# The geographical dispersion of inventor networks in peripheral economies


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## Abstract

This paper explores the dispersion of inventor networks in peripheral economies, a topic that has received relatively little attention in the literature.  As global value chains fragment into geographically dispersed activities, opportunities arise for peripheral economies to participate in these processes of innovation. However, different types of knowledge creation have distinct network properties. While more codifiable innovative activities can be carried out through collaboration by internationally dispersed teams, activities that involve more tacit knowledge are more likely to require the co-location of knowledge workers. This implies that, for peripheral economies, innovation that relies mostly on tacit knowledge will provide the local innovation system with limited connectivity benefits. We hypothesize that, while this is generally true, “leading” innovative multinational enterprises may possess more sophisticated capabilities for transnational collaboration than less innovative firms. Therefore, innovation in activities involving tacit knowledge may show different network characteristics depending on who performs them: leaders or "laggards". Our results, based on two European peripheral economies, are consistent with our hypotheses.

# INTRODUCTION

What determines the level of connectivity of a peripheral economy to global networks of inventors? Global innovation systems are becoming increasingly complex and involving a wider range of locations. As value chains are disaggregated across borders, countries are increasingly interconnected in global invention networks (BALCONI et al., 2004; BRESCHI and LISSONI, 2009). Locations outside core OECD countries, attempting to catch-up technologically with core developed economies, try to attract multinational companies to perform innovative activities in their territories and create linkages to these global innovation networks. Connectivity provides an economy with access to a wider variety of world-class pools of knowledge. However, the factors affecting the connectivity of peripheral economies have been overlooked by the literature; this is the main motivation for our paper. We argue that value chain activities involving a high level of tacit knowledge "tend to remain more agglomerated in the parent company" (CANTWELL and SANTANGELO, 1999: 101). These activities will be performed mostly by collocated teams or teams with members in global centers of excellence (GITTELMAN, 2007) so that the local economy obtains limited connectivity to global innovation networks. We also argue that some leading innovative firms may possess complex organizational capabilities that gives them the ability to orchestrate these such activities in a dispersed manner (CANTWELL, 1995; CANTWELL and MUDAMBI, 2011; TALLMAN and CHACAR, 2011).

The connectivity of a location is defined as the particular configuration of its global linkages combined with the specific network structure of these linkages (LORENZEN and MUDAMBI, 2013). In general, linkages between locations can arise either from organizations or from individuals. In the literature, organization-based linkages have been referred to as “pipelines” (BATHELT et al., 2004), while those arising from individuals have been referred to as “personal relationships” (LORENZEN and MUDAMBI, 2013). Further, locations differ in terms of the extent to which their linkages are concentrated in a few central actors. In this paper, we examine empirically one aspect of connectivity in detail: the geographical dispersion of inventor networks across national borders.

Non-core locations have the most to gain from connectivity to global innovation systems (ABRAMOVITZ, 1986). In particular, these gains can be best leveraged by economies that have achieved some degree of maturity in terms of local innovative capabilities. “Peripheral economies” form a particularly important class of non-core economies. The concept of a “peripheral” economy fills an intermediate category (MOLERO, 1995) in the rigid “developed vs. developing/emerging” economies dichotomy. BENITO and NARULA (2008) provide a definition that characterizes peripheral economies according to detailed criteria like levels of foreign direct investment (FDI), trade in intermediate and manufactured goods and innovation, in order to distinguish them from core OECD economies. Some southern and eastern European countries are good examples (BENITO and NARULA, 2008; LIAGOURAS, 2010; NARULA and GUIMÓN, 2010). This change in global value networks provides opportunities for non-core locations to participate in the high knowledge components of global value chains. Further, since peripheral economies are likely to lag the core in terms of innovation capabilities in almost all sectors, connectivity is likely to have particularly strong effects for them.

We study one particular aspect of the global connectivity of peripheral economies, namely the international dispersion of inventor networks. We use Portugal and Greece as examples of peripheral economies (BENITO and NARULA, 2008; NARULA and GUIMÓN, 2010). Both countries can be considered peripheral to the core region of Europe and are comparable in size, income and the level of development of their innovation systems.

Furthermore, their location in the perimeter of the European continent (Portugal in the southwest and Greece in the southeast) and the fact that they do not share borders with the core European economies, create similar challenges in terms of integration with the rest of the continent. . We analyze patent data for both countries, encompassing all the patenting activity linked to Portugal and Greece. We include patents from local firms with local inventors, patents from foreign assignees with local Portuguese or Greek inventors, and patents from local Portuguese or Greek firms with inventors located abroad. Therefore, our sample includes firms and inventors located in 44 countries. By understanding how inventor networks work in these peripheral economies, we highlight characteristics that we suggest may be typical of peripheral economies in general.

We find that peripheral economy inventors with collaborators in core economies tend to have more internationally dispersed networks. In addition, we provide some of the first empirical evidence on the CANTWELL and SANTANGELO (1999; 2000) research on the dispersion of innovation activities involving tacit knowledge, in this case extending it to the context of peripheral economies.

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

## LITERATURE REVIEW

### Peripheral Economies

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 nineteenth century imperialism. By the last decades of the twentieth century, this research had become outmoded and less useful in understanding the nature of global interactions (CANTWELL, 1995).

More recently, MOLERO (1998) defines peripheral economies as an intermediate group that displays less developed productive structures than the core, less internationalization via outward FDI, and with innovation systems marked by medium-low R&D effort and modest levels of patenting. For BENITO and NARULA (2008), peripheral economies are "not significant destinations for or home to many MNEs; they engage in relatively little trade in intermediate and manufactured goods; they contribute relatively little to innovation and scientific progress; they are weakly linked or accessible physically to the core; they do not play significant decision-making roles within supranational organizations; and they do not share a significant number of formal institutions with core countries" . While displaying these weaknesses, these are relatively affluent economies, with per capita incomes significantly higher than emerging countries, but below the more affluent core economies.

BENITO and NARULA (2008) specifically 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 merely internationalization. The key to interdependence is reciprocity, which involves ongoing, mutual relationships between economic actors. More unequal relationships weaken integration, leading to peripheral status.

## Peripheral regions and knowledge networks

According to SAXENIAN (2006, p. 3), innovation is the key factor driving the evolution of formerly peripheral economies. One of the ways to foster innovation is to attract and embed MNE R&D activity. Since MNEs form internationally integrated intra-firm networks (CANTWELL and PISCITELLO, 2000; MCCANN and MUDAMBI, 2005), more MNE activity is likely to increase the integration of the economy into global networks. However, technologically advanced MNEs are likely to seek locations with significant levels of academic activity (ALCÁCER and CHUNG, 2007), with high R&D intensity and a significant magnitude of technical activity (CHUNG and ALCÁCER, 2002), all of which is not typical of peripheral economies. In general, these economies are not very attractive locations for MNE R&D activities, because of weak location advantages, relatively under-developed scientific and educational infrastructure, low potential for knowledge spillovers, small market size (CANTWELL and PISCITELLO, 2002, 2005) and low absorptive capacity (COHEN and LEVINTHAL, 1990).

The activity of MNEs in these peripheral economies brings the greatest local benefits when it is associated with "capability/knowledge-augmenting" R&D activities - which seek to tap into local sources of knowledge and resources (CANTWELL and MUDAMBI, 2005). Though "competence-creating" MNE subsidiaries are the most attractive, they usually require locations with a rich resource base (CANTWELL and MUDAMBI, 2000). Peripheral economies tend to attract "competence-exploiting", demand-driven R&D activities due to their disadvantage in technological capabilities *vis-à-vis* the core (CANTWELL and MUDAMBI, 2000; NARULA and 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 capabilitycreating mandate. Competence-exploiting subsidiaries focus on routine replication and local adaptation and are the dominant type in Greece and in Portugal, according to MANOLOPOULOS (2010) and TAVARES-LEHMANN (2008). In some cases, especially in oligopolistic industries, the main reason to enter the economy is to preempt a competitor or limit its growth prospects (ALCÁCER et al., 2013). Such subsidiaries are unlikely to spark 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.

There are, *a priori*, clear differences in knowledge-sourcing patterns between MNEs and local firms. MNEs are characterized by "multiple embeddedness" (ANDERSSON and FORSGREN, 1996; MEYER et al., 2011) in their home country context and in that of their subsidiaries. Simultaneously, MNE subsidiaries are externally embedded in their host milieu and internally embedded within their parent organization network (ANDERSSON and FORSGREN, 1996). 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 within the organization. BATHELT, MALMBERG and MASKELL (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 as well as many pipelines in a certain location provides firms with particular advantages. In peripheral economies, pipelines are basically orchestrated by MNEs. Some factors may drive the creation of thicker pipelines; ALCÁCER and ZHAO (2012) found that the presence of direct competitors in the same location tends to favor the creation of more internal linkages across different subsidiaries and more use of cross-cluster teams. However, pipelines are expensive to build and maintain since the establishment of subsidiaries requires relatively large investments. Furthermore, pipelines to other subsidiaries provide access to networks of inventors that are relatively constrained. A subsidiary 'A' collaborating with another subsidiary 'B' may only have access to its local network of inventors and to the local network of subsidiary 'B'. This is especially true as MNEs are concerned about the protection of their intellectual property, and are likely to refrain from open collaboration with external parties whose loyalty may be unknown (MARIOTTI et al., 2010; MCCANN and MUDAMBI, 2005).

Specialized knowledge not only flows through pipelines. It also circulates through personal networks. Some authors talk about "epistemic communities", or 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 these networks as "person-based linkages", which tend to be serendipitous in origin, to distinguish them from pipelines, which are "organization-based linkages" and are usually strategic in origin. 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. Other authors have written about "geographical proximity" and "organized proximity" (TORRE and 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 territory. 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 milieu, are crucial for the innovation process of SMEs; too much reliance on local knowledge seems harmful for innovative capacity and can lead to a "technology trap" (GIULIANI, 2010).

It follows that the innovative activity of domestic firms and other organizations (e.g. universities and research institutions), that do not possess networks of subsidiaries, will rely more on personal networks for establishing collaboration relationships. These networks are "thin" compared to the "thick" pipelines between units of an MNE, but also cheaper and easier to establish and maintain. Knowledge sourcing and collaboration patterns vary depending on regional characteristics. Munificent regions, with high levels of innovation favor local collaboration, given the availability of local knowledge. Conversely, firms in peripheral economies, given their less favorable location, may be compelled to source knowledge from more remote sources by establishing more geographically dispersed networks based on personal relationships.

This complex combination of organizations and individuals sharing knowledge across the geographic spaces creates an array of possible linkages and knowledge sourcing patterns. GITTELMAN (2007) found that the spatial distribution of these collaborations tends to be strongly bimodal, with a large number of local collaborations and a large number of very long distance collaborations, but few at intermediate distances. The rationale behind this distribution is that, when knowledge is not available locally, there is little to gain from tapping regions at intermediate distances if those regions do not possess that knowledge either. Once organizations need to establish collaborations outside the local milieu, they tend to do it with centers of excellence elsewhere, driven more by the availability of the knowledge than by distance considerations.

Another aspect to take into account when studying the patterns of dispersion of knowledge networks is the tacitness of knowledge. CANTWELL and SANTANGELO (1999; 2000) argue that co-location of inventors tends to be more prevalent in innovation activities that depend upon tacit knowledge. R&D related to the firm's core technologies and in science-based fields also seem to require more face-to-face interaction. These authors argue that activities involving tacit knowledge are geographically dispersed only in certain cases: (1) when the knowledge is locally embedded, unique and specialized or (2) when there are complex organizational networks in place. Point (2) implies that the "international dispersion of activity is led by technology leaders" (CANTWELL, 1995: 155), i.e., that only leading firms possess the capabilities to effectively conduct this type of R&D through geographically dispersed teams. We extend the findings of CANTWELL and SANTANGELO (1999; 2000) to the context of peripheral economies.

## THEORY AND HYPOTHESES

Our first hypothesis focuses on the relationship between the location of inventors and the level of disaggregation of innovation across national borders, specifically the dispersion of inventor networks. Inventors related to any country are either based locally or based in foreign locations but employed by local organizations. We examine each of these two classes of inventors in the following analysis. We first consider the more straightforward case, i.e. foreign-based inventors of local (peripheral economy) organizations. Organizations in peripheral economies (firms, research institutions, universities, etc.) 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. Hence, the inventors of peripheral economy organizations based in core economies have access to wider innovation networks than those based in other peripheral economies.

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 in their home location or in other core regions. They usually go to peripheral regions in search of exploitative, cost-driven knowledge. As the inventors they hire in peripheral economies undertake mainly exploitative work, they are only locally connected or at most, connected to a home economy subsidiary or to headquarters. Therefore, their networks will be more limited than those of inventors residing in core economies.

Drawing on the literature and the arguments discussed above, we state the following hypothesis:

**Hypothesis 1:** Among inventors linked to peripheral economies, those located in core innovative economies will be connected to more internationally dispersed inventor networks than those located in peripheral economies

As discussed in the literature section, it is widely accepted that different activities within the value chain have different degrees of transferability, depending fundamentally on the extent of codifiability. More codifiable innovative activities can be either outsourced or disaggregated (even across national borders), through geographically dispersed innovation networks. In contrast, more tacit innovative activities, as a general rule, are more likely to be internalized and conducted by collocated teams. This is true in peripheral economies as much as in other contexts. Therefore, our second hypothesis is the following:

**Hypothesis 2:** When innovation in peripheral economies involves tacit knowledge activities, the inventor networks will be less internationally dispersed than when knowledge is more codifiable

As CANTWELL and SANTANGELO (1999) argue, there are two factors that facilitate the orchestration of tacit-knowledge innovation across dispersed networks. This first is organization-specific capability, typically associated with leading firms in the relevant knowledge space. The second is that the innovation is focused on competencies that are "non-core" for the company (CANTWELL and SANTANGELO, 2000). CALANTONE and STANKO (2007) found that firms that are experienced in conducting exploratory research tend to outsource innovation activities (of any kind) to a higher degree. We argue that being an experienced innovator and having the capabilities associated with it will be most critical when the innovation is focused on tacit components. In addition, as argued by CANTWELL and

SANTANGELO (2000), for the largest and most experienced MNEs, most innovation with tacit components (such as design innovation) that is dispersed is typically not be a core activity . Therefore, there are two reasons to expect that leading innovative companies will show a higher degree of dispersion in tacit innovation, compared to laggard or sporadic innovators. First, they have developed the necessary capabilities through their extensive experience in innovation. Second, innovation with much of the tacit-knowledge components (such as design innovation) that is dispersed is likely to be a non-core component of their activities. Based on these arguments, we arrive to the following hypothesis.

> **Hypothesis 3:** The relationship between tacit knowledge and the international dispersion of inventor networks will be moderated by the innovation capabilities of the firms, such that leading innovative firms will be able to disperse their tacit knowledge innovation across borders to a higher degree than innovation laggards.

In summary, we hypothesize that in the context of peripheral economies, the disaggregation of inventor networks across national borders, will depend on the combination of location, knowledge tacitness and organizational capabilities in innovation.

## THE EMPIRICAL CONTEXT: PORTUGAL AND GREECE

We chose two typical European peripheral countries as the empirical setting to illustrate the processes underlying innovation networks in peripheral economies: Portugal and Greece. Both countries can be considered textbook cases of European peripheral economies, as they display all characteristics usually attributed to such economies. These include the structure of production, the degree of internationalization and international openness, foreign subsidiary roles, linkages among actors, innovation-related indicators, connectivity with the core, and organizational/institutional characteristics (BENITO and NARULA, 2008; MOLERO, 1998; MOLERO, 1995). Compared to core European Union (EU) economies, their economies are marked by a low degree of internationalization, low relevance of high tech sectors and a low weight of high tech exports. Their patent production represents only a minimal fraction of the European patenting activity (ROBERTS and THOMSON, 2003). They also show a predominance of SMEs and micro-enterprises with low productivity and often offering non-tradable services (SIMÕES and GODINHO, 2011), and a scarcity of indigenous MNEs, a relatively low supply of technology and (in the case of Greece) a risk-averse national culture (SOUITARIS, 2001). Particularly in Greece, there is also a significant number of under-educated or under-qualified people in senior positions in numerous companies, which poses additional challenges to fostering an innovative culture (SOUITARIS, 2002). At a more general level, both countries have practically the same population of 10.8 million (CIA, 2013b) and similar income levels: the GDP per capita (PPP) of Greece is US$24,300 and that of Portugal is US$23,000 (CIA, 2013a). They also have comparable sizes and have the disadvantage of being located in the extremes of Europe, relatively far from the core economic and innovative regions in the continent.

As expected in peripheral economies, linkages among actors in these countries are modest. In Portugal, the low degree of autonomy of foreign subsidiaries limits linkages with the Portuguese science, technology and innovation (STI) system (TAVARES-LEHMANN, 2008). Foreign-owned subsidiaries in Portugal also tend to source less locally than their domestic counterparts, since few local suppliers can fulfill the standards they require, in quantity and quality, though this is changing (TAVARES-LEHMANN, 2008). In Greece, there is also little engagement and interaction between the STI programs designed by the government and the innovative firms in the private sector, particularly MNEs (COLLINS and PONTIKAKIS, 2006). Another problem in Greece is the uneven regional distribution of both big companies and R&D, with the bulk of activity concentrated in Southern Greece relatively little activity in other regions such as Thessaloniki (GYÖRGY and VINCZE, 1992).

Literature on patenting activities is more abundant for Portugal than for Greece. Most studies about Portugal (GODINHO, 2009; GODINHO et al., 2004; GODINHO et al., 2008) show that the country 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. Subsidiaries of foreign MNEs and born-globals have been particularly active in filing patents internationally, notably in the United States Patents and Trademark Office (USPTO) (GODINHO et al., 2008). For high tech firms, most of which are 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 headquarters or at a central R&D base. In Greece, there has been a number of programs (EPET I and II, STRIDE Hellas) aimed at increasing the scientific and innovative production of the country. In spite of steady increases in overall production of patents and publications since the 1980s, the country is still a clear innovation laggard in the context of the European Union (COLLINS and PONTIKAKIS, 2006).

## DATA AND METHODOLOGY

### Data

Patent co-inventorship has been used to explore collaboration patterns of inventors (EJERMO and KARLSSON, 2006). However, patent data have 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 and 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 patent systems, particularly in the USPTO (ARCHIBUGI and COCO, 2005).

Our empirical analysis is based on patenting activity involving Portuguese and Greek assignees and inventors. We constructed a population dataset of patents obtained from the USPTO. While the USPTO does not represent the entire innovation output of foreign countries, it tends to contain a valuable portion knowledge generated in a country. 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, instead of European Patent Office (EPO), is justified for several reasons.

First, we want to include the interactions of firms based in foreign countries with local inventors based in the focal peripheral economy. This particular case (for instance, a firm that conducts innovation in the U.S. 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. Second, the European Patent Office (EPO) treats design innovation separately (i.e., there are no design patents), which makes it impossible to use our proxy for tacit knowledge innovation. Third, EPO provides information not only on patents granted, but also includes on the listings applications not yet granted, applications withdrawn, applications deemed to be rejected or withdrawn, among others, for a total of 12 different status. This creates a number of problems, for instance it doesn't allow us to estimate the number of patents a firm possesses, since a search by assignee yields a number of references that are not actual patents (they are applications, patents rejected, etc.). Fourth, the EPO search engine mixes search fields (for instance, company name and street name), which results in unreliable results. And fifth, in Europe it is possible to apply for a patent in the local office of the country (instead of EPO), so many applications are done only in two or three countries and not in EPO; but if these patents are valuable enough, are also likely to be submitted to USPTO. We did, however, conduct an empirical analysis with EPO data. The results are incomplete, since we are missing several variables (Design, MNE, Leader), but the coefficients are consistent with our theory. Based on our partial results, we believe that EPO data would be consistent with the results obtained using USPTO patents, such that the USPTO displays a realistic picture of the invention activity in these peripheral economies.

It is important to emphasize that, while the setting of our study is Portugal and Greece, our sample captures the entirety of these countries' innovation systems, which comprises a set of assignees and inventors located in 44 countries. It includes every firm in the world that patents using a Portuguese or Greek inventor and every inventor in the world that works for a Portugal or Greece-based firm. Obviously, such interactions are better captured by USPTO rather than by local patent data.

We collected all USPTO patents associated with the Portuguese and Greek innovation systems in batches. First we collected all the patents that listed at least one assignee based in Portugal. The second batch 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 duplicate observations (patents included in both batches because they had both assignee and inventors based in Portugal) and also dropped patents assigned to individuals, in order to focus on the patenting activity of companies. We arrived to a first subset of 503 unique patents corresponding to the Portuguese national system of innovation. We repeated the same steps for Greece, constructing a second subset with 864 unique patents corresponding to the Greek national system of innovation. We "pooled" both subsets into one dataset, which we used for our main empirical models. We distinguished the country-subsets by using a dummy variable (*GREE_NSI*) for the patents that are linked to Greece. The final dataset (after dropping a duplicate patent) contains 1,366 unique patents.

**Variable definitions**

***Dependent variable***

- *International dispersion of the network of inventors* (*INV_DISP*): we constructed our dependent variable in two steps. First we computed the Herfindahl index of inventor concentration at the country level. 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, the associated Herfindahl index *'H'* is equal to: $0.75^2 + 0.25^2 = 0.625$. If all inventors are located in one country, the Herfindahl index is equal to 1. Since we are interested in the dispersion rather than the concentration of 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 Herfindahl index '*H'*, such that:

$Y = 1 - H$

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.

***Independent variables***

- *Inventor-country GDP per capita (IC_GDP*): we use GDP as a proxy for the type of country where inventors are located (i.e. core, peripheral, emerging). This indicator is longitudinal and corresponds to the year each patent was filed. 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).
- *Firm innovative leadership (LEADER*): *LEADER* is a dummy variable for firms in the upper quartile of the sample in terms of their patent pool. We operationalized 'patent pool' as the natural logarithm of the number of USPTO patents issued to each company.
- *Tacit Knowledge activity (DESIGN)*: is operationalized by a dummy variable for any "design patent" in our dataset. According to the USPTO description, a "design patent" protects "the way an article looks", in contrast to a "utility patent", which protects "the way an article is used and works". In practical terms, a design patent has a "D" before the number. In the literature, design knowledge has been described as the combination of both explicit components and tacit ones, also dubbed "know-x" (WONG and RADCLIFFE, 2000). The "know-x" component is the ability to select the right piece of

information and to use it in the right way, at a right time and place, to carry out a design. In the same vein, other authors (ARORA et al., 2001; LEONARDI and BAILEY, 2008; YOO et al., 2006) have describe different aspects of design as having a significant tacit component. All of this is consistent with our arguments that (1) design contains tacit elements and (2) design usually requires co-location or proximity of inventors.

**Interactions terms and control variables**

- *Tacit knowledge activities by innovation leaders (LEAD_X_DES)*: this interaction term is the multiplication of *LEADER* and *DESIGN* and reflects the effect of doing innovation in design if the assignee is an innovation "leader", compared to the effect of doing design by any other assignee who is a "laggard".
- *Multinational company (MNE)*: we searched for information on every patent assignee; we considered MNE any firm which had operations in more than one country (not counting sales exports). Universities or research organization with only local operations were not considered MNEs. As our data goes back to 1975, it contains a number of defunct firms or assignees that left no trace on the internet. In these cases, we adopted an inclusive criterion, considering the assignee as 'MNE' if at least one inventor in the patent was located in a country different than that of the assignee.
- *Geographical dispersion of assignees (ASSI_DISP)*: the international dispersion of assignees calculated in the same way we calculated the dispersion of inventors.
- *Number of inventors (NUM_INV)*: number of inventors participating in the patent.
- *Other organizations (OTHER_ORG): dummy variable for organizations that are not business firms (for example universities, research institutions, etc.)*

We also incorporated technology controls. We used each patent class and classify it into a taxonomy based on HALL et al. (2001), which organizes utility patent classes into six major categories. Those six categories are 1) Chemical, 2) Computers and Communications, 3) Drugs & Medical, 4) Electrical & Electronic, 5) Mechanical and 6) Others. Design constitutes a seventh category of patents. In addition, we also controlled for whether the patent is part of the Portugal or Greece subsets and used year fixed effects.

**Estimation**

Table 1 presents the summary statistics for our sample. The dependent variable is bounded, with a minimum value of 0 when all the inventors are in the same country, and a maximum observed value of 0.800. Of the patents in the data set, 694 (50.8 %) only have one inventor-country, which means there was no international collaboration involved. The other 49.2 % 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. The median firm in our sample holds approximately 40 patents. In terms of correlations (Table 2), “International dispersion of the network of inventors” is positively correlated with GDP per capita, implying that in core countries, inventors have access to more extended innovation networks.

[Insert Tables 1-2 about here]

We employ 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 and WEINER, 2012; LAURSEN and SALTER, 2006; MUDAMBI and HELPER, 1998; RAGOZZINO and REUER, 2011).

Multicollinearity diagnostic checks were performed by running each model with an OLS regression and calculating variance inflation factors (VIFs). All the estimates showed values of less than 3, well below the commonly accepted threshold of 10 for VIF values (CHATTERJEE and PRICE, 1991) . Finally, we acknowledge that there may be other factors not included in our model that affect both location and inventor dispersion. For this reason we do not take our coefficients as indicators of causality but rather as indicators of associations between constructs.

## RESULTS

We ran three regression models to test our hypotheses (see Table 3). All models use censored Tobit analysis and the dependent variable is the dispersion of inventors across countries (measured for each focal patent).

Model 1 is the base model and Model 2 is our full model containing the interaction term *Tacit knowledge activities by innovation leaders (LEAD_X_DES)*. Model 3 is similar to Model 2 but only includes patents linked to Greece. As predicted by our Hypotheses 1, higher GDP per capita is associated with more international dispersion of inventors. This implies that inventors located in core economies have access to richer networks of innovation. This finding is consistent with our theory.

Hypothesis 2 focuses on tacit knowledge activities operationalized by design patents. We predict that design patents will be usually authored by co-located teams, due to the high component of tacit knowledge they contain. In other words, the geographical dispersion of teams involved in design patents will be less than for utility patents. The coefficients for DESIGN are negative in all models and significant in our full models 2. This is consistent with H2.

Finally, Hypothesis 3 predicts that innovation leaders are more capable to integrate tacit knowledge innovation across geographic space. Therefore, when innovation in design is carried out by leading firms, the geographical dispersion of inventor teams will be higher than for other organizations. Our interaction coefficient LEAD_X_DES is positive and significant in both model 2 and 3, consistent with H3.

[Insert Table 4 about here]

In terms of controls, MNE shows positive and significant coefficients. This is consistent with the notion that MNEs will have access to networks in multiple countries, which local firms will not be able to match. The *geographical dispersion of assignees (ASSI_DISP)* is positive and significant. This is intuitive; if a patent is coauthored by assignees dispersed in different countries, the inventors are also likely to be geographically dispersed. The coefficient for *number of inventors (NUM_INV)* is also positive and significant. This is not surprising either; the larger the group of inventors participating in the patent, the larger the chance that one or more of them is located in a different country. The coefficient for *other organizations (OTHER_ORG)* is also positive and significant. This is consistent with the notion that person-based linkages (the type favored by research institutions or universities) are easier to establish than organization-based linkages (the type favored by business firms). Finally, the coefficient for the *Greek national system of innovation (GREE_NSI)* is not significant, meaning that Greek innovators and their Portuguese counterparts do not show significantly different levels of dispersion.

To test the robustness of our data, we analyze data from other patent sources (EPO) and from other peripheral economies (Czech Republic, Slovakia and Slovenia). The data is not fully comparable, since some variables were missing. However, results (not reported here) seem consistent with our first hypothesis, that inventors in core economies are connected to more internationally dispersed inventor networks.

## CONCLUDING REMARKS AND IMPLICATIONS

The traditional development economics literature distinguishes between developed and developing countries (MEIER and 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 et al., 2012; CUERVO-CAZURRA, 2012). But, with few exceptions, the growing diversity within the developed country group has not received much attention (BENITO and NARULA, 2008; NARULA and GUIMÓN, 2010). 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.

We use the comprehensive population data set of U.S. patents issued to Portuguese and Greek assignees (organizations) and inventors (individuals) to analyze the dispersion of inventor networks across national borders in these peripheral economies. Most studies of innovation systems are either couched at the level of organizations or at the level of individual inventors.

We build on prior work on inventor networks (BALCONI et al., 2004; FLEMING and MARX, 2006; ZUCKER and DARBY, 1996) and disentangle three factors that are associated with the dispersion of those networks: the location of the inventors, the type of knowledge, and the capabilities of the firm.

The first part analyzes the association between location of inventors and the international dispersion of inventor networks. Our findings are consistent with our theory that inventors located in core innovative countries have access to more internationally dispersed inventor networks. Thus, interaction with them will provide the economic actors based in peripheral economies with the potential benefits derived from this dispersion. In contrast, too much reliance on local knowledge sources may be harmful for innovative capacity and can lead to a "technology trap" (GIULIANI, 2010).

The second part explores how the tacitness of the knowledge involved in the innovation process hinders dispersion. Consistent with our theory, we find that design patents are associated with less dispersed inventor networks. This relationship, however, is moderated by the capabilities of the firms conducting the innovation. Highly innovative firms develop capabilities that allow them to conduct this type of innovation in a more dispersed manner. These findings are consistent with our second and third hypotheses. To the best of our knowledge, this is the first empirical testing of the theoretical work of CANTWELL and SANTANGELO (1999; 2000) about the factors affecting the dispersion of tacit knowledge creation.

We believe our work has two types of implications. For academics, it opens the way to the exploration of a potentially very interesting area of inquiry: the characteristics of innovation in peripheral economies and the differences between the creation of tacit and codified knowledge in those contexts. Further work will be needed to disentangle the complex realities of these economies, but we think this a first step in that direction. For policy makers, we provide some important distinctions about the factor that may affect connectivity in peripheral economies. For economies that are striving to catch up with the core, understanding these drivers may prove to be a very valuable tool.

Concerning policy, the way to diminish the disadvantages of peripherality is to increase connectivity – by promoting the presence of locally based (domestic and foreign-owned) actors in international innovation and supply networks. Such connectivity to global value chains is a key aspect of high levels of local value creation (HUMPHREY and SCHMITZ, 2002; MUDAMBI, 2008). In this context, our findings highlight the crucial role of the individual level of analysis (networks of inventors). Such connectivity requires a strengthening of "system linkages" (HEITOR and BRAVO, 2010) and "systemic density" (GODINHO and SIMÕES, 2013). Given that linkages and networks need time to develop, consistency and predictability of policies is a key factor.

## TABLE 1: Descriptive Statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| International dispersion of inventor networks (INV_DISP) | 1366 | 0.225 | 0.240 | 0 | 0.800 |
| Inventor-country GDP per capita (IC_GDP) | 1366 | 22211 | 10263.9 | 2028 | 50371 |
| Firm innovative leadership (LEADER) | 1366 | 0.250 | 0.433 | 0 | 1 |
| Multinational company (MNE) | 1366 | 0.684 | 0.465 | 0 | 1 |
| Design (DESIGN) | 1366 | 0.138 | 0.345 | 0 | 1 |
| Geographical dispersion of assignees (ASSI_DISP) | 1366 | 0.011 | 0.074 | 0 | 1 |
| Number of inventors (NUM_INV) | 1366 | 2.856 | 1.882 | 1 | 13 |
| Non-business organization (OTHER_ORG) | 1366 | 0.147 | 0.354 | 0 | 1 |
| Design by innovation leaders (LEAD_X_DES) | 1366 | 0.008 | 0.089 | 0 | 1 |
| Greek national system of innovation (GREE_NSI) | 1366 | 0.633 | 0.482 | 0 | 1 |

## TABLE 2: Pearson Correlation Coefficients

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | International dispersion of inventor networks (INV_DIS | 1.000 | | | | | | | |
| 2 | Inventor-country GDP per capita (IC_GDP) | 0.378 | 1.000 | | | | | | |
| 3 | Firm innovative leadership (LEADER) | 0.283 | 0.188 | 1.000 | | | | | |
| 4 | Multinational company (MNE) | 0.087 | 0.087 | 0.155 | 1.000 | | | | |
| 5 | Design (DESIGN) | -0.260 | -0.154 | -0.180 | 0.066 | 1.000 | | | |
| 6 | Geographical dispersion of assignees (ASSI_DISP) | 0.103 | 0.073 | 0.111 | -0.041 | -0.061 | 1.000 | | |
| 7 | Number of inventors (NUM_INV) | 0.418 | 0.378 | 0.241 | 0.045 | 0.242 | 0.143 | 1.000 | |
| 8 | Non-business organization (OTHER_ORG) | 0.204 | 0.017 | 0.027 | -0.565 | 0.168 | 0.110 | 0.151 | 1.000 |

## TABLE 3: Tobit Regression Analysis

| DV: International dispersion of inventor networks (INV_DISP) | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Inventor-country GDP per capita (IC_GDP) | 0.0004 *** | 0.0000 *** | 0.0000 *** |
| | (0.000) | (0.000) | (0.000) |
| Firm innovative leadership (LEADER) | 0.0890 *** | 0.0685 ** | 0.0439 † |
| | (0.021) | (0.021) | (0.023) |
| Multinational company (MNE) | 0.2317 *** | 0.2258 *** | 0.1070 ** |
| | (0.029) | (0.029) | (0.033) |
| Design (DESIGN) | -0.0387 | -0.1090 * | -0.0667 |
| | (0.046) | (0.049) | (0.063) |
| Geographical dispersion of assignees (ASSI_DISP) | -0.1287 | -0.1124 | -0.1609 |
| | (0.106) | (0.105) | (0.129) |
| Number of inventors (NUM_INV) | 0.0353 *** | 0.0341 *** | 0.0123 * |
| | (0.005) | (0.005) | (0.006) |
| Non-business organization (OTHER_ORG) | 0.3168 *** | 0.3109 *** | 0.2003 *** |
| | (0.034) | (0.033) | (0.037) |
| Design by innovation leaders (LEAD_X_DES) | | 0.4160 *** | 0.4424 *** |
| | | (0.092) | (0.114) |
| Greek national system of innovation (GREE_NSI) | -0.0229 | -0.0243 | |
| | (0.020) | 0.020 | |
| Technology controls | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes |
| Constant | -0.4798 *** | -0.4723 | -0.3633 ** |
| | (0.116) | (0.115) | (0.110) |
| Observations | 1,355 | 1,355 | 854 |
| Prob>chi2 | 0.000 | 0.000 | 0.000 |
| Pseudo R2 | 0.620 | 0.631 | 0.742 |

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

## References


ABRAMOVITZ M. (1986) Catching up, forging ahead, and falling behind, *The Journal of Economic History* **46**, 385-406.

ALCÁCER J. and CHUNG W. (2007) Location strategies and knowledge spillovers, *Management Science* **53**, 760-76.

ALCÁCER J., DEZSŐ C. L. and ZHAO M. (2013) Firm rivalry, knowledge accumulation, and MNE location choices, *Journal of International Business Studies* **44**, 504-20.

ALCÁCER J. and ZHAO M. (2012) Local R&D strategies and multilocation firms: The role of internal linkages, *Management Science* **58**, 734-53.

AMBOS B. and AMBOS T. (2009) Location choice, management and performance of international R&D investments in peripheral economies, *International Journal of Technology Management* **48**, 24-41.

ANDERSSON U. and FORSGREN M. (1996) Subsidiary embeddedness and control in the multinational corporation, *International Business Review* **5**, 487-508.

ARCHIBUGI D. (1992) Patenting as an indicator of technological innovation: a review, *Science and Public Policy* **19**, 357-68.

ARCHIBUGI D. and COCO A. (2005) Measuring technological capabilities at the country level: A survey and a menu for choice, *Research Policy* **34**, 175-94.

ARORA A., FOSFURI A. and GAMBARDELLA A. (2001) *Markets for technology: The economics of innovation and corporate strategy*. MIT press.

ASHEIM B. T. and ISAKSEN A. (2002) Regional innovation systems: the integration of local ‘sticky’and global ‘ubiquitous’ knowledge, *The Journal of Technology Transfer* **27**, 77-86.

AWATE S., LARSEN M. M. and MUDAMBI R. (2012) EMNE catch-up strategies in the wind turbine industry: Is there a trade-off between output and innovation capabilities?, *Global Strategy Journal* **2**, 205-23.

BALCONI M., BRESCHI S. and LISSONI F. (2004) Networks of inventors and the role of academia: an exploration of Italian patent data, *Research Policy* **33**, 127-45.

BATHELT H., MALMBERG A. and MASKELL P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in human geography* **28**, 31-56.

BELUSSI F., SAMMARRA A. and SEDITA S. R. (2010) Learning at the boundaries in an "Open Regional Innovation System": A focus on firms' innovation strategies in the Emilia Romagna life science industry, *Research Policy* **39**, 710-21.

BENITO G. and NARULA R. (2008) States and firms on the periphery: the challenges of a globalising world, in BENITO G. and NARULA R. (Eds) *Multinationals on the Periphery*. Palgrave, London.

BOSCHMA R. A. and TER WAL A. L. J. (2007) Knowledge networks and innovative performance in an industrial district: the case of a footwear district in the South of Italy, *Industry and Innovation* **14**, 177-99.

BRESCHI S. and LISSONI F. (2009) Mobility of skilled workers and co-invention networks: an anatomy of localized knowledge flows, *Journal of Economic Geography* **9**, 439-68.

CALANTONE R. J. and STANKO M. A. (2007) Drivers of Outsourced Innovation: An Exploratory Study*, *Journal of Product Innovation Management* **24**, 230-41.

CANTWELL J. (1989) *Technological innovation and multinational corporations*. Basil Blackwell, London.

CANTWELL J. (1995) The globalisation of technology: what remains of the product cycle model?, *Cambridge journal of economics* **19**, 155-.

CANTWELL J. and MUDAMBI R. (2000) The location of MNE R&D activity: the role of investment incentives, *MIR: Management International Review*, 127-48.

CANTWELL J. and MUDAMBI R. (2005) MNE competence-creating subsidiary mandates, *Strategic management journal* **26**, 1109-28.

CANTWELL J. and MUDAMBI R. (2011) Physical attraction and the geography of knowledge sourcing in multinational enterprises, *Global Strategy Journal* **1**, 206-32.

CANTWELL J. and PISCITELLO L. (2000) Accumulating technological competence: its changing impact on corporate diversification and internationalization, *Industrial and Corporate Change* **9**, 21-51.

CANTWELL J. and PISCITELLO L. (2002) The location of technological activities of MNCs in European regions: The role of spillovers and local competencies, *Journal of International Management* **8**, 69-96.

CANTWELL J. and PISCITELLO L. (2005) Recent location of foreign-owned research and development activities by large multinational corporations in the European regions: the role of spillovers and externalities, *Regional Studies* **39**, 1-16.

CANTWELL J. and SANTANGELO G. D. (1999) The frontier of international technology networks: sourcing abroad the most highly tacit capabilities, *Information Economics and Policy* **11**, 101-23.

CANTWELL J. and SANTANGELO G. D. (2000) Capitalism, profits and innovation in the new techno-economic paradigm, *Journal of Evolutionary Economics* **10**, 131.

CHATTERJEE S. and PRICE B. (1991) *Regression Analysis by Example (2nd edn)*. Wiley, New York.

CHUNG W. and ALCÁCER J. (2002) Knowledge seeking and location choice of foreign direct investment in the United States, *Management Science* **48**, 1534-54.

CIA (2013a) Country comparison: GDP - Per capita (PPP), *The World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html*.

CIA (2013b) Country comparison: Population, *The World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/rankorder/2119rank.html*.

COHEN W. and LEVINTHAL D. (1990) Absorptive capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly* **35**, 128-52.

COLLINS P. and PONTIKAKIS D. (2006) Innovation systems in the European periphery: the policy approaches of Ireland and Greece, *Science and Public Policy* **33**, 757-69.

CUERVO-CAZURRA A. (2012) Extending theory by analyzing developing country multinational companies: Solving the Goldilocks debate, *Global Strategy Journal* **2**, 153-67.

DA MOTTA E ALBUQUERQUE E. (2000) Domestic patents and developing countries: arguments for their study and data from Brazil (1980–1995), *Research Policy* **29**, 1047-60.

EJERMO O. and KARLSSON C. (2006) Interregional inventor networks as studied by patent coinventorships, *Research Policy* **35**, 412-30.

FLEMING L. and MARX M. (2006) Managing creativity in small worlds, *California Management Review* **48**, 6.

GITTELMAN M. (2007) Does geography matter for science-based firms? Epistemic communities and the geography of research and patenting in biotechnology, *Organization Science* **18**, 724-41.

GIULIANI E. (2010) Network dynamics in regional clusters: The perspective of an emerging economy, *Papers in Evolutionary Economic Geography (PEEG)* **1014**.

GODINHO M. M. (2009) Dinâmicas regionais de inovação em Portugal. Uma análise baseada na utilização de patentes, *Finisterra* **XLVI**, 37-52.

GODINHO M. M. and SIMÕES V. C. (2013) ERAWATCH Country Reports 2011: Portugal. Luxembourg: Publications Office of the European Union.

GODINHO M. M., SIMÕES V. C., PEREIRA T., MENDONÇA S. and SOUSA V. (2004) Padrões de utilização de propriedade industrial: um estudo sobre a inovação em Portugal, *Lisbon: Instituto Nacional da Propriedade Industrial (INPI)*.

GODINHO M. M., SIMÕES V. C., PEREIRA T. and REBELO G. (2008) Estudo sobre a procura de patentes com origem em Portugal, *Lisbon: CISEP for Instituto Nacional da Propriedade Industrial (INPI)*.

GREENE W. (2000) *Econometric Analysis (4th edn)*. Prentice-Hall, Upper Saddle River, NJ.

GYÖRGY K. and VINCZE J. (1992) Privatization and innovation in the pharmaceutical industry in a post-socialist economy, *Rivista Internazionale di Scienze Sociali* **100**, 403-17.

HALL B., JAFFE A. B. and TRAJTENBERG M. (2001) The NBER patent citation data file: Lessons, insights and methodological tools. NBER Working Paper 8498, Cambridge (MA): National Bureau of Economic Research.

HEITOR M. and BRAVO M. (2010) Portugal at the crossroads of change, facing the shock of the new: People, knowledge and ideas fostering the social fabric to facilitate the concentration of knowledge integrated communities, *Technological Forecasting and Social Change* **77**, 218-47.

HENDERSON J. V. (2003) Marshall's scale economies, *Journal of Urban Economics* **53**, 1-28.

HU M.-C. (2012) Technological innovation capabilities in the thin film transistor-liquid crystal display industries of Japan, Korea, and Taiwan, *Research Policy* **41**, 541-55.

HUMPHREY J. and SCHMITZ H. (2002) How does insertion in global value chains affect upgrading in industrial clusters?, *Regional Studies* **36**, 1017-27.

JEONG Y. and WEINER R. J. (2012) Who bribes? Evidence from the United Nations' oil-for-food program, *Strategic management journal* **33**, 1363-83.

LAURSEN K. and SALTER A. (2006) Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms, *Strategic Management Journal* **27**, 131-50.

LEONARDI P. M. and BAILEY D. E. (2008) Transformational technologies and the creation of new work practices: Making implicit knowledge explicit in task-based offshoring, *MIS quarterly*, 411-36.

LIAGOURAS G. (2010) What can we learn from the failures of technology and innovation policies in the European periphery?, *European Urban and Regional Studies* **17**, 331-49.

LISSONI F. (2001) Knowledge codification and the geography of innovation: the case of Brescia mechanical cluster, *Research Policy* **30**, 1479-500.

LORENZEN M. and MUDAMBI R. (2013) Clusters, Connectivity and Catch-up: Bollywood and Bangalore in the Global Economy, *Journal of Economic Geography* **13**, 501-34.

MANOLOPOULOS D. (2010) Roles of foreign-owned subsidiaries in a European peripheral economy, *Management Research Review* **33**, 840-59.

MARIOTTI S., PISCITELLO L. and ELIA S. (2010) Spatial agglomeration of multinational enterprises: the role of information externalities and knowledge spillovers, *Journal of Economic Geography* **10**, 519-38.

MCCANN P. and MUDAMBI R. (2005) Analytical differences in the economics of geography: the case of the multinational firm, *Environment and Planning A* **37**, 1857-76.

MEIER G. M. and RAUCH J. E. (2005) *Leading Issues in Economic Development*. Oxford University Press.

MEYER K. E., MUDAMBI R. and NARULA R. (2011) Multinational enterprises and local contexts: the opportunities and challenges of multiple embeddedness, *Journal of Management Studies* **48**, 235-52.

MOLERO J. (1998) Patterns of internationalization of Spanish innovatory firms, *Research Policy* **27**, 541-58.

MOLERO J. (Ed) (1995) *Technological Innovations, Multinational Corporations and the New International Competitiveness: The Case of Intermediate Countries*. Harwood Academic Publishers, London.

MUDAMBI R. (2008) Location, control and innovation in knowledge-intensive industries, *Journal of Economic Geography* **8**, 699-725.

MUDAMBI R. and HELPER S. (1998) *The close but adversarial model of supplier relations in the US auto industry*. University of Reading, Department of Economics.

NARULA R. and GUIMÓN J. (2010) *The R&D activity of multinational enterprises in peripheral economies: evidence from the EU new member states*. UNU-MERIT, Maastricht Economic and Social Research and Training Centre on Innovation and Technology.

PAVITT K. (1988) Uses and abuses of patent statistics, *Handbook of quantitative studies of science and technology*, 509-36.

PENROSE E. (1973) International patenting and the less-developed countries, *The economic journal* **83**, 768-86.

PREBISCH R. (1962) *The Economic Development of Latin America and its Principal Problems*. United Nations, New York.

RAGOZZINO R. and REUER J. J. (2011) Geographic distance and corporate acquisitions: signals from IPO firms, *Strategic management journal* **32**, 876-94.

ROBERTS D. and THOMSON K. (2003) Sources of Structural Change in Peripheral Rural Areas: The Case of the Western Isles, 1988/89 to 1997, *Regional Studies* **37**, 61-70.

SAXENIAN A. (2006) *The new argonauts: Regional advantage in a global economy*. Harvard University Press, Cambridge, MA.

SIMÕES V. C. and GODINHO M. M. (2011) Mini Country Report/Portugal (under specific contract for the integration of INNO Policy Trendchart with ERAWATCH 2011-2012). PRO INNO Europe.

SOUITARIS V. (2001) Strategic influences of technological innovation in Greece, *British Journal of Management* **12**, 131-47.

SOUITARIS V. (2002) Firm–specific competencies determining technological innovation: A survey in Greece, *R&D Management* **32**, 61-77.

TALLMAN S. and CHACAR A. S. (2011) Communities, alliances, networks and knowledge in multinational firms: a micro-analytic framework, *Journal of International Management* **17**, 201-10.

TAVARES-LEHMANN A. T. (2008) Public Policy, FDI Attraction and Multinational Subsidiary Evolution: The Contrasting Cases of Ireland and Portugal, in BENITO G. and NARULA R. (Eds) *Multinationals on the Periphery*. Palgrave, London.

TORRE A. and RALLET A. (2005) Proximity and localization, *Regional Studies* **39**, 47-59.

WALLERSTEIN I. (1974) *The modern-world system I: Capitalist agriculture and the origins of the European world economy in the sixteenth century*. Academic Press, New York.

WONG W. and RADCLIFFE D. F. (2000) The tacit nature of design knowledge, *Technology Analysis & Strategic Management* **12**, 493-512.

YOO Y., BOLAND JR R. J. and LYYTINEN K. (2006) From organization design to organization designing, *Organization Science* **17**, 215-29.

ZUCKER L. G. and DARBY M. R. (1996) Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry, *Proceedings of the National Academy of Sciences* **93**, 12709-16.