What are the most promising conduits for foreign knowledge inflows?

Innovation networks in the Chinese Pharmaceutical Industry

This is the post-print version of Perri, A., Scalera, V. G., & Mudambi, R. (2017). What are the most promising conduits for foreign knowledge inflows? Innovation networks in the Chinese pharmaceutical industry. *Industrial and Corporate Change*, 26(2), 333-355. (https://doi.org/10.1093/icc/dtx004). Please refer to the published version and also note that this version might differ slightly from the published version.

What are the most promising conduits for foreign knowledge inflows?

Innovation networks in the Chinese Pharmaceutical Industry

Alessandra Perri*
Department of Management
Ca' Foscari University of Venice
Cannaregio 873 - 30121 Venice, Italy
Email: alessandra.perri@unive.it

Vittoria Giada Scalera
Amsterdam Business School
University of Amsterdam
Plantage Muidergracht 12 - 1018 TV Amsterdam, The Netherlands
Email: v.g.scalera@uva,nl

Ram Mudambi
Frank M. Speakman Professor of Strategy
Department of Strategic Management
Fox School of Business, Temple University
Philadelphia, PA 19122, USA
Email: ram.mudambi@temple.edu

* Corresponding author.

Acknowledgements

The authors would like to thank the Special Issue Section editors, Keld Laursen and Grazia D. Santangelo, and two anonymous referees for their constructive comments in the review process. They are also grateful to John Cantwell, Charles Dhanaraj, Francesco Lissoni, and Samuele Murtinu, as well as to the participants at the launch workshop of the Special Issue Session in Catania, the 2015 Academy of International Business, the 2015 DRUID Summer Conference, the 2015 NSF-sponsored iBEGIN Conference, the 2014 European Academy of International Business, and seminars at BI Norwegian Business School, Politecnico di Milano School of Management, and University of Amsterdam, for their helpful comments.

What are the most promising conduits for foreign knowledge inflows?

Innovation networks in the Chinese Pharmaceutical Industry

Abstract

We study innovation networks in emerging markets, where foreign actors have been identified as key sources of knowledge spillovers as well as progenitors of industry clusters. Focusing on connectivity as a channel for international knowledge sourcing, we widen our lens beyond MNEs to include critical innovative actors such as research institutions (i.e. universities and research centers). We examine the geographic dispersion of co-inventor networks generated by US patents associated with the Chinese pharmaceutical industry. Previous research has highlighted the role of organizationally driven MNE networks as enablers of foreign knowledge inflows to less developed countries. However, our results emphasize the critical role of individually motivated networks arising from advanced economy research institutions in connecting China to global knowledge networks.

JEL codes: O31, O33, F23

1. Introduction

Emerging market multinational enterprises (EMNEs) have risen to occupy important positions in a wide range of global industries (Cuervo-Cazurra and Genc, 2008; Kumaraswamy, *et al.* 2012; Lorenzen and Mudambi, 2013). A key to understanding the rapid pace with which many of these EMNEs have achieved such significant positions on the global stage is to distinguish between output and innovation capabilities (Bell and Pavitt, 1993). While output capabilities depict a firm's expertise in delivering the current generation of products and services, innovation capabilities refer to its inherent proficiency in extending and enriching existing technological knowledge. In this regard, recent studies have demonstrated that emerging country firms are quick in developing output capabilities, but not as quick in terms of innovation capabilities (Awate *et al.,* 2012).

Innovation capabilities are critical for emerging countries, as a persistent lack of such skills would prevent actors originating in these contexts from fully participating in the creation of knowledge-based intangibles that account for the bulk of all value creation in today's global economy (Mudambi, 2008; Corrado and Hulten, 2010). To develop such capabilities, innovative agents in emerging countries may seek to gain access to cutting-edge knowledge developed in other locations, by activating channels for international knowledge sourcing.

A basic requisite of international knowledge sourcing is connectivity, which we define to encompass the full range of potential linkages between one location and all other global locations. Connectivity provides the basis for the potential recombination of ideas from diverse locations. It occurs through the activation of a variety of global linkages that may serve as conduits for valuable knowledge inflows (Lorenzen and Mudambi, 2013). Several studies suggest that it may play a central role in emerging countries' technological upgrading (Amin, 2002; Davenport, 2005; Gertler and Levitte, 2005; Martin and Sunley, 2006).

Knowledge is context-specific (Hayek, 1945) and tends to develop in co-evolution with distinct national characteristics (Bartholomew, 1997). Hence, relying only on local resources exposes emerging countries to the risk of being locked into their poor and low-quality knowledge base (Martin and Sunley, 2006). Conversely, infusions of external knowledge may provide actors in these countries with the novelty and variety that are needed to feed and enrich local innovation processes, especially if the knowledge sources reside in foreign countries (Malmberg and Maskell, 2002; Bathelt *et al.,* 2004). In particular, since there is a systematic lack of parity in the knowledge levels of advanced and emerging countries (Awate *et al*., 2015), with the former being better endowed, knowledge is more likely to flow from advanced to emerging economies than the other way around. These flows create the basis for the development of innovation capabilities (Awate *et al*., 2012).

Multinational enterprises (MNEs) have been recognized as prime developers of connectivity (Gertler and Levitte, 2005; Boschma and ter Wal, 2007; Trippl *et al*., 2009; Mudambi *et al*., 2016). More generally, the literature on technological upgrading and on knowledge inflows to less developed countries has traditionally emphasized the role of firms, and particularly of MNEs, which have been identified as the most critical contributors to these processes (Dunning, 1994), either through foreign direct investment (FDI)-mediated technology spillovers (Kokko *et al*., 1996; Buckley *et al*., 2002) or through the involvement of emerging country locations in global value chains (Mudambi, 2008). In this paper, we suggest that MNEs are only one of the conduits through which foreign knowledge inflows to emerging countries may occur, and may not even be the most important one. Accordingly, we widen our lens beyond MNEs to include other actors that may play a critical role in the development of global linkages that channel foreign knowledge, namely universities and research centers (hereafter, research institutions). Using literature on knowledge networks (Hansen, 2002; Owen-Smith and Powell, 2004) and their governance modes (Inkpen and Tsang, 2005), we argue that MNEs and research institutions create and leverage fundamentally distinct conduits for international connectivity. In turn, we explore which of these conduits is more fecund in terms of generating global linkages.

This issue is particularly relevant for global networks linked to China, and emerging markets more generally. In this context, we have witnessed two very clear trends over the last decades. On one hand, we see an increasing involvement of MNEs from all over the world in the local innovative activities, primarily with the aim of accessing huge and rapidly growing markets as well as pools of skilled human capital at a competitive cost (Lewin *et al.,* 2009; Scalera *et al.*, 2015). On the other hand, researchers have highlighted a new "brain circulation" process, wherein foreign-educated scientists and engineers return to their home countries endowed with wide-ranging personal relationships with mentors and peers from their former host countries (Saxenian, 2005; Freeman, 2010).

Our research context in this study is the Chinese pharmaceutical industry. We use US patent data between 1975 and 2010 to examine the extent to which inventor networks linked to China are geographically dispersed. We consider a patent to generate an inventor network "linked to China" either when it includes one or more Chinese inventors, or when it has been assigned to a Chinese organization.

Our empirical analysis shows that compared to other conduits for international knowledge sourcing, including MNEs, research institutions activate the most dispersed knowledge networks. This is due to the key role played by their affiliated inventors, who act as catalysts for the development of personal relationships that connect geographically distributed locations. Moreover, our results show that, among research institutions, those that are located in the advanced economies are associated with the most valuable conduits for international connectivity. These conduits are generated by their resident inventors, who are the most powerful enablers of global linkages channeling foreign knowledge to emerging countries.

In further analyses we show that connectivity, in the form of geographically dispersed global linkages among inventors, has an impact on the nature of the knowledge that is used to generate innovation. More specifically, a higher geographical dispersion of inventor networks is associated with a more intense leverage of scientific knowledge in the innovation process. This finding validates our idea that foreign research institutions, through their inventors, are indelibly connected to the most basic knowledge creation capabilities: they represent the "roots of creativity" – going deeper from products to patents, to basic scientific knowledge (Florida, 2004).

Our paper contributes to the stream of literature on international knowledge sourcing and, more specifically, on the inflows of foreign knowledge to emerging countries (Bell and Pavitt, 1993; Mudambi, 2008; Kumaraswamy *et al*., 2012; Awate *et al*., 2012, 2015). We advance previous literature that has identified foreign actors as key sources of knowledge spillovers as well as progenitors of industry clusters. In particular, we show that inventors based in advanced economies' research institutions may offer domestic actors in emerging countries access to "individually motivated" global linkages, which channel knowledge resources embedded worldwide. Far from being orchestrated hierarchically and strategically such as those in MNEs, such linkages tend to grow in a serendipitous and organic way, thereby enabling far-reaching knowledge circulation. Our focus on emerging countries also complements literature on knowledge networks (Hansen, 2002; Owen-Smith and Powell, 2004) and their governance modes (Inkpen and Tsang, 2005), by adding insights from an underexplored empirical setting. Furthermore, our findings offer interesting managerial and policy implications.

2. Conceptual framework

2.1 Emerging economies, knowledge inflows and international connectivity

Firms from emerging economies often lack the knowledge and technological expertise to successfully compete with their counterparts from advanced economies (Luo and Tung, 2007; Awate *et al*., 2015), and therefore cannot rely only on their own resources to reduce the gap.

Considering that innovation activities and knowledge resources differ across countries, firms can increase their knowledge base by sourcing technological capabilities internationally (Cantwell, 1989; Kuemmerle, 1999). In particular, given the systematic lack of parity that separates the knowledge levels of advanced and emerging countries, knowledge is more likely to flow from advanced to emerging economies than in the opposite direction (Awate *et al*., 2015).

The disaggregation of global value chains has accelerated geographically dispersed knowledge sourcing as organizations increasingly use their foreign subsidiaries to tap into global centers of excellence (Hannigan *et al*., 2015). The orchestration of fine sliced value chains has played a key role in the creation of global linkages between firms and individuals located in both advanced and emerging economies (Mudambi, 2008; Mudambi and Venzin, 2010; Jensen and Pedersen, 2011). As value chains increasingly span national borders, national systems of innovation have become interconnected in global innovation networks (Narula and Guimòn, 2010).

Global value chains have not only created and intensified global linkages, but they have also changed the configuration of the associated social networks. Traditionally, global innovation networks were concentrated in advanced market economies with relatively low levels of geographical dispersion. However, both these characteristics of global innovation networks are rapidly changing. MNEs based in emerging economies are increasingly entering global innovation networks, so the dominance of advanced market economies is declining. Further, the extent of global innovation networks' geographical dispersion is rising, driven by two processes – spillover and catch-up (Mudambi, 2008). Spillover processes begin with MNEs based in advanced market economies offshoring knowledge creation to subsidiaries in emerging market economies in order to leverage the low cost resources available there (Govindarajan and Ramamurti, 2011; D'Agostino *et al.*, 2013). Spillovers from advanced economy firms spark "catch-up" processes in EMNEs that are accelerated as they strategically acquire knowledge assets in developed countries (Awate *et al.*, 2012; Li *et al.*, 2012). Both of these processes lead to geographically dispersed innovation networks spanning advanced and emerging economies.

In this context global linkages can be defined as channels that allow for the efficient transmission of different types of resources from geographically dispersed locations. In particular, international connectivity facilitates external knowledge infusions that can nourish local innovative activities, especially because it encourages the recombination of knowledge from different sources and countries (Bathelt *et al.*, 2004).

While the foregoing discussion suggests that international connectivity is a critical mechanism through which foreign knowledge inflows reach emerging economies, it also reveals that the existing literature has almost exclusively focused on the role of MNEs, which have been depicted as key enabling actors. The twentieth century literature focusing on the economic performance of developing countries has demonstrated that FDI from advanced economies' MNEs often generates spillovers (Blomström *et al.*, 1994; Kokko, 1994), through which local firms gain access to superior foreign technologies and managerial practices that can be emulated to improve domestic productivity. More recently, the central arguments of this literature have been applied to the case of emerging economies (e.g. Luo and Tung, 2007; Govindarajan and Ramamurti, 2011; Li *et al.*, 2012; Lorenzen and Mudambi, 2013). However, relatively little attention has been paid to the marked differences that separate emerging economies from the reality of poor, developing countries. We complement this literature by stressing that emerging countries have entirely different needs in terms of knowledge sourcing. Hence, in spite of the prime position accorded to MNEs in the traditional research, we maintain that other actors can play a very important role in facilitating foreign knowledge inflows and, in turn, support the process of technological upgrading in emerging countries.

More specifically, we refer to universities and research centers as they embed the roots of connectivity, facilitating global linkages that offset distances and activate knowledge inflows from worldwide sources. Focusing on these actors in the specific setting of this study is relevant as it complements established literature on the critical role of international collaborations in science in the context of advanced economies (Balconi *et al.*, 2004) with original insights from an underexplored empirical setting.

2.2 Knowledge networks in MNEs and research institutions

On the basis of the foregoing discussion, a useful way to explore the role of research institutions is to compare them to MNEs. Both these actors serve as conduits for connectivity. However, they work in fundamentally different ways. To understand these differences, we leverage the literature on knowledge networks (Hansen, 2002; Owen-Smith and Powell, 2004) and their governance modes (Inkpen and Tsang, 2005). This literature, which focuses on the knowledge dimension of networks, has highlighted that connections among organizations and individuals "*channel and direct flows of information and resources from position to position within a social structure*" (Owen-Smith and Powell, 2004: 5). Yet, networks may vary in fundamental ways depending on their structural features (Granovetter, 1973; Burt, 1992; Wasserman and Faust, 1994; Watts and Strogatz, 1998; Barabási and Albert, 1999). A critical element that influences a network's configuration and its potential for knowledge transfer is the network governance (Inkpen and Tsang, 2005), which refers to the extent to which networks are structured and hierarchical. In structured and hierarchical networks, there is usually a clear definition of roles, relationships and goals, while the reverse occurs in unstructured networks (Inkpen and Tsang, 2005).

The intra-corporate network of a MNE is a typical example of a network with structured governance, in which an obvious connection exists between ownership and hierarchical power (Inkpen and Tsang, 2005). Conversely, networks emanating from research institutions (initiated by resident inventors) are normally unstructured: they are emergent, fluid and self-organizing (David, 1998; Wagner and Leydesdorff, 2005), because no centralized authority commands their establishment and development. As a consequence, while MNEs are able to foster global linkages through their transnational organizational structure, research institutions mainly generate international connections through their inventors' ability to promote personal relationships.

To better explicate such differences, let us consider two patents included in our sample. The patent "*7,378,435*" is assigned to F. Hoffmann-La Roche, and has been developed by a team of five inventors, of which one is based in Switzerland, one in China and three in Germany. The patent "*6,805,876*" is assigned to the Johns Hopkins University, and has been developed by a team of four inventors, of which two are based in the Maryland (US), where the university is located, one in China and one in Singapore. Imagining the genesis of these innovations, it is highly unlikely that the first patent arose from the individual inventors' willingness to pursue a joint research project with peers in geographically distant R&D units. Rather, it is much more likely that the innovation emerged from a formal corporate assignment according to which the F. Hoffmann-La Roche administration mandated inventors in the home R&D office to collaborate with inventors in the Chinese and German subsidiaries on a specific matter. Conversely, as far as the second patent is concerned, it is highly unlikely that the Johns Hopkins University administration requested its two US inventors to collaborate with scientists in China and Singapore; it is much more likely that this scientific cooperation resulted from the inventors' individual motivation, which for instance could be rooted in the existence of established social ties among them. In other words, we could argue that while MNEs' global linkages are "*organizationally orchestrated*", research institutions' international networks are "*individually motivated*". Hence, in contrast to MNEs, where linkages are hierarchically designed, the main driver of research institutions' connectivity potential lies in individual researchers' social capital, which has been found to originate not only from the local laboratory network but also from the wider cosmopolitan network "*established through the social patterns* *of collaboration, collegiality and competition that exemplify scientific careers*" (Murray, 2004: 643).

In addition to the differences that characterize their governance modes, another element of distinction between MNE and research institution knowledge networks lies in their goals and motivations. In fact, while MNE networks are subject to the "proprietary technology" incentive structure, research networks respond to the "open science" incentive structure (Dasgupta and David, 1994; Balconi *et al.*, 2004).

As industrial innovators, MNEs pursue research activities to come up with ideas that can be exploited on the market, and are strongly committed to protecting the outcomes of their innovative processes as these represent sources of rents. When a network's dominant actors respond to closed regimes of "proprietary technology", the entire structure is likely to be committed to secrecy, and characterized by more tightly monitored linkages (Owen-Smith and Powell, 2004). In contrast, research institutions' primary focus is on basic research rather than the commercialization of ideas; they aim at advancing the knowledge frontier, a goal that is often driven by researchers' individual motivation to explore the unknown. The social and professional environment to which academic inventors belong stimulates their willingness to disclose the results of their innovative processes, as this increases their personal reputation (Siegel *et al.*, 2003) and sustains their career path (Merton, 1973). Accordingly, the literature on creativity and innovation management, and specifically the stream on academic inventors (Balconi *et al.*, 2004), suggests that such an "open" approach to science and technology fosters social networks among inventors working for research institutions, who collaborate over long geographical distances driven by their incentives to develop contacts with experts and to ensure the widespread diffusion of their ideas[1]. It follows that the community of scientists tends to be highly connected in spite of geographic distance. Accordingly, previous literature has demonstrated that scientists working for research-based institutions are better in "*connecting individuals and network components*" (Balconi *et al*., 2004: 144), compared to non-academic inventors.

2.3 The role of research institutions in emerging countries' international connectivity

The foregoing discussion suggests that both MNEs and research institutions are very fruitful in fostering international linkages. As far as MNEs are concerned, IB research has widely acknowledged that their transnational nature grants them an inherent opportunity to develop a wide spectrum of global linkages (Bartlett and Ghoshal, 1990), through which they move resources – including knowledge and information – across geographic space (Lorenzen and Mudambi, 2013). Like MNEs, research institutions also have a congenital potential to foster global linkages (Murray, 2004). However, in contrast to MNEs, the main driver of this potential lies in individual researchers' worldwide social networks. Hence, in spite of their common strong connectivity potential, there are fundamental differences in the ways MNEs and research institutions are governed and in the objectives they pursue. *Between these two conduits for connectivity, which is more effective in linking emerging market locations to global knowledge networks?*

To address this question, it is critical to ask how the emerging country context of this study interacts with the specific features of the two types of networks we are considering. A major characteristic of emerging countries that matters for the objectives of our analysis is the relative backwardness of the institutional infrastructure, including the intellectual property right (IPR) protection system (Zhao, 2006). In fact, emerging countries' weak appropriability regime is likely to have a very heterogeneous influence on different network types, depending on their governance mode and incentive structure. On the one hand, a network's incentive structure affects the importance that network members ascribe to the higher appropriability risk in emerging countries. Networks that are subject to an incentive structure focused on "proprietary technology" will be much more concerned about weak IPR regimes, compared to networks that are subject to the "open science" incentive structure. On the other hand, because a network's governance has an impact on the *internal* appropriability regime created within the network (Dhanaraj and Parkhe, 2006), different network types will have an inherently different ability to manage higher appropriability risks arising from the external environment. In fact, networks relying on social interaction, trust and reciprocity (Uzzi, 1997) generate stronger *internal* appropriability regimes, compared to those that are based upon contracts and hierarchical mechanisms (Williamson, 1985).

Because MNEs have a strong incentive to protect their proprietary knowledge from external appropriation (Mariotti *et al.*, 2010; Perri and Andersson, 2014), the higher risk of knowledge expropriation that is inherent to emerging countries drives them to carefully orchestrate the resources they leverage in these contexts (Zhao, 2006). For instance, in emerging countries, where many MNEs are foreign and rely on local subsidiaries, centrally mandated tasks, and in turn the innovative activities performed locally, are likely to be limited or organized in ways that allow "*to substitute for inadequate external institutions*" (Zhao, 2006: 1185). Similarly, MNEs can be expected to have lower incentives to develop internationally dispersed inventor teams involving such locations. In fact, systematically connecting emerging country inventors with central innovation teams could reduce the control over their strategic assets, while granting access to low-quality knowledge. In other words, networks governed by MNEs, which are subject to the "proprietary technology" incentive structure and respond to an organizationally orchestrated governance mode, are likely to be limited in their geographical dispersion when emerging country locations are involved.

For research institutions, very different considerations apply. In fact, as we have argued, universities and research centers are less sensitive to knowledge protection imperatives (Balconi *et al*., 2004), and are thus less concerned about threats arising from weak IPR regimes. Moreover, because they work based on personal relationships, they are likely to involve inventors who are linked by social ties. Social ties often features a high reciprocal trust, which in turn secures that the knowledge shared within the relationship will be not exploited beyond what parties expect (Dhanaraj *et al*., 2004; Dhanaraj and Parkhe, 2006). In other words, social ties are more effective than organizational-based transactions in filling the institutional void generated by emerging countries' low IPR protection. It follows that research networks, which are subject to the "open science" incentive structure and respond to a socially-based governance mode, are likely to feature a high geographical dispersion even when involving emerging country locations, as academic inventors retain the willingness to collaborate over long geographical distances as they seek linkages with field experts and the broadest possible diffusion of their ideas. Combining these arguments, we suggest that in emerging country contexts research institutions generate higher international connectivity than MNEs do:

> Hypothesis 1 (H1). *In inventor networks linked to emerging countries, those associated with research institutions are characterized by a relatively higher geographic dispersion than those associated with MNEs.*

2.4 The impact of geographic origin on the role of research institutions

In addition to the importance of structural factors such as the network governance mode, the literature on knowledge networks has also emphasized the role that nonstructural features – such as the characteristics of actors that represent the network nodes, including their geographic location (Owen-Smith and Powell, 2004) - may play in influencing the qualities of the network itself. Geographic origin is crucial in determining access to knowledge, resources and networks (Bartholomew, 1997; Phene *et al*., 2006). In this context, inventors based in research institutions located in advanced market economies have significant advantages over those located in emerging market economies and even bigger advantages over those located in the poorest countries. Accordingly, we consider how location affects research institutions' ability to generate global linkages.

In the foregoing discussion, we have suggested that in research institutions the individual plays the key role in generating the geographical dispersion of the inventor team. In fact, researchers in universities are akin to "academic entrepreneurs" in that their home institutions rarely direct their research endeavors in any significant way. However, individual inventors' ability to spur geographically dispersed networks may be sensitive to whether they perform their scientific work in research institutions based in an advanced or an emerging country.

It is well known that inventor networks have "small world" characteristics (Watts and Strogatz, 1998), so that while all relevant actors are connected, not all of them are equally central or share the same privileged position within the network (Newman, 2001; Fleming and Marx, 2006). Compared to their advanced economy peers, inventors based in research institutions from emerging countries are likely to be relatively marginal members of the scientific community, less able to connect to the global academic network. Accordingly, they may not even possess sufficient resources or know-how to successfully activate dispersed and heterogeneous networks. The relative backwardness and peripheral position of their locality may also play a role in reducing the opportunities for the creation of knowledge linkages with partners from more technologically advanced regions.

Conversely, inventors based in research institutions located in the advanced world are able to spawn a great deal of geographic dispersion in their knowledge networks, for several reasons. First, they have on average wider access to connections, scientific communities and communication infrastructures (David and Foray, 2003). Second, they usually work on frontier technology (Saxenian, 2006), which increases their attractiveness as research partners worldwide, and are typically endowed with a knowledge base that is strong enough to be leveraged in the support of effective R&D collaborations. In turn, they are likely to possess enough international experience and legitimacy to manage the complexity associated with international knowledge networks, which embrace a range of different sources of heterogeneity (Hansen, 2002). In addition, inventors based in advanced economy institutions are often hubs of professional networks incorporating former graduate students and post-doctoral researchers who have returned to their homes, often in emerging countries (Saxenian, 2005; Jonkers and Tijssen, 2008). These professional networks are important channels that enable inventors based in advanced country research institutions to achieve and maintain central positions in truly global networks. In contrast, inventors based in institutions located in emerging countries are likely to remain peripheral players, whose own networks are significantly less geographically dispersed.

Further, the stature, prestige and resources of an inventor's institution can buttress the individual's own personal network. The most prestigious and resource-rich research institutions are located in advanced market economies (Freeman, 2010), and inventors based there have greater opportunities to create and leverage serendipitous linkages formed in places like conferences and other "temporary clusters" (Maskell *et al.*, 2006).

Accordingly, the inventors based in advanced economy research institutions should drive a higher degree of connectivity. Based on this reasoning, we expect that:

> Hypothesis 2 (H2). *In inventor networks linked to emerging economies, inventors based in advanced countries research institutions are the key drivers of geographic dispersion.*

3. Empirical analysis

3.1 Empirical setting

Traditionally regarded as a highly profitable context (Ghemawat, 2010), the global pharmaceutical sector has experienced a number of major changes in the last decades, which have strongly modified the industry's competitive dynamics leading to a gradual shrinking of profit opportunities (Scalera *et al.*, 2015). Faced with these competitive challenges, big pharmaceutical companies had to significantly amend their business model over time. One opportunity for managing these challenges arise from emerging countries, whose enormous populations, growing awareness of the importance of healthcare, and increasing GDP have attracted global pharmaceutical companies whose primary expertise lies in serving mature and stagnant markets. Originally regarded exclusively as final markets where Western pharmaceutical companies could manufacture and sell their products, emerging countries have progressively become the target of knowledge intensive FDI, hosting an increasing number of foreign MNEs' R&D facilities (Scalera *et al.*, 2015). Among these locations, emerging markets like China and India take the lead.

China is one of the largest pharmaceutical markets in the world, and it represents an ideal test-bed for our hypotheses as it matches most of the conditions described in our theory development. Beyond the increasing involvement of MNEs from all over the world in local innovation processes, it has been the scenario of wide-ranging "brain circulation" processes, as local governments have strongly invested both in the education and in scientific infrastructure (Jonkers and Tijssen, 2008; Freeman, 2010). Although in the last decades it has experienced a reform of the healthcare system and a gradual transformation of the local pharmaceutical industry, which is increasingly populated by research-based companies, the market is still highly fragmented, and characterized by a complex system of sub-national segments dominated by small to medium-sized generics and over the counter drugs (OTC) manufacturers. Moreover, in spite of China' adhesion to the in the World Trade Organization (WTO) in 2001, the country is still regarded as an unsafe context for IPR protection (Zhao, 2006). In addition, the pharmaceutical industry is one of the most technology intensive sectors, but simultaneously displays a significant gap, in terms of knowledge-based activities, between advanced and emerging countries (National Science Board, 2014). Thus, it represents an interesting field for exploring how different conduits for international connectivity contribute to facilitate foreign knowledge inflows to emerging countries. Second, agents operating in this industry extensively employ patents to protect their intellectual property (IP), thus making patent information a reliable and comprehensive data source.

3.2 Data

In order to study innovative activities connected to the Chinese pharmaceutical industry, we used patent data as a proxy for innovative output. Following other studies about innovative activities in China (e.g. Zhao, 2006; Scalera *et al*., 2015), we focus on the United States Patent and Trademark Office (USPTO) data, in order to assure the originality and quality of the innovations analyzed (Archibugi and Coco, 2005).

Extant literature has already explored collaboration patterns of inventors employing patent co-inventorship (e.g. Ejermo and Karlsson, 2006; Phelps, 2010). In fact, patents provide detailed information on the team of inventors and their geographical distribution. In order to build our sample of pharmaceutical patents linked to China, we selected all USPTO patents granted between 1975 and 2010 that report at least one Chinese inventor or that were applied for by a Chinese organization. From the initial sample, we selected patents representative of the pharmaceutical industry, referring to the Drug and Medical technological fields defined by Hall *et al.* (2001)[2]. We also included design patents associated with the technological class "Pharmaceutical Devices" (D24). Finally, we excluded patents assigned to individuals, or unassigned. The sample thus generated consists of 1026 patents, emanating from 516 different assignee organizations[3].

In order to ensure the validity of our analysis, it is crucial to identify each individual inventor and determine her or his address. To do so, we complemented our patent data gathered directly from USPTO website using the "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" distributed by The Harvard Dataverse Network (see Li *et al*., 2014)[4].

3.3 Variables and model

3.3.1 Dependent variable: Geographical dispersion

To measure the degree of connectedness of the innovative actors, we employ the UPSTO and "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" location data on the address of patent inventors. Since inventions underlying patents may be the result of R&D activities that are performed in different locations, focusing on each inventor's location enables to account for the whole set of geographic locations[5] that have been involved in the generation of the innovative outcome (Li *et al*., 2014). Following the approach of Hannigan *et al.* (2015), the construction of the *Geographical dispersion* is based on the Herfindahl index, which is commonly used in industrial organization to capture the concentration of an industry (e.g., Tallman and Li, 1996). To measure the dispersion of the inventor networks, the *Geographical dispersion* $_{\mathrm{i}}$ for patent *i* is constructed as follows:

$$Geographical\ dispersion_i = 1 - \sum_{n=1}^{N} (Inv_{i,n}/Inv_i)^2$$

where $Inv_{i,n}$ is the number of inventors of patent *i* located in country *n* (N is the total number of inventors' locations mentioned in patent *i*), and Inv_i is the total number of inventors of patent i. Thus, for each patent, the more internationally dispersed is the inventor team, the higher is the value of the index. For example, if both Patent A and Patent B have four inventors each, but inventors of Patent A are located in two countries, while inventors of Patent B are located in 4 different countries, the latter inventor team shows a greater value of our geographical dispersion index.

Geographical dispersion is a censored dependent variable, which takes the minimum value of 0 when all inventors are located in the same country and an upper limit asymptotically approaching 1 as the inventors network is more dispersed across different countries (the maximum value in our sample is 0.82). To deal with such dependent variable, we adopted a Tobit regression model (Greene, 2000).

3.3.2 Explanatory variables

3.3.2.1 Typology of innovative institutions

In order to classify the actors contributing to the innovative activities in emerging economies, we distinguished between (1) research institutions, (2) MNEs and (3) single-location firms, although we only developed hypotheses on inventor networks associated with research institutions and MNEs. We have carried out a thorough work of cleaning and standardizing assignees' names and addresses. Assignees have been identified in two steps. First, we attached a unique code to all assignees with the same name and country[6]. Then, using *BvD Orbis,* we consolidated the codes for assignees with the same country and very similar names, when inconsistences derived from misspelling, presence/absence of extensions, or presence/absence of spaces between parts of the names.

For each assignee mentioned in the patent document and univocally identified, we analyzed first the institutional typology and then, in the case of commercial firms, the ownership structure, by manually inspecting the assignee name and relying on information from *BvD Orbis,* companies' websites and other online resources, i.e., Bloomberg website. As regards the commercial firms, we defined as MNE any firm that has at least one foreign subsidiary by looking at the company family tree. Because patents may be assigned either to the MNE parent company or to one of its subsidiaries for unobservable reasons (Cantwell and Mudambi, 2005), we considered each multiunit firm as an integrated strategic agent, following the approach of Zhao (2006).

The categorization of the assignee type is time variant, since we checked the status of each assignee in correspondence to the year of the patent application. This procedure enables us to take into account changes in the firm ownership structure (e.g., merger and acquisitions), which are very frequent, especially in the pharmaceutical industry.

After categorizing the assignees for each patent, we created three dummy variables: *Research_institution*, if the patent's assignee is a university or a research center, *MNE,* in case the patent has been assigned to an MNE or one of its subsidiaries, and *Single_location,* otherwise. In case of co-assigned patents, we account for the categories of all co-assignees. For instance if a patent has been assigned to a university and an MNE, both *Research_institution* and *MNE* take the value of 1.

3.3.2.2 Advanced economies innovative institutions

To account for the geographic origin of the innovative actor, we introduced the dummy variable *Advanced*, which takes the value of 1 if the assignee is located in an advanced country, and 0 otherwise. This variable is used as a control in the baseline model, but it is also interacted with our *Research_institution* variable to test *Hypothesis 2*. To build this variable, we relied on the World Bank classification of emerging countries, which is based on the level of per capita income (http://data.worldbank.org/about/country-and-lending-groups). Consequently, assignees located in countries belonging to the lower and upper middle-income groups have been classified as emerging, and the variable *Advanced* is equal to 0.

If the assignee is an MNE's foreign subsidiary, we built the variable using the location of its headquarter (Almeida and Phene, 2004; Phene and Almeida, 2008). We used *BvD Orbis* to identify the locations of the MNE headquarters.[7]

3.3.2.3 Controls

Our regression models include several assignee, patent and time controls.

Assignee innovative leadership: Innovation leaders may be able to generate more geographically dispersed knowledge networks, compared to laggard counterparts, as they can leverage greater experience and a more developed knowledge base to create and manage transnational collaborations (Cantwell, 1995). To control for this effect, we build the dummy variable *Leader,* which takes the value of 1 for assignees that are in the upper quartile (or 75th percentile) of the pharmaceutical patent pool in terms of patent production in the year prior to the patent application (*t-1*). To determine the pharmaceutical patent pool we considered all UPSTO patents granted in Drug and Medical technological fields defined by Hall et al. (2001). We measured patent production as the natural logarithm of the cumulative number of USPTO pharmaceutical patents issued by each assignee in the period 1975 – (*t-1)*. Data come from "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" (Li *et al*., 2014). If the company is part of a group or is the subsidiary of an MNE, we used the pharmaceutical patent stock of its global ultimate owner to calculate the variable. In case of co-assigned patents, *Leader* takes the value of 1, if at least one of the co-assignees is in the upper quartile.

Number of inventors of the inventor team: It is reasonable to expect that the geographical dispersion of the inventor network will be greater, the higher the number of inventors participating in it. Hence, we control for the size of the inventor team by including the variable *Team size*, measured as the number of inventors for each patent.

Design patent: Our sample includes both design and utility patents, as they represent two different aspects of upstream innovation (Scalera *et al*., 2014). While utility patents are meant to protect the way an object works and can be used, design patents protect a product's appearance (USPTO, 2005). It follows that design innovations are likely to embed a higher extent of tacit knowledge (Senker, 1995), which tend to be concentrated in fewer locations in order to minimize the loss of competences and unintended spillovers (Howells, 2002). To control for these features of design patents that could affect their inventor team's geographical dispersion, we include the dummy variable *Design* that takes the value of 1 if the patent is classified by the USPTO as a design patent, and 0 in case it is a utility patent.

Primary pharmaceutical technological class: Previous research shows that some technologies, including pharmaceutical ones, entail a higher degree of complementarity with an array of different competences in both intra- and inter-technological disciplines (Hagedoorn, 1993, 2003). Hence, patents that more clearly match the pharmaceutical field could encompass a technology-specific effect driving a higher geographical dispersion of the inventor network, due to the need to search for spatially distributed complementary competences. To control for this potential effect, we include the dummy *Pharma,* which takes the value of 1, if the patent's first technological class belongs to the pharmaceutical category, as defined in section 3.2, and 0 otherwise.

Technological breadth of the patent: Innovations relying on a broad range of technologies can potentially spawn more geographically dispersed inventor networks, as they require a richer combination of competences and resources. To control for this effect, our empirical analysis includes the variable *Tech breadth* that, for each focal patent *i,* is built as:

$$Tech\ breadth_i = 1 - \sum_{j=1}^{J} (s_{ij})^2$$

where s_{ij} is the percentage of the patents cited by focal patent *i* that belong to the technology class *j* (Jaffe and Trajtenberg, 2002; Singh, 2008).

No backward citations: Since the variable *Tech breadth* cannot be computed when the focal patent has no backward citations, for those observations we set *Tech breadth* to 0 and included the dummy *No backward citations* equal to 1 (for a similar approach see Singh, 2008).

Co-assigned patent*:* In the pharmaceutical industry, the co-application of patents as a result of R&D collaborations is relatively frequent[8] (Hagerdoon, 2003; Giuri *et al*., 2007). Patents with more than one assignee may feature more geographically distributed inventor networks, because of the ability to access wider and more heterogeneous internal and external networks (Lissoni *et al*., 2013). To account for this potential effect, we include the control variable *Co-assigned*, a dummy variable that takes the value of 1 if the patent has more than one assignee, and 0 otherwise.

IP policy changes (Year dummies)*:* Since we pool patent data over a 35-year period characterized by regulatory turbulence in the Chinese IP regime, we include three year dummy variables to control for the most relevant institutional changes that could potentially influence the ability of China to link with geographically dispersed innovation networks. These institutional changes took place in 2002, 2005 and 2007. In 2002, the Chinese Ministry of Finance and the Ministry of Science and Technology issued the so-called "China Bayh-Dole Act", a regulation emulating the U.S. Bayh-Dole Act and granting the IP developed in government founded scientific research programs to the performing organization. In 2005, the Chinese government fully complied with the requirements of the TRIPS agreement, thus moving forward in the convergence towards international standards on IP protection. Finally, in 2007, China introduced the Scientific and Technological Progress Law, with the objective of further improving the existing IP regulatory framework (Paraskevopoulou, 2013).

4. Findings

Table 1 reports descriptive statistics and bivariate correlations among all variables included in our model.

[Insert Table 1 about here]

Table 2 shows the estimated coefficients of the Tobit regressions that use *Geographical dispersion* as the dependent variable.

[Insert Table 2 about here]

All models produced statistically significant results (LR $chi^2(11)=743.82$ in Model 1, LR $chi^2(12)=744.26$ in Model 2, LR $chi^2(12)=761.83$ in Model 3, LR $chi^2(13)=766.08$ in Model 4, LR $chi^2(14)=769.35$ in Model 5). We performed likelihood ratio tests to compare Model 1 to Model 2 (LR ratio $chi^2(1)=0.43$) and to Model 3 (LR ratio $chi^2(1)=18.01$), Model 3 to Model 4 (LR ratio $chi^2(1)=4.25$) and Model 4 to Model 5 (LR ratio $chi^2(1)=3.27$). As a result, all tests show statistically significant improvements, except for the log-likelihood variation from Model 1 to Model 2.

We employed Model 1 as the baseline that includes all our controls and the moderating variables. As expected, the technological leadership of innovative organizations (*Leader*) has a positive (0.143) and significant effect ($p<0.01$ also in Model 2, 3, 4 and 5) on the inventor teams' geographic dispersion, as technologically advanced actors are endowed with appropriate knowledge and relational resources to develop and effectively manage global linkages. Moreover, as predicted, larger inventor teams are also more likely to encompass a higher geographic dispersion, as highlighted by the positive (0.013) and significant ($p<0.01$ also in Model 2, 3, 4 and 5) coefficient of the *Team size* control. Design patents show a negative (-0.128) and significant effect ($p<0.05$ also in Model 2, 3, 4 and 5) on inventor teams' geographic dispersion in accordance with arguments suggesting that design innovation embeds greater degrees of tacit knowledge (Senker, 1995). *Technological breadth* turns out to positively (0.130) and significantly ($p<0.01$ also in Model 2, 3, 4 and 5) impact the inventor teams' geographical dispersion. Moreover, consistent with our predictions, the dummy variable identifying advanced economies innovative institutions (*Advanced*) exhibits a positive (0.609) and significant coefficient ($p<0.01$ also in Model 2, 3, 4 and 5), thus showing that innovative actors located in advanced countries spawn more internationally dispersed inventor networks compared to emerging economy innovative actors. This suggests that, in spite of the economic growth that many emerging economies have achieved in the last years and the openness policies put in place by local governments with respect to foreign investors, innovative actors located in emerging economies are still not able to generate and manage widely dispersed knowledge linkages as their peers based in advanced countries do.

In order to test our first hypothesis, we employed Model 2, 3 and 4. First, we added separately the variables for MNEs and research institutions in Model 2 and 3, respectively. Then, in Model 4 we included the two variables simultaneously. The *MNE* dummy variable turns out to be not statistically significant in Model 2, so when MNEs' global linkages are compared to both single-location firms' and research institutions' linkages they do not seem to be significantly different. The *Research_institution* dummy variable shows a positive (0.115) and significant coefficient ($p<0.01$) in Model 3, providing initial support for our idea that academic inventors play a central role in favoring foreign knowledge inflows to emerging economies through the development of socially-based, organic global networks, and their ability to better fill the institutional void created by the emerging country context's low IP protection. Moreover, further confirmation of our Hypothesis 1 is provided by the results presented in Model 4. Both the *MNE* and *Research_institution* dummy variables turn out to be positive (0.064 and 0.1525, respectively) and significant ($p<0.05$ and $p<0.01$, respectively) suggesting that, compared to single-location firms, both MNEs and research institutions generate more internationally dispersed inventor networks. However, we performed a Wald test on the coefficients of *MNE* and *Research_institution* that rejects the hypothesis of equality of the two coefficients ($F(1, 1013) = 8.70$; Prob > F = 0.0033), thereby providing evidence of the higher connectivity associated with patents assigned to universities and research institutions.

To better evaluate the magnitude of the estimated effects associated with *MNE* and *Research institution*, we calculated marginal effects. In particular, it turns out that:

$$E[Y|X,MNE=1]-E[Y|X,MNE=0]=0.031, \text{ and}$$

$$E[Y|X,Research\_institution=1]-E[Y|X,Research\_institution=0]=0.077,$$

confirming that - other things being equal - the *Research_institution* effect on the geographical dispersion of inventor networks is larger compared to the *MNE* one, with an increase of almost 8% and 3%, respectively. Overall, these results suggest that the involvement of academic inventors drives knowledge networks linked to emerging economies to be more internationally dispersed compared to those orchestrated by MNEs, thus ultimately offering support for Hypothesis 1.

To test Hypothesis 2, Model 5 includes the interaction term that reflects our theoretical arguments, i.e. *Research_institution*Advanced*. The coefficient of the interaction between *Research_institution* and *Advanced* (advanced countries innovative institutions) is positive (0.108) and statistically significant ($p<0.1$).[9] To assess the magnitude of the estimated effect associated with the interaction, we computed marginal effects. In particular, it results that:

$$E[Y|X,Research\_institution=1\&Advanced=1]-E[Y|X,Research\_institution=1\&Advanced=0]=0.15$$

meaning that - other things being equal - an advanced country research institution increases the geographical dispersion of inventor networks by almost 15% (statistically significant at 1%)

compared to a non-advanced country research institution. This lends support to Hypothesis 2 suggesting that inventors based in advanced country research institutions generate the most valuable conduits for connecting emerging countries to global knowledge networks. As a further robustness check of this result, we limited our sample to patents assigned to research institutions, and included the *Advanced* variable which turned out to be positive (0.593) and significant ($p<0.01$) as expected (Table 3, Model 1). Moreover, to deepen our knowledge about the major actors that drive the international connectivity of the knowledge networks linked to China, in Table 4 we present the top university-assignees located in advanced countries drawn from our sample. Top university-assignees are mainly US based and ranked among the best-performing universities in the QS ranking 2013, such as Cornell University, the University of Pennsylvania and Rutgers University.

[Insert Table 3 and Table 4 about here]

As additional robustness checks of our results, we also worked with the control variables. Specifically, in further analyses, we included a country-level measure that accounts for the endowment with innovation resources, or lack thereof, in the specific locations where our patent inventors are established[10]. This measure allows isolating the effect of the heterogeneous distribution of resources that can be used as inputs to the innovation process, which could influence the need to involve inventors from diverse geographic locations to tap into heterogeneous repositories of knowledge required to feed the innovation funnel. To build this variable, we used the Global Innovation Index (GII) 2009-2010, which is supplied by INSEAD and WIPO (World Intellectual Property Organization) and measures the overall innovation performance of countries along several dimensions (Global Innovation Index, 2010). We identified the GII score for the country of every inventor participating to our patents' inventor team, and defined a dummy variable that takes the value of 1 if at least one of the inventor in each patent is located in a country which has a GII score below the 50th percentiles, and 0 otherwise. Countries that score below the GII 50th percentiles can be considered as locations that are relatively under-endowed with innovative resources (examples of such countries are Turkey, Brazil, Philippines, Jamaica). Moreover, since the GII is a composite index and is based on a synthesis of two sub-indices of Innovation Input and Innovation Output, we replicated this measure using only the Innovation Input Index (III), which could be more appropriate to capture a location's endowment with resources that can be used as input for innovation processes. In both cases, the results obtained are in line with the ones reported in Table 2 (and are available upon request).

5. Additional evidence

5.1. The nature of innovation driven by connectivity

Our measure of the geographical dispersion of the inventor team captures the spatial distribution of knowledge networks underlying each patented innovation. Our spatial analysis is also suggestive of the nature of innovation, but only indirectly. In a previous study, Cantwell and Piscitello (1999) have suggested that a greater geographical dispersion of MNEs innovative activity is associated with the involvement in a narrower range of technological fields. More generally, existing research yielded some evidence about the influence of network structure and network composition on innovation (Phelps, 2010).

In order to provide new evidence on the relationship between the geographical dispersion of the inventor team and the nature of the resulting innovation, we undertake some additional analyses. Specifically, we analyze the citations to non-patent literature referenced to by our sample patents, and use them to capture the nature of the innovative output.

Citations in general represent a link between the patented innovation and extant knowledge. The use of non-patent literature in the innovative process suggests that the patent may contain more complex and fundamental knowledge (Brusoni *et al*., 2005; Cassiman *et al*., 2008). As suggested by Tijssen (2001: 53), non-patent references "*are likely to mirror some important features of the complex and interactive nature of knowledge flows*". Previous studies (e.g. Narin and Olivastro, 1992; Verspagen, 1999) have focused on the link between science and technology, tracing the knowledge flows between research papers and patents. Complementary analyses indicate that scientific citations signal the intensity of the interaction between science and technology, rather than the existence of a causal relationship between scientific discoveries and patented innovations (Tijssen *et al*., 2000; Meyer, 2000; Tijssen, 2001). The use of non-patent literature is likely to be an indicator of the innovative organization's ability to "*decode advances in fundamental knowledge*" (Cassiman *et al*. 2008: 613). As such, it provides some clues on the scientific nature of the underlying technology and, more specifically, on the proximity of the patented innovation to the scientific knowledge frontier (OECD, 2011). Following this approach, we use non-patent citations as an indicator providing useful information about the *science-technology relatedness* of the patents in our study (Callaert *et al*., 2006). This enables us to better understand the kind of knowledge flows enabled by global innovation networks linked to emerging economies.

Table 6 shows the results of our additional analysis. We employed *Number of citations to non-patent literature* as dependent variable, and we used the same control and explicative variables described in Section 3. We also included *Geographical dispersion* as an independent variable to account for its role in enabling the access to scientific and basic knowledge and its subsequent use in technological innovation.

The results in Table 5 show that, in innovation networks linked to emerging countries, the geographical dispersion of the inventor team has a strong positive effect on the leverage of basic scientific knowledge. In fact, the coefficient of *Geographical dispersion* is positive (1.471 and 1.338 in Model 2 and 3, respectively) and strongly significant ($p<0.01$ both in Model 2 and 3). This result connects to our findings on the key role of universities and research institutions. In line with our expectations and with the main results shown in Table 2, 3 and 4, the coefficient of *Research_institution* is positive (0.381) and strongly significant ($p<0.01$ in Model 3), confirming that universities and research centers tend to link their newly created technology to more complex and fundamental knowledge as represented by non-patent literature, thus leveraging their pre-existing bodies of scientific knowledge. In contrast, the coefficient of *MNE* is negative (-0.434) and significant ($p<0.01$ in Model 3), suggesting that multinational firms tend to contribute less to the science-technology relationship, since they more likely rely on a knowledge base that is highly output-oriented, rather than science-oriented.

[Insert Table 5 about here]

This evidence supports the underlying claim of our work, which stresses the primacy of knowledge networks activated by academic inventors as conduits for enabling valuable knowledge inflows from advanced to emerging economies. This idea is corroborated by the existence of a strong association between the geographical dispersion of inventor networks linked to emerging economies and the ability of these inventor teams to leverage scientific knowledge for producing innovation. Arguably, when academic researchers involve emerging market locations in their knowledge networks, they contribute to circulate very sophisticated information within a more diverse population of inventors. Hence, these additional results validate our claims on the importance of personal relationships initiated within research institutions for the effective diffusion of complex, fundamental and basic knowledge within emerging countries. Taken together, our empirical findings emphasize the importance for emerging markets of forging and strengthening linkages to universities and research centers in advanced economies, as these are most likely to generate both wide-ranging connectivity as well as highly fundamental knowledge, which are critical to the development of innovation capabilities.

6. Discussion and conclusions

This paper investigates the role that different conduits for international knowledge sourcing may play in facilitating foreign knowledge inflows to emerging countries. While the extant literature has highlighted the role of MNEs in this process, we broaden the discussion by focusing on the importance of research institutions and their inventors. Our analysis complements the traditional view and shows that in the Chinese context, universities and research centers are even more effective than MNEs in connecting the local innovation system to global knowledge networks. This ability to spawn international connectivity can be explained by recognizing that the knowledge networks of research institutions are operationalized, in the main, through the personal relationships of their affiliated inventors. These individually motivated networks are often generated and maintained over significant geographic distances.

Using a knowledge network lens (Hansen, 2002; Owen-Smith and Powell, 2004; Inkpen and Tsang, 2005), we argue that MNE networks and networks initiated within research institutions have different governance modes and incentive structures. Therefore, they react to the institutional voids – that are a characteristic feature of emerging economies – differently. In turn, this leads to a systematic difference in the geographical spread of their innovation networks. Specifically, MNE networks, which are organizationally orchestrated and respond to the "proprietary technology" incentive structure, are likely to be limited in their geographical dispersion when emerging country locations are involved. In contrast, research networks, which are based on social ties and respond to the "open science" incentive structure, are likely to generate a high geographical dispersion even when involving emerging country locations.

Our findings add to the literature stream on international knowledge sourcing and, more specifically, on foreign knowledge inflows into emerging countries (Bell and Pavitt, 1993; Kumaraswamy *et al.*, 2012; Awate *et al.*, 2012, 2015) by documenting the contribution that research institutions may offer in connecting non-traditional locations to worldwide networks. Widening our lens beyond MNEs to include other critical innovative actors, we integrate insights from the literature on creativity and innovation management, specifically the stream on academic inventors (Balconi *et al.*, 2004).

Throughout their career, academic inventors develop and cultivate social ties that span the boundaries of their local laboratory and connect with peers working in very diverse and distant institutions that represent their "invisible college" (Crane, 1972). Far from being influenced by the inventors' home institutions in any significant way, such distance-spanning linkages grow in directions that allow for broader learning, outstanding research activities and widespread recognition, regardless of the institutional threats that could arise when emerging market locations are involved.

The focus on emerging countries also complements the literature on knowledge networks (Hansen, 2002; Owen-Smith and Powell, 2004) and their governance modes (Inkpen and Tsang, 2005), by adding insights from an underexplored empirical setting.

Finally, our findings also confirm the critical role universities play as growth engines (Lundvall, 1992; Dasgupta and David, 1994; Cooke, 2001; Salter and Martin, 2001; Charles, Nelson, 2004). Most importantly, we suggest that more scholarly emphasis should be ascribed to these actors as conduits for international knowledge sourcing and, particularly, as enablers of emerging countries' connection to global knowledge networks.

It should be emphasized that academic inventors play a primary role in fostering internationally dispersed knowledge networks mainly when they originate from advanced countries, suggesting that the periphery's scientific establishment has not yet developed the required skills to connect with the core as an equal partner. Conversely, inventors affiliated to advanced country research institutions are very effective in maintaining productive linkages with skilled scientists and knowledge workers who are based in emerging countries, or have been educated abroad and have returned in their home-countries (Jonkers and Tijssen, 2008). This seems to suggest that, in the emerging country context, numerous individual inventors have accumulated sufficient competencies to structurally interact with advanced country peers. However, the overall scientific capacity in these emerging economies is still quite heterogeneous.

Our further analysis also offers some insights on the relationship between the network features and the nature of the resulting innovation (Phelps, 2010). Our data show that innovations resulting from more geographically widespread inventor teams embed a higher degree of scientific knowledge. Hence, we provide new evidence corroborating the idea that international connectivity, in the form of wide-ranging global linkages among inventors, contributes to the diffusion of more sophisticated knowledge. These results stress the key role that inventors working for research institutions may play in emerging countries' technological upgrading. In fact, it could be argued that connecting to global knowledge networks through personal relationships enabled by academic inventors may help emerging economies to address their deficit in generating innovation capabilities.

From a theoretical viewpoint, our results offer two key contributions. First, they add to the literature on emerging economies' technological upgrading (Luo and Tung, 2007; Govindarajan and Ramamurti, 2011; Li *et al.*, 2012; Lorenzen and Mudambi, 2013), by documenting the need for these countries to establish more sophisticated types of knowledge networks. As countries evolve from a "developing" to an "emerging" status, the upgrading of their national innovation systems can be more effectively achieved by conduits to organizations that produce foundational knowledge. This marks a difference from the 20th century literature on spillovers to developing countries (Blomström *et al.*, 1994; Kokko, 1994), which focused on MNEs as critical knowledge sources. Second, these findings add to the knowledge network literature (Hansen, 2002; Owen-Smith and Powell, 2004), by highlighting the existence of a relationship between the geographical dispersion of knowledge networks and the nature of resulting innovation. Altogether, this relationship validates our arguments on the primacy of academic inventors as conduits for basic and fundamental knowledge from the advanced world within the context of emerging economies.

Our results also seem to be consistent with previous research suggesting that universities and research centers seldom have a direct impact on commercial firms' creation of new products and services (Pavitt, 2001). In fact, while firms are successful in this latter dimension, given their strong motivation toward the (often short-term) objective of market success, research institutions' focus on basic science and technology may provide a greater contribution to the development of more sophisticated, long-term innovation capabilities, by offering a better understanding of underlying technological phenomena (Fleming and Sorenson, 2004). Not surprisingly, previous research has shown that only firms that adopt very "open" search strategies and invest in R&D draw upon university knowledge for their innovative activities (Laursen and Salter, 2004). Overall, our results offer renewed support for the statement according to which "*at best, foreign investment from the core might contribute to the incremental mastery of manufacturing techniques and upgrading of local suppliers. Even the most successful newly industrializing countries are destined to remain imitators as long as leading-edge skill and technology reside in the corporate research labs and universities in the core*." (Saxenian, 2005: 38).

6.1. Managerial and policy implications

Our study offers several implications to both policy makers and managers. First, our findings suggest that both local and global policy-makers aiming at involving emerging countries in global knowledge networks should design policies that target advanced country universities and research centers, along with FDI attraction strategies. In the past, such policies have mainly addressed MNEs, as these have long been considered the most important conduit for foreign knowledge inflows. Our findings show that research institutions can play an even more effective role in facilitating worldwide connections that involve emerging market locations, thereby channeling advanced technological knowledge into emerging country innovation systems. In other words, we show that organic, serendipitous conduits are very important in facilitating the inflow of foreign knowledge into emerging countries, and may considered as crucial complements to the hierarchical, strategic pipelines of MNEs. This is a very important mechanism to be explored; in fact, if the foreign knowledge inflows activated by such conduits are actually fruitful, they can promote emerging countries' technological catch-up (Giuliani *et al.*, 2016), by stimulating the development of pure innovative capabilities, which leverage mainly fundamental and scientific knowledge (Cassiman *et al.*, 2008; Awate *et al.*, 2012). In fact, in many instances, emerging economies have caught up in terms of output capabilities, but still lag in terms of innovative capabilities (Awate *et al.*, 2012), and the latter are based on scientific knowledge (Bell and Pavitt, 1993).

It is important to emphasize that while policy makers are often tempted to implement activist policies, they may function better as "enablers" than "actors" in this context. Their role is to create an environment for connectivity to thrive, not to actually fund linkages, since these are likely to have unintended consequences in terms of incentives. In fact, our arguments on the dynamics of the creation and development of research networks suggest that these are self-organizing, and do not require any centralized authority to orchestrate their functioning.

One reason why these knowledge networks initiated within university/research institution conduits are so valuable is that they are less sensitive to IP protection. As our theoretical development suggests, scientists are more interested in "primacy", while firms and managers are more interested in "secrecy" (Mudambi and Swift, 2009). With a primacy objective, IPR is less important, since the inventor only wishes to have acknowledgement, rather than a claim to the pecuniary proceeds of the knowledge. Hence, even if ties are in place within MNE conduits, it is reasonable to argue that there will not be much knowledge flowing within them in presence of appropriability risks. In fact, since MNEs consider China as a weak IPR country (Zhao, 2006), they are likely to search for ways to restrain knowledge spillovers when dealing with this context. On the contrary, knowledge networks activated by individuals within research institutions will facilitate inflows that carry valuable knowledge, as they are not interested in limiting the diffusion of their research achievements.

Our study also has some managerial implications. Managers working for emerging country firms should be aware of the value of science-related knowledge inflows that mainly proceed from academic inventors affiliated to universities and research centers. Entering global value chains orchestrated by successful MNEs from the advanced world provides them with commercial opportunities. These are useful mainly in terms of generating output capabilities – and these are primarily imitative. However, linkages with advanced country research institutions provide access to the knowledge of underlying scientific and technological phenomena. Such knowledge inflows would help them to develop the innovation capabilities that they lack, thereby feeding their output capabilities with more sophisticated knowledge. This type of knowledge is critical to advance and renew the mastery of existing industrial practices, and is likely to become even more important, as contemporary technologies are increasingly based on scientific knowledge (Mazzoleni and Nelson, 2007).

6.2. Limitations and future research

Some limitations of this study are worth noting as they offer opportunities for future research. First, our empirical analyses are based on secondary data, mainly patent data. Future works could complement our findings adding micro-level inventor data, which have the potential to expand the depth and scope of this work. Differences among academic and industrial inventors in terms of carrier paths, incentives and motivations are substantial, and this can bring the analysis to a more fine-grained level, further clarifying the mechanisms of knowledge networks' formation and governance.

Second, we focused our empirical analysis on the Chinese setting, as it represents one of the most important emerging economies and pharmaceutical markets in the world. Nevertheless, future studies may provide additional evidence expanding the scope of the analysis to other emerging economies, and showing whether and how historical, cultural and institutional heterogeneities among these countries (Hoskisson *et al.*, 2013) interact with the main relationships illustrated in this work.

Third, while this study undertakes a first attempt to demonstrate the existence of a relationship between international connectivity and the nature of the resulting innovation, future works should advance our understanding of the role of global knowledge networks in emerging countries' innovative performance and processes of technological catch-up with analyses at country-, firm-, network- and individual-level.[11]

Finally, the present work focuses on the geographical dispersion of inventor networks as a channel for international knowledge sourcing. Nevertheless, as recognized by existing studies (e.g. Chung and Yeaple, 2008), there are additional ways through which international connectivity materializes, such as strategic alliances, international joint ventures, and crossborder mergers and acquisitions. Future studies should provide further evidence on how these forms complement each other in generating international knowledge flows, considering also the different innovative actors involved and their locations.

References

Almeida, P. and A. Phene (2004), ‘Subsidiaries and knowledge creation: The influence of the MNC and host country on innovation,’ *Strategic Management Journal*, **25**, 847-864.

Amin, A. (2002), ‘Spatialities of globalization,’ *Environment and Planning A*, **34**, 385–399.

Archibugi, D. and A. Coco (2005), ‘Measuring technological capabilities at the country level: A survey and a menu for choice,’ *Research Policy*, **34**, 175-194.

Awate, S., M. M. Larsen and R. Mudambi (2012), ‘EMNE catch-up strategies in the wind turbine industry: Is there a trade-off between output and innovation capabilities?,’ *Global Strategy Journal*, **2**, 205-223.

Awate, S., M. M. Larsen and R. Mudambi (2015), ’Accessing vs. Sourcing knowledge: A comparative study of R&D internationalization between emerging and advanced economy firms,’ *Journal of International Business Studies*, **46**, 63-86.

Balconi, M., S. Breschi and F. Lissoni (2004), ‘Networks of inventors and the role of academia: An exploration of Italian patent data,’ *Research Policy*, **33**, 127-145.

Barabási, A. L. and R. Albert (1999), ‘Emergence of scaling in random networks,’ *Science*, **286**, 509-512.

Bathelt, H., A. Malmberg and P. Maskell (2004), ‘Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation,’ *Progress in Human Geography*, **28**, 31-56.

Bartlett, C. A. and S. Ghoshal. 1990. ‘The multinational corporation as an interorganizational network,’ *Academy of Management Review*. **15**(4) 603–625.

Bartholomew, S. (1997), ‘National systems of biotechnology innovation: Complex interdependence in the global system,’ *Journal of International Business Studies*, **28**, 241-266.

Bell, M. and K. Pavitt (1993), ‘Technological accumulation and industrial growth: Contrasts between developed and developing countries,’ *Industrial and Corporate Change*, **2**, 157–210.

Blomström, M., A. Kokko and M. Zejan (1994), ‘Host country competition, labor skills, and technology transfer by multinationals’, *Weltwirtschaftliches Archiv*, **3**, 521-533.

Boschma, R. A. and A. L. Ter Wal (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**, 177-199.

Brusoni, S., P. Criscuolo and A. Geuna (2005), ‘The knowledge bases of the world’s largest pharmaceutical groups: What do patent citations to non-patent literature reveal?,’ *Economics of Innovation and New Technology*, **14**, 395-415.

Buckley, P., J. Clegg and C. Wang (2002), ‘The impact of inward FDI on the performance of chinese manufacturing firms,’ *Journal of International Business Studies*, **38**, 447-–59.

Burt, R.S. (1992), *Structural holes: The Social \Structure of Competition*. Harvard University Press: Cambridge, MA.

Callaert, J., B. Van Looy, A. Verbeek, K. Debackere and B. Thijs (2006), ‘Traces of prior art: An analysis of non-patent references found in patent documents’, *Scientometrics*, **69**, 3-20.

Cantwell, J. (1989), *Technological Innovation and Multinational Corporations*. Basil Blackwell: London, UK.

Cantwell, J. (1995), ‘The globalisation of technology: What remains of the product cycle model?,’ *Cambridge Journal of Economics*, **19**, 155-155.

Cantwell, J. and R. Mudambi (2005), ‘MNE competence-creating subsidiary mandates,’ *Strategic Management Journal*, **26**, 1109-1128.

Cantwell, J. and L. Piscitello (1999), ‘The emergence of corporate international networks for the accumulation of dispersed technological competences,’ *Management International Review*, **39**, 123-147.

Cassiman, B., R. Veugelers and P. Zuniga (2008), ‘In search of performance effects of (in) direct industry science links,’ *Industrial and Corporate Change*, **17**, 611-46.

Chung, W. and S. Yeaple (2008), ‘International knowledge sourcing: Evidence from US firms expanding abroad,’ *Strategic Management Journal*, **29**, 1207-1224.

Cooke, P. (2001), ‘Regional innovation systems, clusters and the knowledge economy,’ *Industrial and Corporate Change*, **10**, 945–974.

Corrado, C. and C. Hulten (2010), ‘How do you measure a technological revolution?,’ *American Economic Review*, **100**, 99-104.

Crane, D. (1972). *The Invisible College*. University of Chicago Press, Chicago, IL.

Cuervo-Cazurra, A. and M. Genc (2008), ‘Transforming disadvantages into advantages: Developing-country MNEs in the least developed countries,’ *Journal of International Business Studies*, **39**, 957-979.

D'Agostino, L. M., K. Laursen and G. D. Santangelo (2013), 'The impact of R&D offshoring on the home knowledge production of OECD investing regions,' *Journal of Economic Geography*, **13**, 145-175.

Dasgupta, P. and P. David (1994), 'Toward a new economics of science,' *Research Policy*, **23**, 487–521.

Davenport, S. (2005) 'Exploring the role of proximity in SME knowledge-acquisition,' *Research Policy*, **34**, 683–702.

David, P. A. (1998). 'Communication norms and the collective cognitive performance of "invisible colleges",' in *Creation and Transfer of Knowledge*. Springer: Berlin & Heidelberg, Germany, pp. 115-163..

David, P. A. and D. Foray (2003), 'Economic fundamentals of the knowledge society,' *Policy Futures in Education*, **1**, 20-49.

Dhanaraj C, M. Lyles, H. Steensma and L. Tihanyi. (2004), 'Managing tacit and explicit knowledge transfer in IJVs: The role of relational embeddedness and the impact on performance,' *Journal of International Business Studies,* **35**, 428–443.

Dhanaraj, C., and A. Parkhe (2006), 'Orchestrating innovation networks,' *Academy of Management Review*, **31**, 659-669.

Dunning, J H. (1994), 'Multinational enterprises and the globalization of innovatory capacity,' *Research Policy*, **23**, 67–88.

Ejermo, O. and C. Karlsson (2006), 'Interregional inventor networks as studied by patent co-inventorships,' *Research Policy*, **35**, 412-430.

Fleming, L. and M. Marx, (2006), ‘Managing creativity in small worlds,’ *California Management Review*, **48**, 6-27.

Fleming, L. and O. Sorenson (2004), ‘Science as a map in technological search,’ *Strategic Management Journal*, **25**, 909–928.

Florida, R. (2004), ‘America’s looming creativity crisis,’ *Harvard Business Review*, **82**, 122-136.

Freeman, R. B. (2010). ‘Globalization of scientific and engineering talent: International mobility of students, workers, and ideas and the world economy,’ *Economics of Innovation and New Technology*, **19**, 393-406.

Gertler, M. S. and Y. M. Levitte (2005), ‘Local nodes in global networks: The geography of knowledge flows in biotechnology innovation,’ *Industry and Innovation*, **12**, 487–507

Ghemawat, P. (2010), *Strategy and the Business Landscape*. Pearson: Upper Saddle River, N.J.

Giuliani, E., A. Martinelli and R. Rabellotti (2016), ‘Is co-invention expediting technological catch up?: A study of collaboration between emerging country firms and EU inventors,’ *World Development*, **77**, 192-205.

Giuri, P., M. Mariani, S. Brusoni, G. Crespi, D. Francoz, A. Gambardella, W. Garcia- Fontes, A. Geuna, R. Gonzales, and D. Harhoff (2007), ‘Inventors and invention processes in Europe: Results from the PatVal-EU survey,’ *Research Policy*, **36**, 1107-1127.

Global Innovation Index (2010), *‘Global Innovation Index 2009-2010’*, available at: https://www.globalinnovationindex.org/userfiles/file/GII-2009-2010-Report.pdf (accessed 10 January 2014).

Govindarajan, V. and R. Ramamurti (2011), ‘Reverse innovation, emerging markets, and global strategy,’ *Global Strategy Journal*, **1**, 191-205.

Granovetter, M. S. (1973). ‘The strength of weak ties,’ *American Journal of Sociology*, 1360-1380.

Greene, W. (2000). *Econometric Analysis*. Prentice-Hall: Upper Saddle River, NJ, 4th ed.

Hagedoorn, J. (1993), ‘Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences,’ *Strategic Management Journal*, **14**, 371-385.

Hagedoorn, J. (2003), ‘Sharing intellectual property right: An exploratory study of joint patenting amongst companies,’ *Industrial and Corporate Change*, **12**, 1035-1050.

Hall, B. H., A. B. Jaffe and M. Trajtenberg (2001), ‘The NBER patent citation data file: lessons, insights and methodological tools,’ *NBER Working Paper, No. 8498.*

Hannigan, T.J., M. Cano-Kollmann and R. Mudambi (2015), ‘Thriving innovation amidst manufacturing decline: The Detroit auto cluster and the resilience of local knowledge production,’ *Industrial and Corporate Change*, **24**, 613-634.

Hansen, M. T. (2002), ‘Knowledge networks: Explaining effective knowledge sharing in multiunit companies,’ *Organization Science*, **13**, 232-248.

Hayek, F. A. (1945), ‘The use of knowledge in society,’ *American Economic Review*, **35**, 519-530.

Hoskisson, R. E., M. Wright, I. Filatotchev and M. W. Peng (2013), 'Emerging multinationals from mid-range economies: The influence of institutions and factor markets,' *Journal of Management Studies*, **50**, 1295-1321.

Howells, J. R. (2002), 'Tacit knowledge, innovation and economic geography,' *Urban Studies*, **39**, 871-884.

Jaffe, A. B. and M. Trajtenberg (2002), *Patents, Citations, and Innovations: A Window on the Knowledge Economy*. MIT Press: Cambridge, MA.

Jensen, P. D. Ø. and T. Pedersen (2011), 'The economic geography of offshoring: The fit between activities and local context,' *Journal of Management Studies*, **48**, 352-372.

Jonkers, K. and R. Tijssen (2008), 'Chinese researchers returning home: Impacts on international mobility on research collaboration and scientific productivity,' *Scientometrics*, **77**, 309-333.

Kokko, A. (1994). 'Technology, market characteristics, and spillovers', *Journal of Development Economics*, **43**, 279-293.

Kokko, A., R. Tansini, and M. Zejan (1996), 'Local technological capability and productivity spillovers from FDI in the Uruguayan manufacturing sector,' *Journal of Development Studies,* **32**, 602–11.

Kuemmerle, W. (1999), 'The drivers of foreign direct investment into research and development: An empirical investigation,' *Journal of International Business Studies*, **30**,1-24.

Kumaraswamy, A., R. Mudambi, H. Saranga and A. Tripathy (2012), 'Catch-up strategies in the Indian auto components industry: Domestic firms' responses to market liberalization,' *Journal of International Business Studies*, **43**, 368-395

Inkpen, A. C. and E. W. Tsang (2005), 'Social capital, networks, and knowledge transfer,' *Academy of Management Review*, **30**, 146-165.

Laursen, K. and A. Salter (2004), 'Searching high and low: What types of firms use universities as a source of innovation?' *Research Policy*, **33**, 1201-1215.

Lewin, A. Y., S. Massini and C. Peeters (2009), 'Why are companies offshoring innovation?: The emerging global race for talent,' *Journal of International Business Studies*, **40**, 901-925.

Li, G. C., R. Lai, A. D'Amour, D. M. Doolin, Y. Sun, V. L. Torvik and L. Fleming (2014), 'Disambiguation and co-authorship networks of the US patent inventor database (1975–2010),' *Research Policy*, **43**, 941-955.

Li, J., Y. Li and D. Shapiro (2012), 'Knowledge seeking and outward FDI of emerging market firms: the moderating effect of inward FDI,' *Global Strategy Journal*, ***2***, 277-295.

Lissoni, F., F. Montobbio and L. Zirulia (2013), 'Inventorship and authorship as attribution rights: An enquiry into the economics of scientific credit,' *Journal of Economic Behavior and Organization*, ***95***, 49-69.

Lorenzen, M. and R. Mudambi (2013), 'Clusters, connectivity and catch-up: Bollywood and Bangalore in the global economy,' *Journal of Economic Geography*, **13**, 501-534

Lundvall, B.-Å. (1992), *National Systems of Innovation Towards a Theory of Innovation and Interactive Learning*. Anthem Press: London, UK, and New York, NY.

Luo, Y. and R. L. Tung (2007), International expansion of emerging market enterprises: A springboard perspective,' *Journal of International Business Studies*, **38**, 481-498.

Malmberg, A. and P. Maskell (2002), 'The elusive concept of localization economies: Towards a knowledge-based theory of spatial clustering,' *Environment and Planning A*, **34**, 429-450.

Mariotti, S., L. Piscitello and S. Elia (2010), 'Spatial agglomeration of multinational enterprises: The role of information externalities and knowledge spillovers,' *Journal of Economic Geography*, **10**, 519-38.

Martin, R. and P. Sunley (2006), 'Path dependence and regional economic evolution,' *Journal of Economic Geography*, **6**, 395–437.

Maskell, P., H. Bathelt and A. Malmberg (2006), 'Building global knowledge pipelines: The role of temporary clusters,' *European Planning Studies*, **14**(8), 997-1013.

Mazzoleni, R. and R. R. Nelson (2007), 'Public research institutions and economic catch-up,' *Research Policy*, **36**, 1512-1528.

Meyer, M. (2000), 'Does science push technology?: Patents citing scientific literature,' *Research Policy,* **29**, 409–434.

Merton, R. K., (1973). *The Sociology of Science: Theoretical and Empirical Investigations*. University of Chicago Press: Chicago, IL.

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

Mudambi, R., S. M. Mudambi, D. Mukherjee and V. G. Scalera (2016), ‘Global connectivity and the evolution of industrial clusters: From tires to polymers in Northeast Ohio,’ *Industrial Marketing Management* (in press).

Mudambi, R. and T. Swift (2009), ‘Professional guilds, tension and knowledge management,’ *Research Policy*, **38**, 736-745.

Mudambi, R. and M. Venzin (2010), ‘The strategic nexus of offshoring and outsourcing decisions,’ *Journal of Management Studies*, **47**, 1510-1533.

Murray, F. (2004), ‘The role of academic inventors in entrepreneurial firms: Sharing the laboratory life,’ *Research Policy*, **33**, 643-659.

Narin, F. and D. Olivastro (1992), ‘Status report: Linkage between technology and science’, *Research Policy*, **21**, 237-249.

Narula, R. and J. Guimón (2010), ‘The R&D activity of multinational enterprises in peripheral economies: Evidence from the EU new member states,*’ UNU-MERIT Working Paper Series No. 2010-048*.

National Science Board (2014), ‘Industry, technology, and the global marketplace,’ in *Science and Engineering Indicators 2014*. National Science Foundation: Arlington, VA, Chapter 6.

Nelson, R. R. (2004) ‘The market economy, and the scientific commons,’ *Research Policy*, **33**, 455–471.

Newman, M. E. J. (2001), ‘The structure of scientific collaboration networks,’ *Proceedings of the National Academy of Sciences*, **98**, 404-409.

OECD (2011), “Technology-science linkages”, in OECD Science, Technology and Industry Scoreboard 2011, OECD Publishing, available at: http://dx.doi.org/10.1787/sti_scoreboard-2011-25-en.

Owen-Smith, J. and W. W. Powell (2004), ‘Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community,’ *Organization Science*, **15**, 5-21.

Paraskevopoulou, E. (2013), ‘The adoption of Bayh-Dole type policies in developing countries,’. *The Innovation Policy Platform, Policy Brief.* World Bank: Washington, DC.

Pavitt, K. L. R. (2001), ‘Public policies to support basic research: What can the rest of the world learn from US theory and practice? (and what they should not learn),’ *Industrial and Corporate Change*, **10**, 761–779.

Perri, A. and U. Andersson (2014), ‘Knowledge outflows from foreign subsidiaries and the tension between knowledge creation and knowledge protection: Evidence from the semiconductor industry,’ *International Business Review*, **23**, 63-75.

Phelps, C. C. (2010), ‘A longitudinal study of the influence of alliance network structure and composition on firm exploratory innovation,’ *Academy of Management Journal*, **53**, 890-913.

Phene, A. and P. Almeida (2008), 'Innovation in multinational subsidiaries: The role of knowledge assimilation and subsidiary capabilities,' *Journal of International Business Studies*, **39**, 901-919.

Phene, A., K. Fladmoe-Lindquist and L. Marsh (2006), 'Breakthrough innovations in the U.S. biotechnology industry: The effects of technological space and geographic origin,' *Strategic Management Journal*, **27**, 369– 388.

Salter, A. and B. R. Martin (2001), 'The economic benefits of publicly funded basic research: A critical review,' *Research Policy*, **30**, 509–532.

Saxenian, A. (2005), 'From brain drain to brain circulation: Transnational communities and regional upgrading in India and China,' *Studies in Comparative International Development*, **20**, 35–61.

Saxenian, A. (2006). *The New Argonauts: Regional Advantage in a Global Economy*. Harvard University Press: Cambridge, MA.

Scalera, V. G., D. Mukherjee, A. Perri, and R. Mudambi (2014), 'A longitudinal study of MNE innovation: The case of Goodyear,' *Multinational Business Review*, **22**, 270-293.

Scalera, V. G., A. Perri and R. Mudambi (2015), 'Managing innovation in emerging economies: Organizational arrangements and resources of foreign MNEs in the Chinese pharmaceutical industry,' *Advances in International Management*, **28**, 201-233.

Senker, J. (1995), 'Tacit knowledge and models of innovation,' *Industrial and Corporate Change*, **4**, 425-447.

Siegel, D. S., D. A. Waldman, L. E. Atwater and A. N. Link (2003), 'Commercial knowledge transfers from universities to firms: improving the effectiveness of university-industry collaboration,' *Journal of High Technology Management Research*, **14**, 111–133.

Singh, J. (2008), 'Distributed R&D, cross-regional knowledge integration and quality of innovative output,' *Research Policy*, **37**, 77-96.

Tallman, S. and J. Li (1996), 'Effects of international diversity and product diversity on the performance of multinational firms,' *Academy of Management Journal*, **39**, 179-196.

Tijssen, R. J. (2001), 'Global and domestic utilization of industrial relevant science: Patent citation analysis of science–technology interactions and knowledge flows', *Research Policy*, **30**, 35-54.

Tijssen, R.J.W., R. K. Buter and Th. N. Van Leeuwen (2000), 'Technological relevance of a national science base: Validation and analysis of citation linkages between patents and research papers', *Scientometrics*, **47**, 389-412.

Trippl, M., F. Toedtling and L. Lengauer (2009), 'Knowledge sourcing beyond buzz and pipelines: Evidence from the Vienna software sector,' *Economic Geography*, **85**, 443-462.

USPTO (2005), '*Handbook of classification, US Department of Commence'*, available at: www.uspto.gov/web/offices/opc/documents/handbook.pdf (accessed 7 February 2014).

Uzzi, B. (1997), 'Social structure and competition in interfirm networks: The paradox of embeddedness,' *Administrative Science Quarterly*, **42**, 35-67.

Verspagen, B. (1999), ‘Large firms and knowledge flows in the Dutch R&D system: A case study of Philips Electronics,’ *Technology Analysis & Strategic Management*, **11**, 211-233.

Wagner, C. S. and L. Leydesdorff (2005), ‘Network structure, self-organization, and the growth of international collaboration in science’, *Research Policy*, **34**, 1608-1618.

Wasserman, S. and K. Faust (1994), *Social Network Analysis: Methods and Applications*. Cambridge University Press: Cambridge, UK.

Watts, D. and S. Strogatz, S. (1998), ‘The collective dynamics of small world networks,’ *Nature*, **393**, 440-442.

Williamson, O. E. (1985), *The Economic Institutions of Capitalism*. Simon and Schuster: New York, NY.

Zhao, M. (2006), ‘Conducting R&D in countries with weak intellectual property rights protection,’ *Management Science*, **52**, 1185-1199.

Table 1. Descriptive statistics and correlation table.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)Geographic dispersion	1										
(2)Advanced	0.665	1									
(3)MNE	0.257	0.320	1								
(4)Research_institution	-0.045	-0.250	-0.432	1							
(5)Leader	0.471	0.470	0.480	-0.043	1						
(6)Team size	0.146	0.090	0.129	0.073	0.137	1					
(7)Design	-0.113	-0.059	-0.022	-0.230	-0.127	-0.217	1				
(8)Pharma	-0.040	-0.012	-0.023	-0.107	-0.023	0.057	0.164	1			
(9)Tech breadth	0.088	0.105	0.081	-0.132	-0.020	-0.069	0.120	-0.040	1		
(10)No backward citations	-0.021	-0.100	-0.039	0.138	-0.002	0.067	-0.143	-0.043	-0.437	1	
(11)Co-assigned	-0.017	-0.121	0.062	0.265	0.052	0.210	-0.105	0.050	-0.006	0.048	1
Obs.	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026
Mean	0.199	0.528	0.340	0.361	0.319	3.845	0.086	0.682	0.274	0.178	0.105
Std. Dev.	0.235	0.499	0.474	0.48	0.466	3.073	0.28	0.466	0.292	0.383	0.307
Min	0	0	0	0	0	1	0	0	0	0	0
Max	0.82	1	1	1	1	31	1	1	0.893	1	1

Table 2. Tobit regression results (Dependent variable = Geographical dispersion).

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Leader	0.1432***	0.1493***	0.1287***	0.1018***	0.0849***
	(0.0261)	(0.0277)	(0.0260)	(0.0290)	(0.0302)
Team size	0.0128***	0.0130***	0.0135***	0.0128***	0.0136***
	(0.0038)	(0.0039)	(0.0038)	(0.0038)	(0.0038)
Design	-0.1281**	-0.1255**	-0.1071**	-0.1104**	-0.1116**
	(0.0519)	(0.0520)	(0.0517)	(0.0521)	(0.0513)
Pharma	-0.0277	-0.0282	-0.0190	-0.0142	-0.0126
	(0.0249)	(0.0249)	(0.0246)	(0.0247)	(0.0246)
Tech breadth	0.1301***	0.1313***	0.1381***	0.1369***	0.1363***
	(0.0437)	(0.0437)	(0.0432)	(0.0431)	(0.0430)
No backward citations	0.0535	0.0535	0.0460	0.0437	0.0464
	(0.0349)	(0.0348)	(0.0344)	(0.0344)	(0.0343)
Co-assigned	0.0645	0.0657*	0.0298	0.0137	0.0188
	(0.0393)	(0.0393)	(0.0394)	(0.0401)	(0.0402)
Advanced	0.6089***	0.6107***	0.6368***	0.6400***	0.5923***
	(0.0327)	(0.0329)	(0.0338)	(0.0340)	(0.0413)
MNE		-0.0172		0.0644**	0.0813**
		(0.0262)		(0.0313)	(0.0323)
Research_institution			0.1149***	0.1525***	0.0847*
			(0.0271)	(0.0328)	(0.0492)
Research_institution * Advanced					0.1080*
					(0.0595)
Cons	-0.4394***	-0.4386***	-0.5051***	-0.5312***	-0.4960***
	(0.0426)	(0.0425)	(0.0462)	(0.0485)	(0.0507)
Year dummies	Included	Included	Included	Included	Included
Obs.	1026	1026	1026	1026	1026
Log likelihood (LL)	-320.728	-320.511	-311.725	-309.601	-307.967
χ^2	743.82***	744.26***	761.83***	766.08***	769.35***
Pseudo R^2	0.537	0.537	0.550	0.553	0.555

Note: Standard errors in parentheses

*p<0.1, ** p<0.05, *** p<0.01

Table 3. Tobit regression results (Dependent variable = Geographical dispersion), subsamples analysis.

	Model (1)
Leader	0.1622*** (0.0476)
Team size	0.0079 (0.0063)
Pharma	-0.0336 (0.0357)
Tech breadth	0.1672** (0.0663)
No backward citations	0.0307 (0.0469)
Co-assigned	0.0648 (0.0453)
Advanced	0.5934*** (0.0534)
Cons	-0.3406 (0.0603)
Year dummies	Included
Obs.	370
Log likelihood (LL)	-81.389
χ^2	343.45***
Pseudo R^2	0.678

Note: Standard errors in parentheses

*p<0.1, ** p<0.05, *** p<0.01

Table 4. Top university-assignees located in advanced countries: Number of patents with Chinese inventors, and QS Rankings 2013.

University	No. of patents	QS Ranking 2013- Biological sciences	QS Ranking 2013- Pharmacy and Pharmacology	QS Ranking 2013- Life sciences and medicine
Cornell University	6	16	51-100	25
Rutgers, The State University of New Jersey	6	151-200	101-150	215
University of Minnesota	6	101-150	51-100	71
University of California	4	6	18	8
University of Texas	4	51-100	51-100	159
University of Hawaii	3	-	-	325
University of Maryland	3	101-150	-	172
University of Michigan	3	34	15	21
University of Pennsylvania	3	20	23	18
University of Wisconsin	3	31	26	34
Boston University	2	101-150	101-150	28
Johns Hopkins University	2	32	28	4
National University of Singapore	2	17	12	27
New York University	2	43	51-100	37
Purdue University	2	101-150	51-100	137
Pennsylvania State University	2	40	-	98
University of Delaware	2	-	-	-
University of Kansas	2	-	51-100	218
University of Kentucky	2	-	101-150	253
University of New Mexico	2	101-150	-	240
University of North Carolina at Chapel Hill	2	101-150	45	31
University of Pittsburgh	2	101-150	51-100	47

Note: QS Ranking 2013 by subject in columns 3 and 4; QS Ranking 2013 by faculty in column 5 (Source: http://www.topuniversities.com/university-rankings).

Table 5. Negative binomial regression results (Dependent variable= No. of citations to non-patent literature).

	Model (1)	Model (2)	Model (3)
Leader	0.0694	-0.0218	-0.0465
	(0.1363)	(0.1369)	(0.1391)
Team size	0.0351**	0.0296*	0.0436***
	(0.0176)	(0.0167)	(0.0167)
Design	-3.5808***	-3.4511***	-3.4521***
	(0.2646)	(0.2650)	(0.2668)
Pharma	-0.3576***	-0.3300***	-0.3274***
	(0.1055)	(0.1045)	(0.1037)
Tech breadth	1.6603***	1.5825***	1.6541***
	(0.1767)	(0.1769)	(0.1763)
No backward citations	0.4624***	0.4256***	0.4290***
	(0.1408)	(0.1399)	(0.1377)
Co-assigned	0.0446	0.0097	-0.0508
	(0.1644)	(0.1632)	(0.1664)
Advanced	0.6077***	0.1535	0.3650**
	(0.1312)	(0.1571)	(0.1567)
Geographical disp.		1.4705***	1.3381***
		(0.3122)	(0.3003)
Research_institution			0.3806***
			(0.128)
MNE			-0.4343***
			(0.1340)
Cons	1.8801***	1.8425***	1.6215***
	(0.1370)	(0.1336)	(0.1454)
Lnalpha	0. 8148***	0.7882***	0.7436***
	(0.0489)	(0.0492)	(0.0497)
Year dummies	Included	Included	Included
Obs.	1026	1026	1026
χ^2	305.66***	372.72***	368.28***

Note: Standard errors in parentheses; *p<0.1, ** p<0.05, *** p<0.01

---

[1] It should be noted that firms also often participate in the broader scientific community. For instance, in a study on the US biotechnology industry, Gittelman (2007) shows that small and knowledge-intensive firms are able to establish geographically dispersed knowledge-based ties in order to tap into the expertise of distant scientific partners.

[2] The Drug and Medical category as defined by Hall et al. (2001) includes four sub-categories: Drugs (sub-category code 31); Surgery and Medical Instruments (32); Biotechnology (33); and Miscellaneous – Drugs and Medicine (39).

[3] Patents included in our sample ultimately represent the innovative activity of the Chinese pharmaceutical industry. In fact, 90% of patents owned by commercial firms are granted to firms primarily operating in the pharmaceutical sector both in China and internationally, such as Shenzhen Mindray Bio-Medical Electronic Co., Ltd., F. Hoffman-La Roche Inc., Bayer AG., and Lonza AG.

[4] As "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" does not include all the USPTO design patents, we manually checked the address information of the inventors of the design patents not found in the database.

[5] The locations are identified at the country level.

[6] For assignees reporting the same name but different countries, which could be part of the same MNE group, we made further checks as explained in the text that follows.

[7] Our sample includes 108 (10.53%) co-assigned patents, i.e. patents that have more than one assignee. In these cases, the variable *Advanced* takes the value of 1, if all the co-assignees are from an advanced country.

[8] The authors are grateful to an anonymous reviewer for suggesting this point.

[9] In unreported regressions, we estimated the same models excluding from the sample patents co-assigned to both an MNE and a research institution (i.e., 25 patents). The results confirm both Hypothesis 1 and Hypothesis 2, and are available upon request. The authors are grateful to an anonymous reviewer for this suggestion.

[10] The authors are grateful to an anonymous reviewer for this suggestion.

[11] The authors are grateful to an anonymous reviewer for this suggestion.