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Publication date
2016
Document Version
Submitted manuscript
Published in
Uddevalla Symposium 2016: Geography, open innovation, diversity and entrepreneurship

Citation for published version (APA):
Perri, A., & Scalera, V. G. (2016). Global city locations and the geographical reach of knowledge networks. In I. Bernhard (Ed.), *Uddevalla Symposium 2016: Geography, open innovation, diversity and entrepreneurship: Revised papers presented at the 19th Uddevalla Symposium, 30 June-2 July, 2016, London, UK* (pp. 509-530). (Report; No. 2016:5). University West, Department of Economics and IT.

Global city locations and the geographical dispersion of knowledge networks: evidence from the Chinese Pharmaceutical Industry

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Abstract

Firms often establish knowledge linkages to geographically dispersed locations in order to source diversified knowledge. Yet, not all locations offer the same opportunities for knowledge sourcing. This study investigates the relationship between global city locations and the spatial distribution of knowledge networks linked to China. Building on previous literature suggesting that global cities exhibit both properties of local clustering and global bridging, we investigate whether the leverage of global city locations is associated with lower or higher spatial distribution of knowledge networks. Using data on the full sample of USPTO pharmaceutical patents granted between 1975 and 2010 and linked to China, our results show that, consistent with the idea of a prevailing agglomeration mechanism, global city locations are associated with a lower geographical dispersion of inventor networks. However, this relationship is contingent on both the global city profile and the characteristics of the innovative organization that coordinates the knowledge network.

Keywords: global cities, knowledge networks, agglomeration, global bridging, emerging countries

1. Introduction

To engage in the global production of knowledge, a basic prerequisite is the access to a diversified pool of knowledge that may feed the innovation process with novel and varied inputs. Literature suggests that a major channel for tapping into such a mixture of knowledge sources lies in the involvement into global knowledge networks (Lorenzen and Mudambi, 2013; Martin and Sunley, 2006), which expose participating actors to geographically distributed knowledge, thereby facilitating the access to distant and diverse technology. Such a channel is particularly useful for actors originating in emerging country locations, which may seek to establish linkages to geographically dispersed locations in order to offset the relative backwardness of their domestic knowledge base.

Yet, not all locations offer the same opportunities for knowledge sourcing. In this respect, recent literature has emphasized the unique characteristics of global cities, as geographical units that offer a wide array of advantages to actors located within their boundaries (Belderbos et al., 2014; Goerzen et al., 2013). Two major properties of global cities seem to be relevant to understand the knowledge sourcing opportunities associated with these locations, i.e. the local clustering property and the global bridging property. As far as the former is concerned, recent literature leveraging established perspectives on the externalities associated with large metropolitan areas (Jacobs, 1961) hints at the role of global cities as geographic areas featuring a strong centripetal force that drives the local clustering of knowledge sources from different locations, such that locally-generated knowledge offers extensive exposure to the global space (Belderbos et al., 2014; Doel and Hubbard, 2002). As far as the latter is concerned, global cities are also expected to serve a global bridging function, acting as hubs of knowledge production that allow for the development of geographical boundary spanning ties to internationally dispersed knowledge sources (Sassen, 2002; Glückler, 2007).

These two properties of global cities have very different implications for firms' knowledge sourcing strategies. In fact, the local clustering property makes global cities perfect locations to source knowledge of international origin. In turn, this reduces the need to further distribute innovative activities across space, since very diverse knowledge inputs can be simultaneously found within the boundaries of a single city. Conversely, the global bridging property turns global cities into gateways for linking to a variety of different locations. This increases the ease with which innovative activities can be connected across space, thus generating truly global knowledge networks.

In other words, global cities could either reduce or amplify the geographical dispersion of firms' knowledge networks, depending on which – between the local clustering and the global bridging properties – will prevail. To disentangle these two potential effects, this study investigates the relationship between global city locations and the spatial distribution of knowledge networks linked to China. We do so by analyzing inventor networks linked to the Chinese pharmaceutical industry, as highlighted in patents. More specifically, we explore how the presence of inventors in global cities influences the geographical dispersion of inventor networks linked to China. Hence, we seek to address the following research question: what is the relationship between global city locations and the geographical dispersal of knowledge networks linked to China? Empirically, we analyze all USPTO patents granted between 1975 and 2010, which report at least one Chinese inventor or which were applied for by a Chinese organization. Our results show that in general global city locations are associated with a lower geographical dispersion of inventor networks. However, this association is contingent on both the profile of the global city and the characteristics of the innovative organization that coordinate the knowledge work of the inventor teams. This study intends to contribute to the literature lying at the intersection between innovation management, international business and economic geography, by exploring how the characteristics of the places where innovation is generated affect the mechanisms of knowledge creation. We offer original evidence on the relationship between global cities and the spatial distribution of knowledge networks and, specifically, on the agglomeration mechanisms occurring within global cities and discussed by previous research (Goerzen et al., 2013; Sassen, 2001, 2002). In addition, we extend previous theoretical and empirical studies on global cities (e.g. Goerzen et al., 2013) (1) by focusing not only on the commonalities between global cities, but also on the differences separating them, and (2) by further investigating how such differences may interact with the individual innovators' profile.

2. Theoretical background

2.1. Non-local search and global knowledge networks

Creating new knowledge is a key activity for the survival of seemingly all contemporary organizations. In order to accomplish this strategic task, innovative actors need to involve in processes of search and recombination of both novel and existing knowledge inputs (Schumpeter, 1942). Previous literature has documented that search behaviors within organizations are greatly influenced by established routines and past experiences (Nelson, 1991; Malerba, 1992), which result in a widespread focus on local and familiar domains (Helfat, 1994; Stuart and Podolny, 1996; Fleming and Sorenson, 2004). While local search can be considered a reliable and efficient approach for resource-constrained firms (Pavitt, 1988; Cantwell, 1989; Helfat, 1994; Stuart and Podolny, 1996; Tripsas and Gavetti, 2000), it often prevents to uncover effective solutions to new technical problems (Postrel, 2002). In order to find inspiration for successful problem solving, companies must explore distant knowledge areas that usually embed more promising opportunities for recombination and creativity (Rosenkopf and Nerkar, 2001; Fleming and Sorenson, 2004; Rothaermel and Alexandre, 2009). Accordingly, the more diverse is the pool of knowledge that can be used to nurture the innovation funnel, the higher are the chances to generate prominent innovative outcomes (Nelson and Winter, 1982; Metcalfe, 1994; Cohen and Malerba, 2001; Fleming and Sorenson, 2001; Rosenkopf and Nerkar, 2001; Katila and Ahuja, 2002; Lazonick, 2005; Laursen and Salter, 2006; Yayavaram and Ahuja, 2008).

One critical dimension along which search processes can be broadened beyond existing localized boundaries is the geographical dimension (Phene et al., 2006). Knowledge residing in different geographical locations is inherently different. In fact, as highlighted by the literature on national innovation systems, knowledge evolves along distinct patterns of specialization in different countries (Cantwell, 1989; Patel and Pavitt, 1991). Hence, sourcing knowledge from different nations provides firms with insights from a broad set of diverse knowledge bases (Bartholomew, 1997) that may easily ensure the variety needed to generate novel technologies.

In this respect, scholars have emphasized the role of global knowledge networks (Lorenzen and Mudambi, 2013; Martin and Sunley, 2006) as channels for accessing to geographically distributed knowledge. Linkages that connect worldwide-distributed countries facilitate the exposure to technology that does not fully coincide with the participating actors' existing knowledge base and, as such, may instigate more productive innovative processes. Accordingly, the literature on connectivity, defined as the full range of potential connections between one location and all other global locations (Lorenzen and Mudambi, 2013), suggests that these linkages may work as conduits for effective circulation of tacit knowledge, thus generating fruitful opportunities for recombining ideas from diverse locations.

Geographically distributed knowledge networks are particularly important for emerging markets. Because their position is relatively peripheral compared to the locations where the bulk of the world most advanced technology develops, actors originating in such contexts are likely to reap invaluable benefits from knowledge-based linkages to more central regions (Sytch and Tatarynowicz, 2014). In fact, the opportunity to connect to distant locations avoids lock-in situations and improves the variety of the knowledge bases to which these actors gain exposure. Since value chains have disaggregated globally through the leverage of MNEs' orchestrating capabilities, the involvement of emerging country locations in worldwide knowledge networks has become increasingly frequent (Mudambi, 2008; Mudambi and Venzin, 2010; Jensen and Pedersen, 2011). Yet, all knowledge networks are not the same. Rather, they vary along several dimensions such as their structure, governance, and social capital (Granovetter, 1973; Burt, 1992; Wasserman and Faust, 1994; Watts and Strogatz, 1998; Barabási and Albert, 1999; Inkpen and Tsang, 2005).

The geographic location of the actors involved in the knowledge networks has also been identified as a factor influencing the network features (Owen-Smith and Powell, 2004; Funk, 2014; Sytch and Tatarynowicz, 2014). Locations differ depending on their spatial position, the endowment with natural resources, infrastructures and knowledge, and the distribution of activities that are performed within them. Given these sources of variation, actors that operate in different locations are likely to be exposed to very heterogeneous knowledge access opportunities and needs, which in turn will likely influence the geographical dispersion of their knowledge networks. In fact, both organization theory (Owen-Smith and Powell, 2004; Freeman and Audia, 2006) and economic geography research (Bathelt et al., 2004; Agrawal et al., 2006; Glückler, 2007; Singh and Agrawal, 2011) have put forward the idea that this locational heterogeneity is likely to shape the way networks involving different locations develop. In the words of Glückler (2007: 621-622):

" […] *place makes a difference. Borrowing the notion of the resource bundle from the theory of the growth of the firm (Penrose, 1959), a place may be conceived as a bundle of resources and opportunities with the additional characteristic of spatial contiguity. A* *place-specific resource profile conveys a source of contextuality, difference and contingency for economic development (Sayer, 1991; Bathelt and Glückler, 2005). This localized resource profile comprises the structural aspects of relationships (e.g. social capital, structural holes) as well as the material, social and institutional resources that these relationships access and transfer*."

To shed more light on this realm, in this study we focus on a specific type of locations, i.e. global cities (Sassen, 1991; Goerzen et al., 2013). In particular, we explore how the properties of global cities may influence the geographical dispersion of the networks involving these sub-national spatial units.

2.2. Global cities: international business and economic geography perspectives

The concept of global cities comes from the literature on urban studies and economic geography (e.g., Derudder et al., 2010; Friedmann, 1986; Sassen, 1991, 2002), but more recently it has been introduced in the international business literature to analyze the location choices and entry decisions of MNEs (e.g., Belderbos et al., 2014; Blevins et al., 2016; Goerzen et al., 2013; Nachum and Wymbs, 2005).

Global or world cities can be broadly defined as urban contexts that facilitate the conduct of transnational business. Relying on Sassen's pioneer works (1991), the emergence of global cities can be explained in the light of the geographical agglomeration of MNEs and their advanced service providers, which is in turn motivated by the need to reduce coordination costs and maximize the speed of information (Arzaghi and Henderson, 2008).

Global cities, such as London, New York, Los Angeles, Amsterdam, Paris, Tokyo, are intrinsically different from other cities, even within the same country, and they combine traits of both the urban dimension and the globalized economy (Sassen, 1991) – Iammarino and McCann (2016), for example, refer to global cities as "global urban centers". By definition, global cities are not only highly connected with the global networks, but they also enjoy highly central positions in the world economy (Sassen, 1991, 2002; Wall and van der Knaap, 2011). Such centrality arises from the disproportioned concentration of "*command points*" (Sassen, 2001, p.3), i.e. worldwide office networks, that accumulates within their spatial boundaries. Ultimately, global cities represent the location of the bulk of the cutting-edge business, financial and technical services (A.T. Kearney, 2015; Sassen, 2002). Hence, they exert leadership within the global markets (Sassen, 2012), being at the core of the infrastructure of the world economy and operating as hubs of economic and financial activities, culture, politics and technology, able to attract a substantially diversified pool of investments and human capital from all over the world (A.T. Kearney, 2015).

Cities defined as global cities are not necessarily characterized by large population (i.e., megacities) or industrial agglomeration (i.e., industrial clusters) (Goerzen et al., 2013), but they are fundamentally involved and central in a growing and continues flow of global linkages through which ideas, goods, services, travelers, brains, investments, and knowledge circulate, thus fuelling and reinforcing their leading role in global networks. Accordingly, Ni and Kresl (2010) find that the key driver of global cities' performance does not lie in their urban size or structure, bur rather in their connectivity.

The central and highly interconnected position global cities have in the global networks provide them unique characteristics, summarized by Goerzen et al. (2013) in the following properties: 1) high degree of international connectedness, 2) cosmopolitanism, and 3) high levels of advanced producer services. These distinctive traits are the result of a virtuous circle generated by the co-evolution between firms and locations, and reinforced by the formation of global linkages and pipelines, leveraging not only physical infrastructures – airports, ports and train stations (Burghouwt 2005; Leinbach and Capineri 2007), but also formal and informal channels, such as MNEs' networks, global value chains, personal relationships, and brain circulation (Cano-Kollmann et al., 2016; Bathelt et al., 2004; Lorenzen and Mudambi, 2013; Saxenian, 2005). Previous literature (Nachum, 2003) has highlighted that global cities' advantages directly affect the sources of costs experienced by foreign firms operating in host-country markets, defined as "liability of foreignness" (Zaheer, 1995) by international business literature, or "border effects" (McCallum, 1995) by the economic geographers. More specifically, Goerzen at al. (2013) argue that the three distinctive properties of global cities reduce the liability of foreignness perceived by MNEs' subsidiaries, by decreasing the degree of uncertainty, discrimination and complexity firms are usually exposed to when entering foreign markets.

2.3. Connectedness within knowledge networks: The role of the location of global cities

The current wave of globalization has emphasized the role of cities as knowledge sources (Iammarino and McCann, 2016). Adopting the technology-based classification prosed by

Iammarino and McCann (2006, 2010, 2013 and 2016), the spatial model of global cities is identified in the *pure agglomeration* spatial configuration, where "*the knowledge base is primarily explicit and codified, and available to any local actor and organization, and generated outside firm's boundaries, being largely created in other private and public organizations*" (Iammarino and McCann, 2016). The authors identify "*variety and promiscuity*" as the distinctive characteristics of global cities, which ultimately determine the inability to establish long-term relationships between the actors involved in the global-city knowledge network. As a result, knowledge networks based within global cities are the result of Jacobs-style externalities and non-repetitive and unforeseeable linkages between individuals and organizations (Iammarino and McCann, 2016).

Given these agglomeration mechanisms, global cities may grant access to significant amounts of wide-ranging, state-of-the-art technology of different geographic origins. In fact, beyond pulling local organizations, global cities also substantially attract subsidiaries of foreign MNEs (Goerzen et al., 2013), which contribute to generate a cosmopolitan environment where knowledge from various countries converges. It follows that linkages involving global city locations are likely to expose participating agents to sufficient levels of variety to feed their knowledge creation processes. Hence, network agents may be able to limit the geographical span of their search processes, because the access to the knowledge base embedded in global cities already provides them with enough diversity of non-local innovation inputs.

Even if global cities are traditionally associated with the agglomeration of advanced service providers, Doel and Hubbard (2002) promote global cities to a higher level, by highlighting their role as hubs of knowledge production that generates global space of ingoing and outgoing knowledge flows. Global cities "[…] *are location which not only exhibit significant agglomeration advantages, but which also primarily interact with other similar globally-oriented cities in other countries, rather than with smaller urban centres and regions within their national boundaries or even within the same macro-region* […]" (Iammarino and McCann, 2016). In other words, global cities play an increasingly critical role in ensuring direct linkages with global circuits (Sassen, 2002).

Hence, while there is a number of arguments and evidence supporting the centripetal force of global cities, and the predominance of the geographical agglomeration and concentration effects of knowledge networks involving these locations, global cities may also generate dispersion, because actors involved in global city networks may leverage such locations as gateways to get in contact with more isolated and distant peers, that they would have unlikely connected with otherwise. The superior connectedness of global cities and their highly central position play a key role in fueling this dispersion effect. The counter-argument to geographical agglomeration, often overlooked especially by the existing international business literature, is that global cities can also increase the geographical dispersion of knowledge networks, due to their bridging function to a variety of distributed opportunities, innovative sources, individuals and institutions, that increases the likelihood to have new or stronger international stimuli that bring beyond the limited city space.

To put it differently, global cities feature two critical properties that matter for understanding the knowledge sourcing opportunities associated with these locations, i.e. the local clustering property and the global bridging property (Glückler, 2007). On one hand, they exert a strong centripetal force that drives the local clustering of knowledge sources from different locations, such that locally-generated knowledge offers extensive exposure to the global space (Belderbos et al., 2014; Doel and Hubbard, 2002). On the other hand, they serve a global bridging function, acting as hubs of knowledge production that allow for the development of geographical boundary spanning ties to internationally dispersed knowledge sources (Sassen, 2002; Glückler, 2007).

These two properties of global cities have very different implications for firms' knowledge sourcing strategies. In fact, while the local clustering property lessens the need to distribute innovative activities across space, the global bridging property increases the ease with which innovative activities can be linked across space, thus generating truly global knowledge networks.

Disentangling the effects and the predominance of these mechanisms is critical to understand how global city locations influence the geographical dispersion of knowledge networks. Yet, whether global cities are positively or negatively correlated with the spatial dispersion of knowledge networks is still an open question, that deserves further investigation also from an empirical perspective.

In addition, it should also be considered that even within the spatial category of global cities, some degree of heterogeneity could exist (Goerzen et al., 2013). In particular, while the most important classification of global cities, such as Beaverstock et al. (1999), Mastercard (2015), A.T. Kearney (2015), include both "traditional" global cities located in advanced economies and "emergent" ones located in developing countries, these cities may have inherently differences that could affect their relationship with the networks configuration. According to Iammarino and McCann (2016):

> “[…] *despite the emergence of global hubs in some emerging economies, most of the world’s largest cities located in developing countries still do not exhibit the same information, financial, transportation and management bi-directional flows – together with comparable local institutional settings – that the established global cities in the world exhibit.”*

Global cities located in emerging economies suffer from the relative backwardness of the domestic institutional, cultural and infrastructural context in which they are embedded. Even if to a lesser extent compared to other domestic but peripheral locations, global cities located in emerging economies may experience comparative disadvantages with respect to their *established* counterparts, due to poorer institutional settings, less efficient infrastructures, weaker IP protection, lower international experience and legitimacy (Peng et al., 2007; Scalera et al., 2015; Wright et al., 2005, Zhao, 2006). These differences can be amplified when we include into the picture the different perception and behavior that innovation institutions originating from emerging or advanced economies may have. In particular, while innovative organizations originating from emerging economies are more likely to be satisfied with what they can find in domestic global cities in terms of services, knowledge and assets needed, advanced-countries organizations may experience more difficulties in finding wide-ranging and highly-specialized resources in emerging economies global cities, and therefore are driven to look around by using those locations as gateways to further global linkages.

We therefore claim that the predominance within global cities networks of either the agglomeration or the dispersion effect is likely to be contingent upon the origin of the global cities and of the organizations underlying the knowledge networks. To disentangle these effects, we distinguish between global cities in advanced and emerging economies, as well as between innovative organizations from advanced and emerging economies.

3. Data and methods

3.1. Empirical context

In the last few decades, China has been regarded as the most striking case of a developing country’s catch-up with the OECD economies (Kaplinsky and Messner, 2008). China’s production capabilities have improved substantially, driving the country’s industrial system to be increasingly involved in global trade flows and – most importantly – in a worldwide production network that has undergone a massive shift in manufacturing activities from North America and Western European countries to East

Asia (Altenburg et al., 2008). The innovation gap between China and the most advanced countries has also been reducing along the years. Yet, China’s capacity to develop substantial, rather than merely adaptive, technological advancements remains largely unsatisfactory and suggests that the country has still a long road to cover until it becomes an innovation leader. As this study suggests, this road can be eased and shortened through the involvement in different types of knowledge linkages that connect Chinese innovators with foreign knowledge sources, allowing for learning, skill development and technology flows. In order to empirically investigate our research question, we focus on the knowledge networks linked to the Chinese pharmaceutical industry, as highlighted in patents. The choice of this industry setting is driven by several factors. First, the pharmaceutical industry is a key setting for emerging countries, and particularly for China, which currently represents the second largest pharmaceutical market in the world (IMS, 2015). While national companies may beat foreign competitors on price, as they produce the bulk of pharmaceutical ingredients, over time the rivalry will necessarily shift to the quality of innovative drugs, thus requiring Chinese pharmaceutical companies to develop sufficient innovation capabilities to combine to their production skills. Second, the pharmaceutical industry is characterized by a high technological intensity. In this setting, patents represent a widespread protection tool as the inventions over which innovators claim a property right are usually chemical entities, which are easier to safeguard compared, for instance, to electronic or mechanical inventions (Mansfield, 1986). Thus, by using patent data, we can be relatively confident to be capturing the outcome of the industry’s innovative efforts. Third, as our focus is on the role of global city inventors, the analysis of inventor networks linked to China allows to look at both foreign and domestic global cities, since Beijing and Shanghai have grown to become important business, political and cultural centers.

3.2. Data

Following other studies about innovative activities in China (e.g. Branstetter et al., 2013; Scalera et al., 2015; Zhao, 2006), we use the United States Patent and Trademark Office (USPTO) data. This choice ensures that the innovations for which a protection right is granted have been rigorously and transparently evaluated and hence are sufficiently novel, thus being indicative of actual inventive efforts[1] (Archibugi and Coco, 2005).

To build our sample, we first identified all USPTO patents granted between 1975 and 2010, which report at least one Chinese inventor or which were applied for by a Chinese organization. From the initial sample, we only included patents representative of pharmaceutical innovations, referring to the Drug and Medical technological fields defined by Hall et al. (2001)[2]. We also included design patents containing the technological class "Pharmaceutical Devices" (D24). Finally, we excluded patents assigned to individuals, or unassigned, since we are interested in innovations that are developed within organizations. The sample thus generated consists of 1026 patents. We complemented our patent data gathered directly from USPTO website using inventor-level information from the "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" distributed by The Harvard Dataverse Network (Li et al., 2014)

3.3. Variables

Dependent variable: the *Geographical dispersion* of the network of inventors is measured at patent level, following the approach of Hannigan et al. (2015). The construction of *Geographical dispersion* is based on the Herfindahl–Hirschman Index. Since we are interested in the dispersion of the inventor networks, the *Geographical dispersion* $_i$ 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, the value of the index will increase for more internationally dispersed inventor teams. For example, if Patent X and Patent Y have six inventors each, but inventors of Patent X are located in two different countries, while inventors of Patent Y are located in six different countries, the value of our geographical dispersion index will be higher for Patent Y.

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[1] An alternative option would have been the use of patents filed to the Chinese patent office. However, there is some skepticism on the quality of these patents (The Economist, 2015).

[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).

In particular, this variable varies between a 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).

Independent variables: in order to investigate the effect of having an inventor team more or less concentrated in global cities, we build different types of ratios using information on the inventor locations, as indicated in the patent documents. First, we compute the "*GC inventors over total inventors"* dividing the number of the patent inventors located in global cities by the total number of inventors in the patent inventor team. Second, in order to distinguish between inventors located in Chinese (Beijing and Shanghai) vs. non-Chinese global cities, we build two ratios, "*Chinese GC inventors over total inventors"* and "*Non-Chinese GC inventors over total inventors",* by dividing the number of the patent inventors located respectively in Chinese/non Chinese global cities by the total number of inventors in the patent inventor team. Finally, in order to account for the distribution of a patent's global city inventors across Chinese vs. non Chinese global cities, we build the ratio "*Chinese GC inventors over total GC inventors",* by dividing the number of the inventors located in Chinese global cities by the total number of global city inventors in the patent inventor team. To identify global cities, we used the list of the top 20 cities identified in the A.T. Kearney's 2014 report on global cities[3].

Controls: We controlled for several characteristics both at the assignee- and patent-level.

First, we wanted to account for the fact that patent assignee is a multinational enterprise (MNE), because compared to other types of companies, these firms might have a higher ability to generate geographically dispersed inventor networks. In order to identify MNEs, we used a two-step procedure to analyze and standardize assignees' names and addresses. First, we attached an identification code to all assignees featuring the same name and country[4]. Then, using *BvD Orbis,* we consolidated the identification codes for assignees reporting the same country and very similar names, when inconsistences derived from presence/absence of extensions, misspelling or presence/absence of blank spaces between parts of the names.

For each univocally identified corporate assignee, we analyzed the ownership structure relying on information from *BvD Orbis,* companies' institutional websites and other

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[3] The 20 global cities are: New York, London, Paris, Tokyo, Hong Kong, Los Angeles, Chicago, Beijiing, Singapore, Washington, Brussels, Seoul, Toronto, Sydney, Madrid, Vienna, Moscow, Shanghai, Berlin, Buenos Aires.

[4] For assignees with the same name but different countries, which could belong to the same multinational group, we conducted further checks as discussed in the text that follows.

online resources such as the Bloomberg website. In particular, we defined as MNE any company that has at least one foreign subsidiary in its family tree. Because MNE patents can be assigned either to the MNE headquarters or to one of its foreign units for unobservable reasons (Cantwell and Mudambi, 2005), we followed the approach of Zhao (2006) and considered each multi-unit company as an integrated strategic agent[5]. Hence, we created the dummy variable "*MNE",* which takes the value of 1 in case the patent has been assigned to an MNE or one of its subsidiaries, and 0 otherwise. In case of co-assigned patent, MNEs take the value of 1 if at least one of the patent co-assignees is an MNE.

In order to distinguish between domestic (Chinese) and foreign (non Chinese) innovative actors, we introduced the dummy variable *Chinese Assignee,* which takes the value of 1 if the assignee is located in China, and 0 otherwise[6]. If the assignee is an MNE's foreign subsidiary, the variable was built using the location of the MNE's global ultimate owner (Almeida and Phene, 2004; Phene and Almeida, 2008), leveraging information from BvD Orbis.

The ability to spawn more geographically dispersed inventor networks could also depend on the assignee's technological capabilities. Innovation leaders typically have more experience and greater technological resources to use in favor of a more globally distributed organization of their R&D activities, compared to laggard counterparts (Cantwell, 1995). To control for this effect, we use 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 year (*t-1*). To define the pharmaceutical patent pool we considered all UPSTO patents granted in Drug and Medical technological fields defined by Hall et al. (2001). We computed patent production as the (natural logarithm of the) cumulative number of USPTO pharmaceutical patents filed by each assignee in the period 1975 – (*t-1)*, using data from the "*Disambiguation and co-authorship networks of the U.S. patent inventor database (1975 - 2010)*" (Li et al., 2014). If the assignee is part of a group or is the subsidiary of an MNE, the variable is calculated as the pharmaceutical patent stock of its global ultimate owner. In case of co-assigned patents, *Leader* takes the value of 1 if at

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[5] Since an assignee type can vary over time, we verified the type of each assignee in correspondence to the year of the patent application. This procedure allows us to account for changes in companies' ownership structure (e.g., merger and acquisitions), which are very frequent in the pharmaceutical setting.

[6] Our sample includes 12 patents co-assigned by a Chinese and one or more foreign institutions. In these cases, the variable Emerging takes the value of 1, because we applied an inclusive criterion as at least one of the assignees is Chinese.

least one of the patent co-assignees is in the upper quartile of the pharmaceutical patent pool.

Moving to the patent-level, since we expect that the geographical dispersion of the inventor network will be higher in bigger inventor teams, we control for the size of the inventor team by including the variable *Team size*, calculated as the number of inventors listed in each patent document. We also expect that the *Team size* effect can be not linear, so we also include its squared term, i.e. *Team size squared*, to capture the possible inversed U-shape relationship.

We also build the control *Pharma*, which is a dummy variable that takes the value of 1, if the first technological class of the focal patent is included in the pharmaceutical category, as defined in section 3.2, and 0 otherwise. This variable is meant to control for the fact that, according to previous literature, some technologies, such as pharmaceutical ones, are highly complementary with a range of different competences in both intra- and inter-technological disciplines (Hagedoorn, 1993, 2003). Thus, patents that more directly relate to the pharmaceutical domain might feature a technology-specific effect that generates a higher geographical dispersion of the inventor network, due to the need to combine spatially distributed complementary competences.

Innovations that span a broader range of technologies are likely to be associated with more geographically dispersed inventor networks, as they typically build on extensive sets of competences and resources (Singh, 2008) that are more easily found in diverse locations. To account for this effect, we include in our empirical analysis the variable *Technological breadth* that, for each focal patent *i*, is equal to:

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

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

Because this variable is not defined when the focal patent does not reference any existing patent as prior art, we treat these cases by setting *Technological breadth* equal to 0 and by including the dummy *No backward citations, which* equals to 1 for these observations (for a similar approach see Singh, 2008).

Finally, we wanted to account for a major change in the Chinese intellectual property (IP) regulation, i.e., the Chinese government full compliance with the requirements of the TRIPS agreement in 2005, which certainly played a critical role in the country's convergence process towards international standards on IP protection. Thus, we include a year dummy variable to control for this relevant institutional change that could potentially affect the ability of China to participate to more geographically dispersed innovation networks, that takes the value of 1 for patents that have been applied for after 2005, and 0 otherwise.

3.4. Methodology

To perform the econometric analysis, we employed a multiple regression approach. Given that our dependent variable is censored, taking a minimum value of 0 and an upper limit asymptotically approaching 1 (the maximum value in our sample is 0.82), we adopted a robust Tobit regression model.

4. Results

In Table 1, we first test our baseline model (Model 1) that includes all our control variables. The variable *MNE* has a negative (-0.056) and significant effect ($p<0.05$) on the geographical dispersion of inventor networks. This result can be explained by considering that, while MNEs are likely to generate more dispersed inventor networks compared to single-location firms, in knowledge networks linked to emerging countries, MNEs can be expected to have relatively less dispersed inventor networks particularly compared to universities and research centers, which are not subject to strict knowledge protection imperatives (Perri et al., 2015). As predicted, *Chinese Assignee* has a negative (-0.587) and significant ($p<0.001$) effect, since innovators based in emerging countries are likely to have lower ability and less opportunities to spawn international knowledge networks compared to more advanced country organizations, which may leverage a more central position in global networks. Conversely, *Leader* positively (0.175) and significantly ($p<0.001$) affects the geographical dispersion of inventor networks, since innovators' technological leadership facilitates the involvement into linkages with even very distant partners. *Team Size* has a curvilinear effect on the geographical dispersion of inventor networks. In fact, while the linear effect is positive (0.106) and significant ($p<0.001$), the quadratic effect is negative (-0.006) and significant ($p<0.001$). Bigger teams are more likely to be used for technological projects of high strategic importance to which innovative actors allocate a considerable budget. For such projects, innovative actors have an incentive to search for the best available human resources worldwide and to combine geographically separated team members who can offer fresh and diverse perspectives thus increasing the chances of successful innovation (McEvily and Marcus, 2005). However, as the team size increases beyond a certain threshold, coordination and communication problems arise (Ziller, 1957; Zender and Lawrence, 1989; Hoegl, 2005), thus making the geographic dispersion of team members too complex to manage (Allen, 1977). Finally, as predicted, *Technological Breadth* have a positive and significant effect on our dependent variable, confirming that teams innovating on broader and more complex technologies are more likely to feature a higher geographical reach.

In Model (2), we analyze the relationship between global city locations and the geographical dispersion of inventor networks linked to China. The negative (-0.140) and significant ($p<0.001$) coefficient of *GC inventors over total inventors* suggests that having a high proportion of inventors in global cities is associated with a lower geographical dispersion of inventor networks. This lends support for the idea that global cities play a centripetal force that attracts knowledge of different geographical origins, thereby allowing organizations to find the heterogeneous inputs they need to perform their innovative activities within the boundaries of the global city. Hence, teams that involve global city inventors feature less knowledge linkages with cross-border locations, most likely because of the agglomeration dynamics that animate such spatial units.

In Model (3), we unpack global city locations to account for potential heterogeneity between Chinese global cities and other global cities, which in the case of our study are all located in advanced countries. Both coefficients of *Chinese GC inventors over total* and *Non-Chinese GC inventors over total* are negative (respectively -0.126 and -0.169) significant (respectively $p<0.001$ and $p<0.01$). Hence, having a higher proportion of inventors in global city locations, regardless of their national context, is associated with lower geographical dispersion of the inventor team. In other words, both Chinese and advanced country global cities exhibit agglomeration effects that are consistent with more concentrated inventor networks. In order to ascertain whether the magnitudes of the coefficients of Chinese GC inventors over total and Non-Chinese GC inventors over total are significantly different, we also performed a Wald test that, however, did not support a statistically significant difference.

Finally, in Model (4) we analyze the distribution of global city inventors across Chinese and non-Chinese global cities. In other words, we explore how the presence of a higher number of Chinese global city inventors, compared to non-Chinese global city inventors, correlates with the geographical dispersion of inventor networks. The positive (0.145) and significant ($p<0.001$) coefficient of *GC inventors over total GC inventors* suggests that when a team’s global city inventors concentrate in Chinese global cities, the team is likely to exhibit a higher geographical dispersion. In other words, the higher the number of inventors in Chinese global cities compared to the number of inventors in non-Chinese global cities, the more geographically distributed is the team. This result, combined with previous models’ findings, seems to suggest that while both Chinese and non-Chinese global cities, if compared to other locations, are associated with lower geographical dispersion of inventor networks, when comparing the two types of global cities with each other rather than with other non-global city locations, these are not the same. In particular, compared to non-Chinese global cities, Chinese global cities are associated with a higher geographical dispersion of inventor networks. This result seems to signal that the agglomeration dynamics characterizing Chinese global cities differ from those occurring in advanced country global cities. One possible explanation is that the innovative activities that cluster in Chinese global cities are not as sophisticated as those that converge in advanced global cities. In turn, this could be associated with more geographically dispersed search processes that allow to complement what can be found in global cities. Hence, compared to non-global city locations, global cities are associated with a prevailing agglomeration effect regardless of their national context; however, compared to non-Chinese global cities, Chinese global cities are associated with global bridging effects and, in turn, with higher geographical dispersal.

To complement our analysis, we also split our sample distinguishing between inventor teams that are coordinated by Chinese vs. non-Chinese organizations, in order to understand whether the dynamics that characterize Chinese global cities vary for different types of innovative actors. In Models (1) and (2), we observe that *Chinese GC inventors over total inventors* is respectively negative (-0.540) and significant ($p<0.01$) and positive (0.171) and significant ($p<0.01$) for Chinese and non-Chinese innovative actors. This seems to suggest that while for Chinese actors, having a higher proportion of inventors in Chinese global cities is associated with lower geographical dispersion of inventor networks, the opposite is true for non-Chinese actors. One explanation for this result could be that Chinese global city locations satisfy the knowledge sourcing needs’ of Chinese organizations, whose technological skills are likely to be limited. In other words, for Chinese organizations, having a higher number of inventors located in Chinese global cities reduces the need for geographically dispersed knowledge linkages. Conversely, for non-Chinese organizations, Chinese global cities’ prevailing function is the global bridging function, as Chinese global cities may serve as gateways for reaching out less traditional locations. Similarly, in Models (3) and (4) we observe that *Chinese GC inventors over GC inventors* is positive (0.127) and significant ($p<0.001$) only for non-Chinese organizations, while it is not significant for Chinese organizations. Hence, while for Chinese organizations, the distribution of inventors across Chinese vs. non-Chinese global cities is equivalent, since both are associated with lower geographical dispersion of inventor networks, for non-Chinese organizations, having more inventors in Chinese global cities, compared to those in non-Chinese global cities, is associated with a higher geographical dispersion of inventor networks. Again, a possible explanation for this result could be that when non-Chinese organizations increase the number of inventors located in Chinese global cities, compared to those located in non-Chinese global cities, they need to broaden their geographical search through a more geographically dispersed knowledge network, since the technology that can access in Chinese global cities does not satisfy their more sophisticated needs in term of knowledge sourcing.

5. Discussion and Conclusions

Our results provide several contributions to the literature at the intersection between innovation management, international business and economic geography. We offer original evidence on the relationship between global cities and the spatial distribution of knowledge networks. First, this study suggests the existence of a negative correlation between the number of inventors located in global cities and the geographical dispersion of the inventor network. Our findings are therefore consistent with the agglomeration mechanisms occurring within global cities, and discussed by previous research (Goerzen et al., 2013; Sassen, 2001, 2002).

However, although it is generally true that tapping into a global city grants access to significant amounts of wide-ranging, state-of-the-art technology of different geographic origins, the analyzed correlation is contingent on the characteristics of the global cities and the geographical origin of the organizations underlying the knowledge networks, i.e. the patent assignees. Hence, we extend previous theoretical and empirical studies on global cities (e.g. Goerzen et al., 2013) by focusing not only on the commonalities between global cities, but also on their differences – comparing Chinese and non-Chinese global cities, i.e. emerging vs. advanced countries' global cities (considering the characteristics of our sample). On average, our results show that, *compared to other locations*, there is not a significant difference between the magnitude of the negative correlation driven by Chinese and non-Chinese global cities. Yet, interestingly, *when it comes to the comparison between Chinese and non-Chinese global cities*, we show that the first are more positively correlated with the geographical dispersion of the inventor networks. In other words, compared to non-Chinese global cities (which in our case are all located in advanced economies), Chinese global cities show a stronger ability to work as gateways of linkages with a variety of different locations.

Further, when we deepen the investigation of this phenomenon by separately analyzing the relationship for Chinese and non-Chinese patent assignees, the results enable us to better disentangle the distinctive characteristics of Chinese global cities. Specifically, our results suggest that for Chinese assignees, the overall negative correlation of the presence of inventors within global cities on the geographical dispersion of the inventor networks is driven by the domestic global cities. On the other hand, our results provide evidence that for non-Chinese assignees a positive correlation exists between the number of inventors located in Chinese global cities and the geographical dispersion of their inventor networks. This seems to suggest that Chinese global city locations satisfy the knowledge sourcing needs' of Chinese organizations, but not those of non-Chinese ones, which mainly leverage the high connectedness ensured by Chinese global cities for reaching out to other locations.

These results offer new insights not only from a theoretical, but also from a practical point of view. On the hand, most of the international business and urban studies literature dealing with global cities has mainly analyzed "traditional" global cities locate in advanced economies, while little is known about emerging global cities. In this respect, we aimed at shedding more light on the commonalities and differences existing when related to the knowledge networks' configuration. On the other hand, local government policy makers from China and emerging economies can derive interesting and valuable policy implication from our results. In particular, we provide insights on how Chinese global cities can be leveraged as gateways to connect China and Chinese inventors with the rest of world by attracting foreign innovative institutions, including MNEs, universities and research institutions.

5.1. Limitations and future research

Our work has a number of limitations that need to be acknowledged and may reflect promising avenues for future works. First, while our sample analyzes only patents linked with China, it may be that knowledge networks involving other emerging economies have different needs, and therefore may show dissimilar distribution effects driven by global cities. Hence, testing our theoretical and empirical framework on other emerging market contexts would provide interesting additional evidence.

Second, while we document the existence of a correlation between global cities and the geographical distribution of the knowledge networks, further research should investigate how the value of firms' innovation outcome benefits from the presence of inventors located in global cities. It could be that knowledge networks with inventors located in global cities are able to generate more valuable or complex innovation, due to the access to a highly diversified pool of knowledge and resources (Feldman and Florida, 1994; Jaffe et al., 1993) On the hand, these positive effects may be counterbalanced by coordination or search costs arising from the complexity of managing congested locations such as global cities. Future studies should analyze the relation between knowledge networks distribution within global cities and their innovative outcome.

Finally, since we use data from secondary sources, we are not able to univocally identify and disentangle the mechanisms underlying the formation of linkages within global cities, and test whether they are different from the ones generated elsewhere. Future studies could rely on primary data gathered directly from patent inventors and/or assignees in order to deepen the genesis of knowledge networks within global cities and the existence of specific mechanisms or channels driving this process.

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Table 1. Correlation matrix and descriptive statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Geographical dispersion	1													
2. GC inventors over total inventors	-0.2567*	1												
3. Chinese GC inventors over total inventors	-0.1893*	0.7621*	1											
4. Non-Chinese GC inventors over total inventors	-0.1223*	0.4423*	-0.2435*	1										
5. Chinese GC inventors over total GC inventors	0.1326*	0.5379*	0.8054*	-0.3099*	1									
6. MNE	0.2570*	-0.1501*	-0.0748*	-0.1214*	0.0660*	1								
7. Chinese Assignee	-0.6496*	0.2450*	0.2415*	0.0325	-0.0319	-0.3531*	1							
8. Leader	0.4714*	-0.2267*	-0.1128*	-0.1833*	0.1140*	0.4802*	-0.4551*	1						
9. Team size	0.1458*	-0.0189	-0.0411	0.0852*	0.2230*	0.1293*	-0.0839*	0.1373*	1					
10. Team size squared	0.0324	-0.0232	0.0285	-0.0743*	0.1476*	0.0722*	-0.0324	0.0734*	0.8919*	1				
11. Pharma	-0.0395	-0.0759*	-0.0585	-0.0327	-0.0647*	-0.0226	0.0083	-0.0229	0.0569	0.0821*	1			
12. Technological breadth	0.0880*	-0.0819*	-0.0635*	-0.0348	-0.033	0.0810*	-0.1059*	-0.0198	-0.0688*	-0.0327	-0.0398	1		
13. No backward citations	-0.0214	0.1259*	0.0970*	0.0543	0.0960*	-0.039	0.1012*	-0.0018	0.0674*	0.0153	-0.0429	-0.4372*	1	
14. TRIPS dummy	0.0626*	-0.1647*	-0.1690*	-0.0126	-0.1163*	0.1565*	-0.0283	0.1023*	-0.0158	-0.0079	0.0378	0.0475	-0.0253	1
Obs	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026	1026
Mean	0.199	0.387	0.282	0.104	0.445	0.340	0.460	0.319	3.845	24.219	0.682	0.274	0.178	0.270
Std. Dev.	0.235	0.417	0.386	0.279	0.491	0.474	0.499	0.466	3.073	51.961	0.466	0.292	0.383	0.444
Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1	0.000	0.000	0.000	0.000
Max	0.820	1.000	1.000	1.000	1.000	1.000	1.000	1.000	31.000	961.000	1.000	0.893	1.000	1.000

*p<0.05.

Table 2. Robust tobit regression results (full-sample analysis)

	Model (1)	Model (2)	Model (3)	Model (4)
Chinese GC inventors over total			-0.126*** (0.0363)	
Non-Chinese GC inventors over total			-0.169** (0.0541)	
Chinese GC inventors over total GC				0.145*** (0.0291)
GC inventors over total inventors		-0.140*** (0.0328)		-0.247*** (0.0424)
MNE	-0.0561* (0.0254)	-0.0579* (0.0251)	-0.0590* (0.0250)	-0.0605* (0.0242)
Chinese Assignee	-0.587*** (0.0303)	-0.563*** (0.0303)	-0.566*** (0.0309)	-0.543*** (0.0298)
Leader	0.175*** (0.0253)	0.163*** (0.0257)	0.160*** (0.0258)	0.136*** (0.0251)
Team size	0.106*** (0.0141)	0.106*** (0.0140)	0.105*** (0.0141)	0.0930*** (0.0133)
Team size squared	-0.00643*** (0.00106)	-0.00649*** (0.00107)	-0.00648*** (0.00107)	-0.00598*** (0.000969)
Pharma	-0.0266 (0.0242)	-0.0270 (0.0240)	-0.0265 (0.0241)	-0.0213 (0.0237)
Technological breadth	0.132** (0.0426)	0.129** (0.0421)	0.129** (0.0421)	0.119** (0.0408)
No backward citations	0.0410 (0.0306)	0.0498+ (0.0302)	0.0498+ (0.0302)	0.0418 (0.0300)
TRIPS dummy	0.0310 (0.0243)	0.0256 (0.0243)	0.0264 (0.0243)	0.0281 (0.0240)
Constant	-0.0713 (0.0491)	-0.0191 (0.0498)	-0.0171 (0.0501)	-0.00257 (0.0481)
Sigma	0.289*** (0.0105)	0.285*** (0.0102)	0.285*** (0.0102)	0.279*** (0.00990)
Obs.	1026	1026	1026	1026
Log pseudo likelihood	-301.739	-292.139	-291.839	-278.431
F	99.67***	93.45***	87.43***	88.59***
Pseudo R^2	0.564	0.578	0.579	0.598

Note: robust standard errors in parentheses; +p<0.1, * p<0.05, ** p<0.01, ***p<0.001.

Table 3. Robust tobit regression results (split-sample analysis)

	Model (1) Chinese assignee	Model (2) Non-Chinese assignee	Model (3) Chinese assignee	Model (4) Non-Chinese assignee
Chinese GC inventors over total inventors	-0.540**	0.171**		
	(0.205)	(0.0623)		
Chinese GC inventors over GC inventors			0.349	0.127***
			(0.274)	(0.0238)
GC inventors over total inventors	0.0450	-0.248***	-0.602*	-0.238***
	(0.192)	(0.0528)	(0.271)	(0.0452)
MNE	0.0170	-0.0743**	-0.0950	-0.0700**
	(0.246)	(0.0230)	(0.231)	(0.0225)
Leader	0.165	0.134***	0.201	0.123***
	(0.342)	(0.0234)	(0.314)	(0.0227)
Team size	0.399***	0.0938***	0.405***	0.0802***
	(0.0849)	(0.0146)	(0.0841)	(0.0137)
Team size squared	-0.0274**	-0.00581***	-0.0294**	-0.00522***
	(0.00919)	(0.00106)	(0.00892)	(0.000940)
Pharma	-0.0728	-0.0131	-0.102	-0.00976
	(0.141)	(0.0229)	(0.142)	(0.0226)
Technological breadth	1.009***	0.0385	0.952***	0.0358
	(0.266)	(0.0391)	(0.263)	(0.0386)
No backward citations	-0.00607	0.0623*	0.0362	0.0532+
	(0.220)	(0.0298)	(0.215)	(0.0295)
TRIPS dummy	-0.126	0.0491*	-0.0317	0.0484*
	(0.176)	(0.0233)	(0.175)	(0.0231)
Constant	-2.137***	0.0510	-2.126***	0.0680
	(0.278)	(0.0485)	(0.288)	(0.0469)
Sigma	0.756***	0.237***	0.757***	0.234***
	(0.0503)	(0.00851)	(0.0501)	(0.00813)
Obs.	472	554	472	554
Log pseudo likelihood	-107.315	-116.148	-108.064	-108.254
F	9.10***	14.71***	8.75***	17.01***
Pseudo R^2	0.165	0.445	0.159	0.483

Note: robust standard errors in parentheses; +p<0.1, * p<0.05, ** p<0.01, ***p<0.001.