that can advance the explorative efforts of the advanced economy based MNE parent. Both of these innovative tasks involve innovative linkages with their parents' headquarters, but not with their parents' widely dispersed global innovation system. Firms headquartered in peripheral countries have access to local knowledge resources, which are relatively more limited. We argue that firms in these countries attempt to compensate for the lack of local knowledge inflows in their home locations by developing stronger "pipelines". Further, since their own domestic knowledge networks are relatively weak (Narula & Guimón, 2010), they are more likely to find knowledge resources in other peripheral economies that can aid them in their own explorative efforts. As a consequence, they are more likely to involve their peripheral-economy-based subsidiaries in global innovation networks. In short, a German MNE operating in Portugal either through a subsidiary or a locally based inventor is likely to be linked through its headquarters only to the German innovation network. On the other hand, an Indian MNE operating in Portugal is likely to be linked through its headquarters to the firm's global innovation network.

It follows from these arguments that, the more advanced the innovation system of an MNE's home economy, the more likely it is that its peripheral economy operations are linked mainly to the home innovation system. Conversely, MNEs with less advanced home innovation systems (i.e., those from peripheral economies), tend to have knowledge networks linked to global innovation systems. This implies that the knowledge networks of advanced economy firms in peripheral economies are geographically less dispersed (see Image 1). In contrast, the knowledge networks of peripheral economy firms in peripheral economies are geographically more dispersed.

*Hypothesis 2: In peripheral economies, knowledge linkages to MNEs from core innovative countries are associated with less dispersed organizational networks of inventors than to firms from less innovative countries.*

[Insert Image 1 about here]

Hypotheses 2 focuses on the relationship between the location of firms and the dispersion of inventor networks associated with those firms. We now proceed to examine the location of the inventors themselves and how that affects the connectivity of those inventors to global innovation networks. Inventors in any national innovation system are either based locally or based in foreign locations but employed by local organizations. We examine each of these two classes of inventors subsequently.

We first consider the more straightforward case, i.e. foreign-based inventors of local (peripheral economy) firms. Firms in peripheral regions seek knowledge from both local and non-local inventors, but they are likely to source the most complex, capability-driven, explorative knowledge (requiring the highest degree of collaboration) from core regions, given the shallow knowledge bases of peripheral milieus. It follows that inventors from core regions will be engaged in more international collaboration relationships than their colleagues from peripheral economies. Inventors based in core economies have access to wider innovation networks than those based in other peripheral economies, e.g., R&D employees of Portuguese firms based in Germany have access to more diverse innovation networks than those based in Angola.

Next we consider the case of locally-based inventors in a peripheral economy. As previously discussed, firms from core regions typically search for explorative knowledge either locally or in other core regions and usually go to peripheral regions in search of exploitative, cost-driven knowledge. While the inventors they hire in peripheral economies undertake mainly exploitative work, they are connected to inventors in the core economy of the parent firm who tend to undertake both exploitative and explorative activities. They collaborate with core economy-based inventors that have wide global innovation networks. Their linkages based personal relationships are likely to foster innovation that is 'emergent' in that it is "the product of creative individuals that are more focused on knowledge outcomes than firm performance outcomes" (Lorenzen and Mudambi, 2013: 508). As such, peripheral economy-based inventors of core economy firms have access to their employer's wider innovation network. In contrast, inventors in peripheral economies hired by local firms or based in other peripheral economies have access to inventors who are relatively isolated and whose own networks are relatively less diverse. Therefore, while they may undertake explorative activities, their personal relationships do not yield much richness in terms of geographical diversity.

The foregoing arguments allow us to state the following hypothesis:

*Hypothesis 3: For inventors associated with peripheral economy innovation systems, those located in peripheral economies have less dispersed innovation networks than those located in core innovative countries.*

## THE EMPIRICAL CONTEXT: PORTUGAL

### Portugal as a 'textbook' case of a peripheral (European) economy

Portugal is the empirical setting chosen to illustrate the processes underlying innovation networks in peripheral economies. Portugal can be considered a textbook case of an European peripheral economy, as the country displays all characteristics usually attributed to such economies, notably in terms of productive structure, degree of internationalization and international openness, foreign subsidiary roles, linkages among actors, innovation-related indicators, connectivity with the core, and organizational/institutional characteristics (Benito & Narula, 2008; José Molero, 1998; J. Molero, 1995). Compared to core EU economies, the Portuguese economy is marked by a low degree of internationalization, low relevance of high tech sectors, low weight of high tech exports, dominance of micro and SMEs – with low productivity and often offering non-tradable services (Simões & Godinho, 2011), and scarcity of indigenous MNEs. Portuguese business groups are latecomers in the internationalization process; Portugal has a degree of openness that is below that of other EU economies of similar size, both in the core and in the Southern and Eastern peripheries. Subsidiaries located in Portugal tend to have rationalized subsidiary roles that are specialized, export-oriented and characterized by reduced autonomy (Tavares-Lehmann, 2008).

As expected in a peripheral economy, linkages among actors are modest. The low degree of autonomy of foreign subsidiaries limits linkages with the Portuguese scientific and technological (S&T) system (Tavares-Lehmann, 2008). Foreign-owned subsidiaries in Portugal also tend to source less locally than their domestic counterparts. One of the reasons is the scarcity of suppliers that fulfill the standards foreign MNEs require, in quantity and quality. There seems to be, however, a positive time trend regarding such linkages (Tavares-Lehmann, 2008). The innovation-related indicators for Portugal are also typical of a peripheral economy.

**Literature on patents in Portugal**

Most studies (Godinho et al., 2004; Godinho et al., 2008, Godinho, 2009) show that Portugal is well below the OECD average in terms of patent indicators. Yet, there has been an acceleration in patent applications since 2000 (Godinho, 2009). The recent increase in international patenting is mainly driven by the business sector. Particularly active in filing patents internationally, notably in the USPTO, are subsidiaries of foreign MNEs and born globals (Godinho, et al., 2008). For high tech firms, most of them SME startups, patenting in the USPTO is a matter of reputation and "signaling" to potential partners and clients. MNE subsidiaries tend to centralize patenting processes, including patent applications, at HQs or at a central R&D base.

## DATA AND METHODOLOGY

### Data

Our empirical analysis is grounded on the study of the patenting activity involving Portuguese firms, Portuguese inventors, or both. We constructed a dataset with data obtained from the United States Patents and Trademark Office (USPTO). Previous works (e.g. Podolny & Stuart, 1995; Stuart & Podolny, 1996; Rosenkopf & Nerkar, 2001) have used patent citations as indicators of knowledge flows. Patent co-inventorship has been used to explore collaboration patterns of inventors (Ejermo & Karlsson, 2006). However, patent data has certain limitations (Archibugi, 1992; Pavitt, 1988), such as lack of consistent quality across national patent systems and uneven approval rates in different countries; for that reason it is recommended that datasets contain patents registered in one single patent institution (Archibugi & Coco, 2005). Another limitation is that patents are poor indicators of innovation output for sectors where most innovations go unpatented (Hu, 2012). The propensity to patent in a foreign system depends on many factors, but the most valuable inventions tend to be patented in the most important countries, particularly in the USPTO (Archibugi & Coco, 2005). USPTO, while it doesn't represent the entire innovation output of foreign countries, represents the most valuable and significant part of it. Another advantage of USPTO is the predominance of patents granted to firms (the focus of this study), whereas national patent systems, particularly in developing countries, show high incidence of patents granted to individuals (Da Motta e Albuquerque, 2000; Penrose, 1973). In our study the use of USPTO data is also justified by the fact that we are trying to understand the inventor networks of peripheral economies in its entirety, including the interactions of firms based in foreign countries with local inventors based in the focal peripheral economy. This particular case (e.g. a firm that conducts innovation in a different country but uses a Portuguese inventor) is not likely to be captured in the Portuguese patent system, since the firm is more likely to patent in its home country and in USPTO rather than in Portugal. It is important to remark that, while the setting of our study is Portugal, our sample comprises firms and inventors located in 35 countries, because we are trying to capture every firm in the world that patents using a Portuguese inventor, and any inventor in the world that works for a Portuguese-based firm; this type of interactions will be better captured by USPTO rather than by Portuguese patent data.

The first batch of patents (219 patents) contained all patents granted until July 31, 2012, with at least one assignee based in Portugal. The second batch (544 patents) contained all patents granted where at least one of the inventors was based in Portugal, regardless of the location of the assignee (Portugal- or foreign-based). Then we eliminated duplicated observations (patents included in both batches because they had both assignee and inventors based in Portugal). We also dropped patents assigned to individuals, in order to focus on the patenting activity of companies. Finally we dropped 3 patents from firms based in Macau and Taiwan because we lacked innovation scores for those countries. The final data set contains 503 unique patents; these are all the patents assigned by USPTO until July 31, 2012, where the assignee is a company, and where at least one of the assignees or one of the inventors is based in Portugal. In other words, this data set contains all patenting activity related to Portugal in the USPTO, encompassing both levels of analysis considered (firm and inventor). Considering both levels (assignee and inventor) the dataset contains information about firms and inventors located in 35 countries.

We analyzed the location (country) of inventors in each patent to understand the geographical dispersion of inventor networks in the Portuguese NSI. To determine 'core' or 'peripheral' status in innovation at the country level, we used the scores provided by the Global Innovation Index (Dutta, 2012). In the case of Liechtenstein we used innovation scores from Austria as a proxy.

## Variable definitions

### *Dependent variable*

*Geographical dispersion of the network of inventors (INV_DV)*: we constructed our dependent variable in two steps. First we built an index 'x' to measure how concentrated the inventors are across countries. The index 'x' is defined, for each focal patent, as the sum of the squares of the shares of inventors from each country over the total number of inventors. For instance, if a patent was authored by four inventors, of which three are located in country A and one is located in country B, country A has a share of 0.75 in the inventor group of the focal patent (3/4 = 0.75) and country B has a share of 0.25 in the inventor group of the focal patent (1/4 = 0.25). Thus, the index 'x' will be equal to: 0.75^2 + 0.25^2 = 0.625. If all inventors are located in one country, the share of that country in the inventor group will be 1, thus the index 'x' will be equal to 1 as well (because the square of 1 is 1). As we attempt to measure how dispersed, not concentrated, the inventor networks are, and we want our coefficient to be positive on the dispersion of inventors, the second step was to construct our dependent variable 'y' by transforming 'x', such that:

$$Y = 1 - X$$

As a result, our dependent variable is censored, with a minimum value of 0 (when all inventors are concentrated in one country), and an upper limit asymptotically approaching 1 as the inventors are more dispersed across countries. In our sample, the maximum observed value is 0.667 corresponding to a patent with inventors dispersed across four different countries.

***Independent and control variables***

*Inventor country innovation context (I_WA_GII)*: country score for inventor country, from the Global Innovation Index 2012 (Dutta, 2012). The GII is published by INSEAD and WIPO (World Intellectual Property Organization) and measures the overall innovation performance of a country along seven dimensions. In patents with inventors in more than one country, the weighted average is used (weighing each country score based on the share of inventors from each country in the inventor group).

*Assignee country innovation context (A_WA_GII)*: GII country score for assignee country. In patents with assignees based in more than one country, the weighted average of the country scores is used.

*Geographical dispersion of the network of assignees (SUM_AC)*: number of assignee-countries for each patent.

*High technology (HI_TECH):* to identify patents in high technology fields, we followed the criteria established by the Trilateral Statistical Report (EPO, JPO, & USPTO, 2007). The Trilateral Report, a joint project by the European Patent Office (EPO), the Japan Patent Office (JPO) and the USPTO, defines high technology as any of the following six fields: computers and automated business equipment, micro-organism and genetic engineering, aviation, communication technology, semi-conductors, and lasers. We added a dummy called ‘hi-tech’ which is equal to 1 if the USPTO class of a patent belongs to one of those six fields.

*Firm technological leadership/laggardship (L_PATPOOL)*: patent pool of the firm, measured as the natural logarithm of the number of USPTO patents of the company. For the purpose of our empirical analysis, we considered ‘leader’ firms those in the upper quartile of the sample and ‘laggard’ firms those in the lower two quartiles

*MNE*: the assignee of the patent is a firm located in a foreign country.

We additionally included a number of controls, such as the number of forward and backward citations of each patent, the technology category and the year the patent was granted.

**Statistical Analysis**

Table 1 presents the summary statistics for our sample. The dependent variable is bounded, with a maximum value of 0 when all the inventors are in the same country, and a maximum observed value of 0.667. 296 patents in the sample (58.5%) only have one inventor-country, which means there was no international collaboration involved. The other 41.5% of the patents involved networks of collaboration between inventors in different countries. There is a large dispersion of innovative capabilities among the sample firms, as measured by their patent pool. Consistent with intuition, as the country with more firms in the sample is Portugal, the median number of patents per firm is low; approximately half the firms have 15 or less USPTO patents. In terms of correlations, “Dispersion of inventors” is positively correlated with the innovation score of the inventor country (implying that inventors from more innovative countries engage more in internationally extended networks of inventors). “MNE” is positively correlated with “Number of inventor countries”, since many MNEs perform R&D activities in multiple countries. This is expected and consistent with our baseline hypothesis. “Hi-tech” is positively correlated with both “MNE” and “Patent pool”; “MNE” also shows a very strong positive correlation with “Patent pool”. This implies that MNEs and firms with a large innovation output are those that tend to produce high-technology patents. The correlation between MNE and patent pool means that multinationals tend to have a much larger pool of patents than local firms.

[Insert Tables 1-2 about here]

We employed a multiple regression approach to test our hypotheses. As described previously, our dependent variable is double censored; the most appropriate technique for this type of dependent variable is a Tobit regression (Greene, 2000: 905-926). Tobit models have been used in many studies with similarly censored dependent variables (Jeong & Weiner, 2012; Laursen & Salter, 2006; Mudambi & Helper, 1998; Ragozzino & Reuer, 2011). Multicollinearity diagnostic checks were performed by running each model with an OLS regression and calculating variance inflation factors (VIFs). Although the commonly accepted threshold for VIF values is 10 (Chatterjee & Price, 1991), we analyzed all values above 5. We found indications of collinearity between "hi-tech" (VIF 8.31) and certain technology categories (VIF 7.07 for category 2), which was expected since "hi-tech" is determined by the technology category. We dropped the variable "hi-tech" and VIF values fell to satisfactory ranges (maximum VIF = 4.63). We also tested for normality of residuals using a skewness-kurtosis test in Stata, which is a variety of the Jarque-Bera test (Jarque & Bera, 1980). Although our data is skewed due to a large number of observations where the dependent variable has a value of zero, the normality null hypothesis was not rejected when we dropped the observations with zero value for the dependent variable. Finally, we acknowledge that the cross-sectional nature of the data implies that coefficients must be understood as indicators of relationships between constructs.

## RESULTS

We ran four regression models to test our hypotheses. All models use censored Tobit analysis and the dependent variable is the geographical dispersion of inventors across countries (measured for each focal patent). Model 1 is the base model containing the full sample of 503 patents related to the Portuguese innovation system (either through a Portugal-based assignee or through a Portugal-based inventor). Model 2 contains only firms based in core countries and firms based in Portugal; MNEs from other peripheral countries are dropped. The cutoff threshold used to distinguish between core and peripheral countries was a score of 50 in the assignee-country innovation score. In Model 3 we eliminated Portugal-based firms, leaving only patents from firms based in other countries (either core or peripheral). Model 4 is a robustness check of our base model; it contains the full sample, but the dependent variables corresponding to the assignee and inventor country innovation scores were replaced with dummy variables corresponding to the four assignee countries and the four inventor countries with the highest innovation score.

To test hypothesis 1, our base regression was model 1. As predicted, multinationality (*MNE*) shows positive and highly significant coefficients. Similar results were obtained in models 2 and 4, confirming that in the context of peripheral economies, MNEs networks of inventors are more geographically dispersed than those of purely domestic firms.

Hypothesis 2 states that, in the context of peripheral economies, MNE subsidiaries from core countries have less dispersed networks of inventors than firms from less innovative countries (either multinational or domestic). The coefficient for the innovation score of the assignee country is negative and significant in models 1, 2 and 3. This implies that the dispersion of the innovation networks tends to decrease when the assignees are located in core countries, providing support for H2. In model 3 we dropped the patents from domestic Portuguese firms, therefore testing only other peripheral economies MNEs versus MNEs from core innovative countries. Results hold, providing evidence of their robustness.

Hypothesis 3 states that inventors in peripheral economies have less dispersed networks than those located in core innovative economies. The coefficient for the innovation score of the inventor country is positive and significant in models 1, 2, 3, providing support for H3.

In order to test the robustness of our results, in model 4 we replaced the variables 'innovation score of the inventor country' and 'innovation score of the assignee country' with dummy variables for inventor-countries and assignee-countries with high innovation scores. Out of 35 countries in our sample (for inventor and assignee location) we chose the upper 1/3 (12 countries) with the highest innovation score; the cutoff score was 55. Then, we dropped countries with less than 10 observations. The final list of countries for 'inventor-country' was United Kingdom, United States, Germany and Netherlands. The list for 'assignee-country' was United Kingdom, United States, Germany and Switzerland. Results of model 4 support our hypotheses. All coefficients for inventor-country are positive, and three of them are significant (except for Netherlands), supporting hypothesis 3. All the coefficients for assignee-country are negative and significant, supporting hypothesis 2. In summary, our hypotheses are supported in our robustness test. As an additional test, we replaced our dependent variable for a count variable (*SUM_IC*) which is the number of inventor-countries for each focal patent (with a maximum value of 4 and a minimum of 1). Our results (not included here) were also consistent with our hypotheses, providing reassurance that our results are very robust to different empirical designs.

In terms of controls, the international dispersion of the network of assignees (number of assignee-countries) is a positive and significant predictor of the dispersion of inventors, which is expected: when firms from different countries partner to obtain a patent, they are more likely to use inventors in different countries than individual local firms pursuing a patent on their own. Patent pool is also positive and significant; this is intuitive, since MNEs are usually the firms with most patent production and at the same time tend to have more dispersed networks of inventors. In terms of technology classes, pharmaceutical & medical patents (*CAT_3*) tend to have the most internationally dispersed network of inventors.

[Insert Table 5 about here]

In order to evaluate the conditions under which our hypotheses are more or less relevant, we conducted a sub-sample analysis, running regression models for smaller samples in our data set. Table 6 shows the results for the analysis of 'leading' versus 'laggard' innovative firms (by patent pool). Leading firms are those in the upper quartile by number of patents and laggard firms are those in quartiles 3 and 4. The results support our hypotheses in both sub-samples. A particularly interesting result is that multinationality only increases inventor dispersion for the laggard firm subsample. This implies that ‘leading’ Portuguese firms behave similarly to ‘leading’ MNEs, but ‘laggard’ Portuguese firms fare worse than ‘laggard’ MNEs; therefore, the difference in results for multinationality comes from the laggard firms. These results seem to be aligned with those of Cantwell and Mudambi (2011). Table 7 contains the results for hi-tech patents versus non hi-tech patents. Our hypotheses are supported for both sub-samples, although coefficients are slightly larger for hi-tech patents. This suggests that technological complexity increases the incentives for inventors in advanced countries to collaborate with other inventors, while firms in those countries will focus their knowledge sourcing more locally because their own (core) countries are those which tend to dominate high technologies. Table 8 shows the sub-sample analysis for six technology classes. The coefficient for innovation score of the inventor’s country is positive and significant in all six categories, strongly supporting hypothesis 2. The coefficients for innovation score of both inventor-country and assignee-country are largest for category 5 (mechanical) and 2 (computers and communications), which is aligned with the results for high-technologies in table 4. The coefficient for assignee country is only significant in categories 2 and 5. This suggests that our results are stronger for the inventor effects than for the assignee effect. In summary, our sub-sample analysis supports our hypotheses and provides new distinctions about the factors that affect the magnitude of our results.

[Insert Tables 6-7-8 about here]

## CONCLUDING REMARKS AND IMPLICATIONS

Traditional literature on development economics distinguished between developed and developing countries (Meier & Rauch, 2005). Later literature identifies some of the old developing country group that experienced rapid catch-up along a number of dimensions as ‘emerging economies’ (Awate, Larsen, & Mudambi, 2012; Cuervo-Cazurra, 2012). But, with few exceptions, the growing diversity within the developed country group has not received much attention. This paper focuses on the sub-group of developed countries that have been labeled ‘peripheral’ due to their relatively lower connectivity with the global economic system, as compared to the ‘core’ developed countries. This paper analyzed the connectivity of peripheral economy innovation systems. Most studies of innovation systems are either couched at the level of organizations or at the level of individual inventors. The NSI literature (Lundvall, 2007; Nelson, 1993) is the major example of the first tradition, while the work on inventor networks is the chief example of the second (Balconi, Breschi, & Lissoni, 2004; Fleming & Marx, 2006; Zucker & Darby, 1996). This paper takes the first steps towards an integrative framework by analyzing Portugal’s NSI both dimensions simultaneously. This integration yields the key insight that connectivity along these two dimensions differs in systematic ways.

We use the comprehensive population data set of U.S. patents issued to Portuguese assignees (organizations) and Portuguese inventors (individuals). We find strong support for our baseline expectation that MNE subsidiaries located in Portugal have significantly more international innovation networks than domestic Portuguese firms. Thus, MNE subsidiaries provide pipelines supporting connectivity between the Portuguese NSI and the global innovation network. This supports the idea that MNE subsidiaries are critical sparks for change in the domestic economy (Mudambi & Swift, 2012). Further, while peripheral economies have significantly higher incomes and superior infrastructural development than emerging economies, they display some similarities in terms of their innovation systems (Kumaraswamy et al., 2012).

For assignee firms with innovative activities in Portugal, we find that those with parents located in countries with higher innovative capabilities tend to have less dispersed innovative networks.

This supports the idea that when the parent is located in a more munificent setting , subsidiaries tend to be competence-exploiting and mostly source knowledge from their home location (Cantwell & Mudambi, 2011). Conversely, when the parent is located in a setting either on a par with or less munificent than the peripheral economy, the subsidiary must source knowledge from a wider range of locations, since its home location is relatively weak.

In contrast, for patents linked to the Portuguese NSI, the more munificent the location of inventors, the more internationally dispersed the relevant innovation networks. This occurs because inventors in more munificent locations usually have access to more pipelines and personal relationships (Lorenzen & Mudambi, 2013), and tend to bring these to bear on their innovation projects.

We believe that heretofore there was an assumption that innovation networks at the level of the organization and at the level of the individual had similar properties. Our results suggest that there are fundamental differences between these two networks, at least for peripheral economies. At the organizational level, subsidiaries with parents in highly innovative core economies may provide the local economy with limited connectivity benefits. Conversely, at the personal level, innovative interactions with inventors based in highly innovative core economies may provide the local economy with substantial connectivity benefits. These results complement those on the differences between pipelines and personal relationships reported by Lorenzen and Mudambi (2013). While the results we report are conditional on one node of the innovation network being in Portugal, we posit that they may be true for peripheral economies in general.

This paper’s findings yield benefits for academics, managers and policy-makers.

For academics, the contribution is to disentangle the organizational and the personal levels in innovation networks, opening a fertile field for future research, both in other peripheral contexts and in other type of economies.

Regarding managerial implications, two situations should be distinguished. First, for managers of domestic firms aiming to upgrade their companies' competitiveness via innovation and internationalization, it would be wise to strengthen linkages with entities and inventors located abroad, with foreign MNEs' subsidiaries located in Portugal and with the Portuguese S&T system. In the first case, the logic of collaborating with entities from abroad would be competence seeking, bringing new perspectives to their own innovation. In the second case, the intensification of linkages with other entities located in the domestic economy may also be strategic. Both in terms of reaping the benefits of the high quality of research done in universities and other centers (providing the demand these organizations need to focus on applied industry problems) and in terms of becoming suppliers to foreign subsidiaries located in the peripheral economy. This is only valid for domestic firms with a certain level of absorptive capacity. In turn, managers of foreign subsidiaries located in Portugal should understand the relevance of linking with the best agents in the local environment in order to leverage their bargaining power within their group – both *vis-à-vis* HQ and 'sister' subsidiaries (Andersson & Forsgren, 1996; Meyer et al., 2011).

Concerning policy, the way to diminish the disadvantages of peripherality is to increase connectivity – by promoting the intensification of the presence of locally-based (domestic and foreign-owned) actors in international innovation and supply networks.

There are different levels on which to act to achieve increased connectivity. One is a long term bet, i.e. measures aimed at increasing absorptive capacity, acting on human capital formation. Another is based on providing the right incentives to promote the desired outcomes. Since there are considerable funds available (e.g. via EU programs) for peripheral economies to fund their innovation infrastructure, emphasis should be put on channeling the funds to sustain collaborative efforts linking S&T actors with firms, with funding indexed to results. A linkage program between MNEs and local companies would also be relevant. .

One of our results points to the potential benefits of foreign MNEs as pipelines for innovation – supporting efforts to continue attracting MNEs to peripheral economies. Another area of focus, related to linkages and collaborative initiatives, is the promotion of cluster policies, implying a more strategic and targeted approach. The need to strengthen “system linkages” (Heitor & Bravo, 2010) and “systemic density” (Godinho & Simões, 2013) is acute. For all this, given that linkages and networks need time to develop, consistency and predictability of policies is a key factor.

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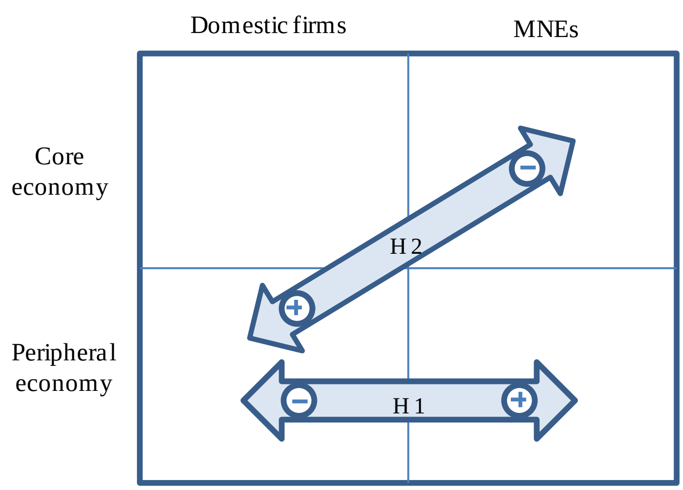
**Image 1: Dispersion of inventor networks**



## TABLE 1: Descriptive Statistics

| | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Geographical dispersion of inventors | 503 | 0.194 | 0.236 | 0 | 0.667 |
| Innovation score of the inventors' countries | 503 | 49.207 | 5.126 | 30.9 | 68.2 |
| Innovation score of the assignees' countries | 503 | 52.503 | 7.012 | 35.3 | 68.2 |
| Number of assignee-countries | 503 | 1.024 | 0.165 | 1 | 3 |
| High-tech patent class according to NBER taxonomy | 503 | 0.159 | 0.366 | 0 | 1 |
| Natural log of the patent pool | 503 | 3.702 | 3.014 | 0 | 11.202 |
| MNE | 503 | 0.584 | 0.493 | 0 | 1 |
| Number of USPTO backward citations | 503 | 12.185 | 28.810 | 0 | 358 |
| Number of USPTO forward citations | 503 | 4.642 | 9.559 | 0 | 108 |

## TABLE 2: Pearson Correlation Coefficients

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 Geographical dispersion of inventors | 1.000 | | | | | | | | |
| 2 Innovation score of the inventors' countries | 0.553 | 1.000 | | | | | | | |
| 3 Innovation score of the assignees' countries | 0.445 | 0.307 | 1.000 | | | | | | |
| 4 Number of assignee-countries | 0.190 | 0.064 | 0.009 | 1.000 | | | | | |
| 5 High-tech patent class according to NBER taxonomy | 0.235 | 0.068 | 0.196 | 0.102 | 1.000 | | | | |
| 6 Natural log of the patent pool | 0.495 | 0.327 | 0.558 | 0.109 | 0.370 | 1.000 | | | |
| 7 MNE | 0.504 | 0.269 | 0.850 | -0.074 | 0.223 | 0.607 | 1.000 | | |
| 8 Number of USPTO backward citations | 0.090 | 0.059 | 0.043 | -0.031 | -0.012 | 0.005 | 0.057 | 1.000 | |
| 9 Number of USPTO forward citations | 0.017 | 0.009 | 0.061 | -0.032 | 0.134 | 0.046 | 0.080 | 0.016 | 1.000 |

## TABLE 3: Skewness-Kurtosis (Jarque-Bera) Test of Normality

Normality test performed for all observations for which dependent variable was >0. The Joint P-value of 0.1844 is above accepted thresholds of significance, indicating that we cannot reject the null hypothesis of normality.

| | | | | Joint | |
|---|---|---|---|---|---|
| Variable | Obs. | Pr (Skewness) | Pr (Kurtosis) | Adj. chi2 | Prob>chi2 |
| Residuals | 214 | 0.2697 | 0.1445 | 3.38 | 0.1844 |

## TABLE 4: Multicollinearity Test.

| Variable | VIF |
|---|---|
| Innovation score of the inventor's country | 1.45 |
| Innovation score of the assignee's country | 4.18 |
| Number of assignee-countries | 1.15 |
| Natural log of the patent pool | 2.16 |
| MNE | 4.63 |
| Patent category: Chemical | 1.66 |
| Patent category: Computers & Communications | 1.65 |
| Patent category: Drugs & Medical | 1.5 |
| Patent category: Electrical & Electronic | 1.43 |
| Patent category: Mechanical | 1.43 |
| Number of USPTO backward citations | 1.08 |
| Number of USPTO forward citations | 1.65 |

# TABLE 5: Tobit Regression Analysis

All models use censored Tobit analysis. The dependent variable is the geographical dispersion of inventors across countries (measured for each focal patent). Model 1is the base model containing the full sample of 503 patents related to the Portuguese innovation system (either through an assignee or through an inventor). Model 2 contains only firms based in core countries and firms based in Portugal; MNEs from other peripheral countries are dropped. The cutoff threshold used to distinguish between core and peripheral countries was a score of 50 in the assignee-country innovation score. In Model 3 we eliminated Portugal-based firms, leaving only patents from firms based in other countries (either core or peripheral). Model 4 is a robustness check of our base model; it contains the full sample, but the independent variables corresponding to the assignee and inventor country innovation scores were replaced with dummy variables corresponding to the four assignee countries and the four inventor countries with the highest innovation score.

| | Model | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **DV: Geographical dispersion of inventors** | **1** | | **2** | | **3** | | **4** | |
| Innovation score of the inventor's country | 0.042 | *** | 0.042 | *** | 0.054 | *** | | |
| | (0.004) | | (0.003) | | (0.004) | | | |
| Innovation score of the assignee's country | -0.014 | ** | -0.013 | ** | -0.016 | *** | | |
| | (0.004) | | (0.004) | | (0.003) | | | |
| Number of assignee-countries | 0.384 | *** | 0.373 | *** | 0.147 | | 0.345 | *** |
| | (0.084) | | (0.082) | | (0.111) | | (0.078) | |
| Natural log of the patent pool | 0.016 | * | 0.015 | * | 0.000 | | 0.023 | *** |
| | (0.007) | | (0.006) | | (0.005) | | (0.006) | |
| MNE | 0.548 | *** | 0.533 | *** | | | 0.459 | *** |
| | (0.067) | | (0.077) | | | | (0.048) | |
| Patent category: Chemical | 0.166 | ** | 0.156 | ** | 0.038 | | 0.096 | * |
| | (0.051) | | (0.051) | | (0.046) | | (0.045) | |
| Patent category: Computers & Communications | 0.141 | * | 0.138 | * | 0.112 | * | 0.093 | † |
| | (0.056) | | (0.055) | | (0.045) | | (0.048) | |
| Patent category: Drugs & Medical | 0.207 | ** | 0.202 | *** | 0.052 | | 0.101 | * |
| | (0.053) | | (0.053) | | (0.048) | | (0.047) | |
| Patent category: Electrical & Electronic | 0.126 | † | 0.113 | † | 0.140 | * | 0.060 | |
| | (0.065) | | (0.065) | | (0.055) | | (0.057) | |
| Patent category: Mechanical | 0.118 | † | 0.105 | | 0.089 | | 0.067 | |
| | (0.066) | | (0.067) | | (0.057) | | (0.057) | |
| Number of USPTO backward citations | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| | (0.000) | | (0.000) | | (0.000) | | (0.000) | |
| Number of USPTO forward citations | 0.003 | | 0.003 | | 0.003 | | 0.002 | |
| | (0.002) | | (0.002) | | (0.001) | | (0.001) | |
| Inventor country: UK | | | | | | | 0.409 | *** |
| | | | | | | | (0.049) | |
| Inventor country: USA | | | | | | | 0.444 | *** |
| | | | | | | | (0.044) | |
| Inventor country: Germany | | | | | | | 0.595 | *** |
| | | | | | | | (0.088) | |
| Inventor country: Netherlands | | | | | | | 0.095 | |
| | | | | | | | (0.088) | |
| Assignee country: Germany | | | | | | | -0.454 | *** |
| | | | | | | | (0.097) | |
| Assignee country: Switzerland | | | | | | | -0.155 | * |
| | | | | | | | (0.068) | |
| Assignee country: UK | | | | | | | -0.170 | * |
| | | | | | | | (0.079) | |
| Assignee country: USA | | | | | | | -0.309 | *** |
| | | | | | | | (0.047) | |
| Constant | -2.169 | *** | -2.222 | *** | -1.765 | *** | -0.768 | ** |
| | (0.255) | | (0.291) | | (0.243) | | (0.221) | |
| Patent year dummies | Yes | | Yes | | Yes | | Yes | |
| Observations | 503 | | 492 | | 294 | | 503 | |
| Prob > chi2 | 0 | | 0 | | 0 | | 0 | |
| Pseudo R2 | 0.6358 | | 0.652 | | 0.8925 | | 0.7282 | |

## TABLE 6: Sub-sample analysis: leading vs. laggard innovating firms

| | Leading firms (Quartile 4) | | Laggard firms (Quartiles 1-2) | |
|---|---|---|---|---|
| Innovation score of the inventors' countries | 0.043 | *** | 0.047 | *** |
| | (0.005) | | (0.009) | |
| Innovation score of the assignees' countries | -0.017 | *** | -0.028 | * |
| | (0.005) | | (0.012) | |
| Number of assignee-countries | 0.194 | | 0.520 | |
| | (0.140) | | (0.431) | |
| MNE | 0.048 | | 0.866 | *** |
| | (0.192) | | (0.190) | |
| Patent category: Chemical | -0.057 | | 0.771 | ** |
| | (0.094) | | (0.223) | |
| Patent category: Computers & Communications | 0.065 | | 0.398 | |
| | (0.088) | | (0.349) | |
| Patent category: Drugs & Medical | -0.015 | | 0.926 | *** |
| | (0.093) | | (0.232) | |
| Patent category: Electrical & Electronic | -0.015 | | 0.537 | † |
| | (0.099) | | (0.295) | |
| Patent category: Mechanical | 0.049 | | 0.583 | * |
| | (0.101) | | (0.249) | |
| Patent category: Others | 0.114 | | 0.432 | † |
| | (0.110) | | (0.234) | |
| Constant | -1.215 | ** | -2.723 | |
| | (0.449) | | (0.842) | |
| Observations | 125 | | 252 | |
| Prob > chi2 | 0.000 | | 0.000 | |
| Pseudo R2 | 1.209 | | 0.374 | |

† p <0.10; * p < 0.05; ** p < 0.01; *** p < 0.001

## TABLE 7: Sub-sample analysis: Hi-tech vs. Non hi-tech patents

| DV: Geographical dispersion of inventors | High-tech patents | | Non high-tech patents | |
|---|---|---|---|---|
| Innovation score of the inventor's country | 0.044 | *** | 0.042 | *** |
| | (0.003) | | (0.002) | |
| Innovation score of the assignee's country | -0.028 | *** | -0.013 | ** |
| | (0.005) | | (0.003) | |
| Number of assignee-countries | 0.331 | *** | 0.426 | *** |
| | (0.076) | | (0.091) | |
| Natural log of the patent pool | 0.008 | | 0.010 | |
| | (0.007) | | (0.005) | |
| MNE | 0.418 | *** | 0.482 | *** |
| | (0.110) | | (0.059) | |
| Number of USPTO backward citations | 0.003 | † | 0.000 | |
| | (0.001) | | (0.000) | |
| Number of USPTO forward citations | 0.001 | | -0.004 | † |
| | (0.001) | | (0.002) | |
| Constant | -1.301 | *** | -2.265 | *** |
| | (0.239) | | (0.208) | |
| Observations | 80 | | 423 | |
| Prob > chi2 | Leading firms | | Laggard firms | |
| Pseudo R2 | 1.578 | | 0.813 | |

† p <0.10; * p < 0.05; ** p < 0.01; *** p < 0.001

## TABLE 8: Sub-sample analysis: By technology category of the patent

| DV: Geographical dispersion of inventors | Category 1 Chemical | | Category 2 Computers & Communications | | Category 3 Drugs & Medical | | Category 4 Electrical & Electronic | | Category 5 Mechanical | | Category 6 Others | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Innovation score of the inventor's country | 0.036 | *** | 0.051 | *** | 0.043 | *** | 0.046 | *** | 0.077 | *** | 0.048 | *** |
| | (0.003) | | (0.005) | | (0.004) | | (0.009) | | (0.017) | | (0.007) | |
| Innovation score of the assignee's country | -0.007 | | -0.026 | *** | 0.000 | | -0.016 | | -0.051 | ** | -0.016 | |
| | (0.005) | | (0.006) | | (0.006) | | (0.010) | | (0.014) | | (0.010) | |
| Natural log of the patent pool | 0.020 | * | 0.003 | | 0.006 | | 0.007 | | 0.019 | | 0.014 | |
| | (0.009) | | (0.008) | | (0.010) | | (0.024) | | (0.013) | | (0.015) | |
| MNE | 0.236 | ** | 0.211 | * | 0.129 | | 0.449 | † | 1.199 | *** | 0.786 | ** |
| | (0.080) | | (0.092) | | (0.093) | | (0.249) | | (0.274) | | (0.225) | |
| Constant | -1.638 | *** | -1.225 | *** | -2.215 | *** | -1.816 | ** | -2.393 | *** | -2.332 | *** |
| | (0.325) | | (0.272) | | (0.386) | | (0.656) | | (0.559) | | (0.615) | |
| Observations | 108 | | 69 | | 76 | | 50 | | 51 | | 66 | |
| Prob > chi2 | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| Pseudo R2 | 0.855 | | 1.413 | | 1.047 | | 0.549 | | 1.275 | | 0.879 | |

† p <0.10; * p < 0.05; ** p < 0.01; *** p < 0.001