Paper to be presented at the DRUID Academy conference in Rebild, Aalborg, Denmark on January 15-17, 2014

Global Cities as Innovation Hubs:The Location of R&D investments by Multinational Firms

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Abstract

The increasing internationalization of R&D activities by multinational firms has spurred research on multinational firms? location choices for cross-border R&D investments. Extant research has examined such locational decisions primarily at the country level (e.g Bas & Sierra, 2002; Belderbos, Leten, & Suzuki, 2009; Kumar, 2001). This approach, however, contrasts with the stylized fact that multinational firms take regions or city areas across multiple countries into consideration when they decide on locations for R&D investments (Thursby & Thursby, 2006).

In this study we take a global perspective to R&D location decisions and focus on the role of ?global cities? in attracting R&D investments by multinational firms. Historically, many innovations originate in large cities (Bairoch, 1991; Jacobs, 1969) and cities are often viewed as engines of technology growth (Fujita, Krugman, & Venables, 1999; Henderson, 2007). ?Global cities? are those major metropolitan areas characterized by a high degree of connectivity; a cosmopolitan cultural environment; and a rich supply of advanced producer services (e.g Goerzen, Asmussen, & Nielsen, 2013; Sassen, 2006). They host a disproportional share of skilled workers, innovative companies, prestigious universities and other high quality public and private institutions (Mastercard, 2008). These global cities are viewed as important locations for multinational firms, as they often serve as command and control nodes in the ?global reach? of worldwide production by large corporations (Friedmann, 1986; Taylor, 2004). Notable examples of such global cities are

New York, London, Paris, Hong Kong, and Singapore.

In this paper we contribute to the literature by examining the locational drivers of R&D investments by multinational firms in global cities, with a focus on these cities? roles as innovation hubs. We consider a number of salient characteristics of cities? innovation systems: the international and national connectedness of inventor networks, the intensity of intra-city collaboration, the presence of leading research universities, and the cities? track record in generating breakthrough innovations. We differentiate R&D investments by their main mandate: research or development. Research activities differ significantly from development activities in scope, objectives, and external embeddedness and are accordingly subject to different locational drivers (Belderbos, Fukao, & Iwasa, 2009; Kenney & Florida, 1994; Von Zedtwitz & Gassmann, 2002), with features of innovation hub strength expected to attract research activities primarily.

We draw on the Financial Times? Cross-border Investment Monitor (2003-2012) to extract data on R&D investment projects by multinational firms in global cities. This database records cross-border R&D projects at the city level and provides information enabling us to distinguish between research and development investments. To define ?global cities?, we refer to the 75 global cities worldwide defined by Mastercard (2008). We identify 655 international R&D investment projects located in the 75 global cities, among which; 205 projects focus on research, 141 on development and 309 on both research and development.

We make use of the OECD REGPAT Database (version 2013) and the OECD Patent Citation Database (version 2013) to construct various indicators of innovation hub activities in the global cities, which include the technological strength (the number of patents invented in the city), the technological connectivity (the degree to which city inventors collaborate with inventors outside the city and internationally), collaboration intensity (the degree to which patents are co-owned by multiple entities in the city), and the occurrence of breakthrough inventions, defined as patents that are cited disproportionally by subsequent patents (forward citations).

We also examine the role of the presence of world leading universities, measured as the number of global top 500 universities according to the rankings by Shanghai Jiaotong University. The analysis controls for city population, city market size (GDP), the unemployment rate, wage levels for engineers, firms prior (headquarter) investments in the city, taxes and R&D taxation benefits, intellectual property rights protection (at the country level), and geographical and language ?proximity? between the city and home country of the firm. We analyse location decisions by estimating mixed and conditional logit models.

Keywords
Multinational Firms; R&D investment; global cities, connectivity

Jelcodes:M21,F23

Global Cities as Innovation Hubs:

The Location of foreign R&D investments by Multinational Firms

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Keywords
Multinational firms; R&D investment; global cities; international connectivity

ABSTRACT

The world's leading internationally connected cities ("global cities") host a disproportional share of skilled workers, innovative companies and high quality public and private institutions, but yet their role as innovation hubs in international R&D networks has been underexposed. In this paper we examine how characteristics of global cities' innovation systems attract or discourage R&D investments by multinational firms. An analysis of location decisions for 971 cross-border R&D investments in 50 global cities during 2003-2012 confirms the significance of cities' specialized technological strengths, international inventor connectivity, and the strengths of local universities as key attractors of R&D. Wage costs strongly discourage R&D investments, while political and social stability facilitates R&D. The role of university strength is substantially more pronounced for research investments, but market potential (GDP and GDP growth) attract development projects.

Acknowledgements
We thank Jon Copestake of the Economist Intelligence Unit for making the data on global city stability available to us.

1. INTRODUCTION

The increasing geographic dispersion of technological innovation and the rising importance of emerging markets have been accompanied by a widespread phenomenon of internationalization of R&D activities by multinational firms (e.g. Belderbos et al., 2013 forthcoming; Cantwell, 1995). This has spurred research on changing geographic distribution of R&D activities and multinational firms' location choices for R&D investments. Extant research has examined such locational decisions at the country level (e.g. Kumar, 2001; Bas and Sierra, 2002; Belderbos, Leten, and Suzuki, 2009), or if examining regional patterns, has primarily focused on regional locations within one country (Abramovsky, Harrison and Simpson, 2007; Autant-Bernard, 2006; Bania, Calkins and Dalenberg, 1992; Hilber and Voicu, 2010).[1] These approaches, however, contrast with the stylized fact that multinational firms take regions across multiple countries into consideration when they decide on locations for R&D investments (Thursby and Thursby 2006).

In this paper we take a global perspective on R&D location decisions and focus on the role of metropolitan regions – specifically: global cities - in attracting R&D by multinational firms. Historically, many innovations originated in large cities (Jacobs, 1969; Bairoch, 1991) and they are often viewed as engines of technology growth Fujita, Krugman and Venables, 1999; Henderson, 2007), while they host major R&D facilities of firms and world leading universities.

Dense and well connected metropolitan areas can often evolve into important local and international innovation hubs. The creation of new inventions is a process that involves the integration and recombination of existing knowledge originating from different individuals, locations, institutions and organizations (e.g. Fleming 2001). The size, density and compactness of urban agglomerations foster interpersonal interactions and create opportunities for enhanced information flows.

Global cities, i.e. major metropolitan areas characterized by a high degree of interconnectedness to local and global markets; a cosmopolitan cultural environment; and a rich supply of advanced producer services (e.g Taylor, 2004; Sassen, 2001; 2006; Goerzen, Asmussen and Nielsen, 2013) provide additional benefits for R&D activities. Global cities host a disproportional share of skilled workers, innovative companies and high quality public and private institutions (Mastercard 2008). They are seen as important investment locations

[1] An exception is Belderbos et al., 2013, who examine the role of university research as a driver for R&D location decisions in NUTS-1 regions across the EU.

for multinational firms, as they often serve as command and control nodes in the "global reach" of worldwide production by large corporations, where headquarter operations of multinational firms are located (Friedmann, 1986; Taylor et al., 2009). Notable examples of such global cities are New York, London, Chicago, Los Angeles, Paris, Shanghai, Hong Kong, and Singapore.

Given the importance of global cities for multinational firms, it is surprising that studies examining the location decisions of multinational firms at the city level generally remain scarce (Goerzen et al. 2013), while there appears no prior study on R&D in global cities. In this paper we contribute to the literature by examining the locational drivers of R&D investments by multinational firms in global cities, with a focus on these cities' roles as innovation hubs. We consider a number of salient characteristics of cities' innovation systems: the technological strength of the city related to R&D agglomeration, the international connectedness of inventor networks, the intensity of intra-city collaboration, the research strength of local universities, and the cities' market potential. We differentiate R&D investments by their main mandate: research or development. Research activities differ significantly from development activities in scope, objectives, and external embeddedness and are accordingly subject to different locational drivers (Kenney and Florida, 1994; Von Zedtwitz and Gassmann, 2002; Belderbos, Fukao, and Iwasa, 2009), with some features of global cities expected to attract research activities primarily.

Empirically, we examine the location choices (2003-2012) for 971 cross-border R&D investments by 777 multinational firms from 41 countries operating in manufacturing industries. We consider 50 global cities as potential locations for the R&D investments of these firms.

The remainder of this paper is organized as follows. In the next section we offer the background of our study and propose hypotheses. Section 3 describes the data, variables and the empirical model employed in the analysis and reports descriptive statistics. Section 4 reports the results. Finally, section 5 concludes and discusses our findings.

2. BACKGROUND and HYPOTHESES

Global cities are important actors in the global knowledge economy and play a crucial role in the economic performance of countries. The 90 largest metropolitan cities in the OECD countries account for around 40% of the OECD population and are responsible for about half of the OECD economic activity (OECD 2011). As documented by a stream of research on global cities (Beaverstock et al., 2002; Taylor, 2004; Sassen, 2006), such cities are characterized by state-of-art infrastructure, international connectedness, the presence of highly skilled employees and agglomeration of specialized producer services industries. Global cities foster interpersonal interactions, encourage knowledge exchange and can be considered as important innovation hubs where an important part of technological output is generated (Carlino, 2001). The availability of specialized (service) providers and the knowledge flows stemming from agglomerated activities generate agglomeration externalities that improve the performance of firms. Empirical research has documented that multinational corporations clearly gravitate toward global cities (e.g. Goerzen et al. 2013), in particular where it concerns sales, service and headquarters investments.

Although there is abundant evidence on the importance of global cities for multinational corporations, the literature examining location decisions at the global city level remain remarkable scarce. Furthermore, research has treated global cities as a selected group of large cities sharing a number of salient characteristics, but has not focused on the heterogeneity within this group. Global cities can differ substantially in many important dimensions relevant to multinational firms' location decisions, such as market size, R&D agglomeration and socio-political stability. In this study we examine why multinational firms prefer specific global cities over others when deciding on new locations for R&D activities. Below we discuss a number of hypotheses as to which global city characteristics attract R&D investments by multinational firms.

Technological strength

Several studies have found that the presence of clustered technology activities and its associated knowledge spillovers attract R&D investments (e.g. Cantwell and Piscitello., 2005; Belderbos et al., 2009). As knowledge spillovers tend to be geographically bounded and decay over distance, firms have to be located in the close vicinity in order to benefit from these externalities (Anselin, Varga and Acs., 1997; Autant-Bernard, 2001; Rosenthal and Strange, 2003; Orlando, 2004). Empirical studies have confirmed that firms can improve their innovative performance by benefitting from knowledge spillovers in clusters (e.g. Baptista and Swann, 1998; Beaudry and Breschi, 2003). By locating their R&D investments in technology clusters, firms can get access to relevant knowledge and improve the productivity of their R&D activities.

Hypothesis 1: The probability that a firm chooses a particular global city as the location for its foreign R&D investment is greater, the higher the relevant technological strength of the global city.

International Knowledge Connectivity

International knowledge connectivity of a city refers to the extent to which knowledge created in the city is connected to knowledge sources residing in geographic locations outside the country of the city. Cities with high international knowledge connectivity are characterized by many international knowledge linkages. To succeed in an increasingly knowledge-based competition, a city or region is not only dependent on its internal knowledge base, but also on knowledge influxes from outside (Maillat, 1998; Castells, 2002; Bathelt, Malmberg and Maskell, 2004; Asheim and Coenen, 2006). Truly dynamic economics regions are characterized both by dense local knowledge circulation as well as strong international connections to outside knowledge sources (Bathelt et al., 2004).

Knowledge tends to be relatively homogenous within a region, thus external knowledge influxes tend to be conducive to the novelty and diversity of local knowledge base. When firms only draw upon local knowledge for their innovations, this might lead to the (re)combination of redundant pieces of knowledge, and consequently organizations could end up stuck in networks that tend to resist innovation change (Grabher, 1993; Boschma and Frenken, 2010) and prevent them from recognizing opportunities in new markets and technologies (Lambooy and Boschma, 2001). The organizational network theory refers to this phenomenon as over-embeddedness (Uzzi, 1996; Uzzi, 1997). Over-embeddedness occurs when local innovation networks are conceptually too close, too exclusive and too rigid for the firm or a group of firms which could pose a threat to their competitiveness[2]. This over-embeddedness in local innovation systems can create a dependence that may eventually result in familiarity or learning traps (Levinthal and March, 1993; Ahuja and Lampert, 2001), which can reduce the firm’s willingness to experiment with new problem solving approaches. It is important that firms get access to extra-local knowledge pools to overcome potential situations of regional “entropic death” or “lock-in” (Camagni, 1991; Bathelt et al., 2004; Boschma, 2005).

Prior studies have suggested that geographically distant inventor ties are superior conduits for knowledge flows as they increase the diversity of ideas within the local knowledge base and enrich the local innovation dynamics (Malmberg and Maskell, 2002; Bell and Zaheer, 2007). Empirical work has also confirmed the importance of extra-local

[2] Uzzi (1996;1997) documented this phenomenon for the New York textile industry.

knowledge sources on firms' innovative performance (Oinas and Malecki, 2002; Rosenkopf and Almeida, 2003; Owen-Smith and Powell, 2004; Gertler and Levitte, 2005; Gittelman, 2007), while cross-regional linkages are positively associated with technological performance of regions (Maggioni, Nosvelli and Uberti., 2007; Miguélez and Moreno, 2012).

Given the importance of international knowledge linkages for innovative performance, it follows that global cities that are better connected in international researcher and inventor networks are more attractive locations for R&D investments.

Hypothesis 2: The probability that a firm chooses a particular global city as the location for its foreign R&D facility is greater, the higher the international knowledge connectivity of the global city.

Intra-city R&D collaboration

The literature on open innovation and strategic alliances has shown that firms in technology intensive environments rely heavily on knowledge exchange with external parties, such as suppliers, customers, universities, and competitors (Dyer and Singh, 1998; Landry, Amara and Lamari, 2002; Chesbrough, 2003; Laursen and Salter, 2006). External R&D collaboration might provide access to knowledge sources and complementary assets that cannot be generated internally (Hoekman, Frenken and van Oort, 2008; Kleinknecht and Reijnen, 1992; Hagedoorn 1993; Powell, Koput and Smith-Doerr, 1996; Dyer and Singh, 1998; Chesbrough, 2003; Laursen and Salter, 2006).

Firms engaging in collaboration with other companies may benefit from reduced research and development costs and an acceleration of product or process development, as collaboration enable the partners to share risks and reduce uncertainty. A range of studies has confirmed a positive impact of R&D collaboration on firms' innovative performance (e.g. Deeds and Hill, 1996; Powell et al., 1996; Becker and Dietz, 2004; Yamin and Otto, 2004; Czarnitzki, Ebersberger and Fier, 2007).

Firms take the potential for collaboration and the associated benefits into account when they decide on the location of their R&D facilities (e.g. Chung and Alcácer, 2002; Cantwell and Piscitello, 2005; Aharonson, Baum and Feldman, 2007). Global cities characterized by an innovation culture emphasizing knowledge sharing and collaboration are likely to be more attractive to multinational firms.

Hypothesis 3: The probability that a firm chooses a particular global city as the location for its foreign R&D facility is greater, the more intensive intra-city R&D collaboration.

University Strength

The importance of academic research for the innovative and competitive performance of firms has been widely acknowledged (Mansfield, 1995; 1997; Cohen, Nelson and Walsh, 2002; Fleming and Sorenson, 2004; Cassiman, Veugelers and Zuniga, 2008). There are several mechanisms through which universities may have an impact on firms' innovation activities. Universities continuously supply firms with a skilled labour force of scientists and engineers, act as collaboration partners, supply consultants, and transfer new and embryonic technologies to firms (e.g. Branstetter and Kwon, 2004; Cassiman et al. 2008). Universities also perform academic research which generates scientific knowledge on which firms can build upon in their applied technology activities (Klevorick et al., 1995). Scientific (basic) knowledge might deliver firms with a deeper understanding of the technological landscape (Fleming and Sorenson, 2004) and help them to pursue the right research path with avoiding wasteful experimentation costs. Also, scientific knowledge might help firms to better evaluate their applied research activities and estimate its economic implications. It has been even argued that a good understanding of academic research and an effective translation into specific application can lead to first mover advantages (Rosenberg, 1990; Fabrizio, 2009). The benefits of academic research to firms' innovation performance are highly localized (Piergiovanni, Santarelli and Vivarelli., 1997; Autant-Bernard 2001; Fischer and Varga, 2003; Del Barrio-Castro and García-Quevedo, 2005; Belderbos et al., 2013), implying that R&D activities in the vicinity of universities are required to reap the benefits. It follows that global cities hosting strong research universities that conduct relevant research are more attractive environments for firms' R&D investments.

Hypothesis 4: The probability that a firm chooses a particular global city as the location for its foreign R&D facility is greater, the stronger the performance of universities in the global city.

The distinction between research and development

The inherent differences between research and development activities have been well documented in the literature. Research activities are characterized as aiming to acquire or generate new knowledge and technology expansion, involving more non-routine tasks than development (Karlssen, Trygg and BO., 2004; Leifer and Triscari, 1987), maintaining close links to universities (Van Ark et al., 2007), and being relatively independent of the rest of the organization (Leifer and Triscari, 1987). In contrast, development activities are characterized as aiming at technology exploitation and introducing adapted products or processes. They are involved in more routine tasks (Leifer and Triscari, 1987), are more closely controlled and supervised, and require intensive communication with other units within the organization (Allen, Tushamn and Lee., 1979; Tushman, 1978). These difference relate with the distinction made in the international R&D literature between "home-base exploiting" foreign R&D, focusing on technological adaptation and development, and "home-base augmenting" foreign R&D, focusing on new knowledge creation and hence research activities (Florida, 1997; Kuemmerle, 1997; von Zedwitz and Gassmann, 2002).

In line with the different characteristics between research and development, location decisions for research and development activities are expected to be subject to different location drivers (Kenney and Florida, 1994; von Zedwitz and Gassmann, 2002; Belderbos, Fukao and Iwasa, 2009). Kenney and Florida (1994) reported that basic research enjoys more locational flexibility. Belderbos, Fukao and Iwasa (2009) separate R&D into research and development and find that foreign research expenditures respond to technological opportunity, while foreign development expenditures respond to market demand. It follows that the drivers of R&D location decisions in global cities will also depend on the type of R&D investment: research versus development. Research activities will be more attracted to university research, while development activities will be more attracted to local market characteristics.

Hypothesis 5: Global cities' university strength is a stronger driver of location decisions for research projects, while global cities' market potential is more important for decisions where to locate development activities.

3. DATA, VARIABLES and EMPIRICAL MODEL

To define "global cities", we made use of a classification developed by Mastercard (2008). This classification includes 75 global cities worldwide, which are ranked according to various dimensions, among which knowledge creation, economic stability, financial transactions, political and legal stability, and livability. Due to data limitations, we can only cover 50 global cities, spread over 27 countries in our research.

To define the boundaries of each global city, we rely on the OECD methodology of metropolitan regions. The OECD developed this methodology to enable a uniform comparison of cities across countries. National governments often define their metropolitan areas on the basis of legal boundaries. This approach, however, often does not coincide with the actual agglomeration of the city and does not take changing population patterns into account. In contrast, the OECD developed a methodology based on a harmonised definition that identifies urban areas as functional economic units, using population density and travel-to-work flows as key information. In this way, urban areas can be characterised by densely populated "urban cores" and "hinterlands" whose labour market is highly integrated with the cores[3].

We draw on the Financial Times' Cross-border Investment Monitor (2003-2012) to extract data on foreign R&D investment projects by multinational firms in global cities. This database is developed by the Financial Times Ltd and tracks global cross-border Greenfield investments, drawing on press releases, newspaper reports, information from local and national investment agencies, and information from the investing firms themselves (for the majority of the projects). It consists of more than 100,000 cross-border investments worldwide across various value chain activities such as manufacturing, R&D, logistics, headquarter services, wholesaling, etc. It records cross-border projects since 2003 and provides information on the investing company, the parent company, the type of project, the source country, source state and source city, the destination country, state and city and the industry in which the firms are active. We categorized the R&D projects in twelve 2-digit NACE manufacturing industries, for which we can also construct measures of industry-specific patent activity.

In total we identify 971 cross-border R&D investments. Table 1 shows the distribution of these R&D investments across the 50 global cities during the period 2003-2012.

Each R&D project in the database was classified as a research or development project. Classification were made based on the text description accompanying each investment project in the FDI Market database.

R&D investments are classified as research projects if the detailed text description of the database contains such keywords as "basic", "research", "research facility", "research and

[3] We would like to refer to the OECD website for a detailed description; http://www.oecd.org/regional/redefiningurbananewwaytomeasuremetropolitanareas.htm

technology", "scientific", "fundamental", "frontier technology". We classify projects as development investments if the description contains such keywords as "development", "solutions", "technical services", "adaptation", products", "processes".

We provide two illustrative descriptions of a research and a development investment project in a global city, respectively.

"May 2011 - GE Healthcare [Subsidiary of General Electric (GE)] (United States) is investing in the city of Stockholm (Sweden), in the Medical Devices sector in a Research & Development project. GE Healthcare, has established a life sciences demonstration laboratory in Stockholm, Sweden. The new facility, located at the Science for Life Laboratory (SciLifeLab), will focus on life sciences research and joint research collaborations with *SciLifeLab."*

"November 2008 - Takeda Pharmaceutical (Japan) is investing in the city of Singapore (Singapore), in the Pharmaceuticals sector in a Research & Development project. Takeda has established a new entity in Singapore: Takeda Clinical Research Singapore (TCRS). TCRS will serve as the company's centre of clinical development in the Asia-Oceania region, in close coordination with the company's clinical development activities in Japan, Europe and the U.S. Through this center, Takeda seeks to expand access to patients on a global scale, and to achieve the earliest possible application, approval and launch of its new *products in its target markets worldwide."*

Dependent variable and hypothesis testing variables

The dependent variable, R&D investment location choice, is a binary variable, which indicates in which global city the R&D investment is made. This variable takes the value one if a foreign firm made its R&D investment in a particular city, and zero otherwise.

To construct our key explanatory variables, we make use of patent data. Patent data have been used by several prior studies on international R&D and as an indicator of innovative activities (Belderbos, 2001; Acs, Anselin and Varga, 2002; Bas and Sierra, 2002; Hagedoorn and Cloodt, 2003; Cantwell and Piscitello, 2005; Allred and Park, 2007). The main advantages of patent data are their consistent availability over time and the detailed information on technological content and location of inventive activity (Griliches, 1998). The main drawback is that they differ in quality, that not all inventions are patented and the patent propensity differs across industries (Griliches, 1998).

To examine how technological strength of the host city influences R&D location decisions, we calculated the number of patented inventions originating in each city and relevant to the firms' industry. This variable measures the availability of technological knowledge and potential R&D spillovers relevant for the investing firm.

To allocate patents to global cities (i.e. metropolitan areas), we used the OECD REGPAT Database, which provides region indicators for each patent, utilizing the addresses of the applicants and inventors. The database currently covers more than 5500 regions across OECD countries, EU-27 countries, Brazil, China, India, Russia and South Africa. The regional breakdowns provided in REGPAT correspond to NUTS-3 regions (Nomenclature of territorial units for statistics) for European countries and TL3 regions (Territorial level) for other countries. The REGPAT database derives its data from the European Patent Office's Worldwide Statistical Patent Database (PATSTAT, October 2012). We use patents filed under the Patent Co-operation Treaty (PCT)[4]. The PCT provides a unified procedure for filing patent applications to protect inventions in each of the contracting states of the PCT. These patents are generally applied for inventions for which firms seek protection in various regions (e.g. The US, the EU, and Japan) and are the least likely to exhibit a regional or city bias.

We matched inventions to global cities based on an available concordance table linking NUTS-3/TL3 regions with metropolitan areas. Patents are assigned to global cities based on the regionalized addresses of the inventors that are listed on the patents. Use of inventor addresses is more accurate than using assignee (patent applicant) addresses because firms tend to use the headquarters' address as assignee address, instead of the subsidiary's address or the address where the invention originated (Deyle and Grupp, 2005). In order to allocate patents to industries, we make use of the patent technology class to industry concordance table developed by Schmoch et al. (2003). This concordance table links the technology codes (IPC) of the patents to their corresponding NACE code at the two-digit level. If a patent lists multiple inventors and IPC classes, we use fractional counts to assign the patent to a global city and industry, as fractional patent counts are more reliable than using full patent counts. Full patent counts would artificially increase the patent counts for

[4] The PCT provides a unified procedure for filing patent applications to protect inventions in each of the contracting states of the PCT. Accordingly, patent applications filed under the PCT can be considered as international patent applications.

cities with patents involving multiple inventors. The variable technological strength then is the fractional count of the number of patents invented in a city's metropolitan area and classified in the industry of the investing firm. Hypothesis 1 predicts a positive sign.

To measure the international knowledge connectivity of the global city (Hypothesis 2), we collected information about the inventors collaborating on patents and examined the inventor addresses. When a patent with an inventor in of global city involves at least one co-inventor residing outside the global city's country, we count this as an international knowledge linkage. Our measure of international knowledge connectivity is then constructed as the share of patents with international knowledge linkage(s) over the total number of patents in the city. This measure defines the connectedness of the focal global city to regions outside the global city's country and how globally connected the city is. The connectivity measure is calculated at the industry level.

To measure intra-city R&D collaboration between firms, we count the number of occurrences of joint firm ownership of patents originating in the city. We capture intra-city collaboration by identifying assignees of patents invented in the city and examined which patents were jointly applied for by co-assignees. These "co-patents" are the output of R&D collaboration activities. We restrict the measure to co-patents between two different private enterprises. We relied on a sector allocation algorithm (Calleart et al. 2011) to identify the type of patent assignee (individuals, private enterprises, public and private non-profit organizations, universities). The algorithm consists of an iteration of steps until 99% of the patent volume has been correctly assigned.

Intra-city R&D collaboration is the ratio of co-patents originating in the city over the total number of patents invented in the city per industry. To ascertain that the collaboration occurs within the city, we take co-patents into account of which one of the assignees is based in the city. Hypothesis 3 suggests a positive effect on R&D location.

To construct measure for university strength, we incorporated all university patents invented in the global city. A patent is considered to be a university patent, if at least one of the assignees is a university. We relied on the sector allocation algorithm and identified patents invented by universities. We measure university strength as the share of university patents in the total patents of the global city. The variable is an indicator of the relative strength of universities research present in the global city and the entrepreneurial orientation of these universities in terms of their aims to commercialize the output of research efforts. Hypothesis 4 predicts a positive effect for this variable.

Market potential of a global city is measured by two variables: market size (GDP) and GDP growth. Market size is proxied by GDP (expressed in purchasing power parity) of the global city drawn from the OECD regional database defining metropolitan areas. For Beijing and Shanghai, no such OECD data were available but we could rely on the TL2 region definition. For Australian global cities (Melbourne and Sydney), the approximation of the metropolitan area is the TL3 level. The OECD (2012) identifies these regional levels as appropriate proxies for metropolitan areas in these cases. For Singapore and Hong Kong, we used GDP data from the Citymayor database. In addition to GDP levels, R&D investments are likely to be attracted to economic regions exhibiting a strong market growth as this signals a positive evolution of the host market and captures future market potential. We take this market growth into account by calculating the GDP growth rate as yearly proportional growth in GDP. Hypothesis 5 predicts that GDP and GDP growth are more relevant for development investments than research investments.

Control variables

We also include a series of control variables including wage, the corporate tax rate, political and social stability, the number of parent firm's existing subsidiaries in the city, language similarity between the city and source city, and the geographic distance between the city and source city.

We control for wage level of the city as prior researchers found that wage costs have a negative effect on R&D location decisions Kumar (1995, 2001). Data on relative wages indices in global cities are taken from UBS (Union Bank of Switzerland) Price & Earning reports.

Data on the corporate tax rate come from KPMG and are at the country level, as there is no or little difference in the corporate tax rate between the country and the city level. Although several studies have found a negative effect of corporate tax rate on R&D location decisions (e.g. Hines, 1995; Buettner and Wamser, 2009; Mudambi and Mudambi; 2005), some studies have also documented that this effect is negligible (e.g. Cantwell and Mudambi; 2000).

We control for socio-political stability of the global city as we expect that this factor will have a positive effect on attracting foreign direct investment. Data on socio-political stability were provided by the Economist Intelligence Unit (EIU). .

Firms will be more likely to invest in R&D in a global city if they have previous investments in the city. To control for earlier investments in the global city, we calculated the number of subsidiaries in the city prior to the investment project. We identified parent firms' subsidiaries in the city by using the ORBIS database developed by Bureau Van Dijk and included the total number of subsidiaries located in the city prior to the investment project.

We also included a dummy variable indicating language similarity between the global city and the source city of the investing firm. It takes the value of one when the two cities share at least one official language, and zero, otherwise. As a shared language facilitates cross-border communication and collaboration between the home country and host country (Guellec and Van Pottelsberghe, 2001), firms may have a preference for cities that utilize a shared language. The data were obtained from the CEPII database which provides information about languages spoken in countries around the world.

Finally, we control for geographic distance between the city and the source city of the firm, as a larger distance can have a negative impact on R&D investments location decision due to increasing informational uncertainty and coordination costs (Solocha and Soskin, 1994; Ghemawat, 2001; Castellani et al., 2011). We calculated the geographic distance between the city and source city based on the latitude and longitude of each city. We obtained these coordinates from genonames.org. We measure geographic distance as the great circle distance between the source and the destination city, defined as the shortest distance between two points on the surface of a sphere, measured along a path on the surface of the sphere.

All explanatory variables are one year lagged with respect to the year when the foreign R&D investment is carried out to allow for a response time by the investing firm. All continuous variables are taken in natural logarithms to reduce variance and facilitate the interpretation of the results as average elasticities (Head et al., 2004). The definition and summary statistics of explanatory variables are provided in Table 2 and the correlation coefficients of these variables are given in Table 3.

Empirical Model: Mixed logit

Within the location choice literature (e.g. Alcacer and Chung, 2007; Head et al, 1995; 1999), the conditional logit model (Mc Fadden, 1974) has been widely used to analyze the location determinants of foreign direct investments. A drawback of this model is the restrictive assumption of independence of irrelevant alternatives (IIA). The IIA property states that for any two alternatives the ratio of probabilities is independent of the characteristics of any other alternative in the choice set. This characteristic also implies the absence of correlations between error terms across alternatives. In practice however, this assumption is frequently violated in location choice analyses. More recent studies (e.g. Basile et al, 2008; Chung and Alcacer, 2002) have therefore used the mixed logit model, which does not rely on the IIA assumption (McFadden and Train, 2000). In this study we estimate mixed logit models of regional location choice for foreign R&D investments.

The mixed logit model starts from a random utility maximization (RUM) setting to examine the location choices of R&D investments. Having a choice set of alternative host regions r = 1,…, R to locate an overseas R&D project at time t, multinational firm f seeks to maximize its expected utility ($U_{fr,t}$) as a function of observable regional or firm attributes and unobservable regional factors ε_{fr}. The expected utility of a multinational firm f choosing region r among other host regions at time t can be expressed by the function:

$$U_{fr,t} = \alpha X_{fr,t-1} + \varepsilon_{fr} \tag{1}$$

in which $X_{fr,\ t-1}$ represents a vector of region-specific characteristics that can vary across industries or firms, while ε_{fr} defines a city-specific independent random disturbance term. While the standard conditional logit model restricts the coefficients α to be equal across firms, the mixed logit allows the coefficients to be normally distributed. Accordingly, coefficients are decomposed into a fixed part and a random part that accounts for unobservable effects. The error term incorporates the random components of the coefficients and takes the following form:

$$\varepsilon_{fr} = \lambda_f Z_{fr,t-1} + \mu_{fr} \tag{2}$$

where $Z_{fr,t-1}$ is a vector of observable variables while λ_f is a vector of randomly distributed parameters with zero mean following a normal distribution with variance Ω. The parameter μ_{fr} is an independent and identically distributed error term. If the parameter λ_f would be observed, the probability that a firm f would locate its foreign R&D investment in city r could be expressed as a standard logit model. However, since the coefficients in the mixed logit model are not known but are assumed to follow a certain density function $g(\lambda_f)$, the locational choice probability has to be calculated over all possible values of λ_f. The mixed logit probability is obtained by taking the integral of the multiplication of the conditional probability with the density functions describing the random nature of the coefficients. This is described by the following equation:

$$P_{fr} = \int \frac{\exp(\alpha X_{fr,t-1} + \lambda_f Z_{fr,t-1})}{\sum_{j=1}^{J} \exp(\alpha X_{fj,t-1} + \lambda_f Z_{fj,t-1})} g(\lambda_f) d(\lambda_f) \quad (3)$$

There is no closed form solution for the mixed logit probability such that this probability has to be approximated by simulation techniques. In a first step, values for the coefficients are drawn from their density functions and the conditional probability (equation 3) is calculated for these values. This step is repeated several times and the simulated probabilities are averaged to obtain an approximation of the mixed logit probability. We follow the suggestion of Revelt and Train (1998) and use 100 draws for each R&D investment to have confidence in the estimated results.

We note that our empirical model includes variables with different characteristics. A number of variables vary over cities and time (e.g. GDP, stability), while there are also time-variant industry-specific variables at the city level (e.g. technological strength, connectivity). Yet other factors are firm- and city-specific but remain constant over time (language similarity and geographic distance), while the variable prior investment varies by firm, city and time. Finally, some variables included in the model are only available at the country level, such as the corporate tax rate.

4. EMPIRICAL RESULTS

The results of the mixed logit models are reported in Table 4. Model 1 is estimated with the full sample of projects. Model 2 is estimated for research investments only, while model 3 is only for development investments. In this table, we present coefficients of the fixed part of the coefficients and we report the random parts of the coefficients if they are significant.

In all of the three models, technological strength, international knowledge connectivity and university strength have a significant and positive effect on R&D location choice, providing strong support for Hypothesis 1, 2 and 4 are supported. The coefficient on collaboration in the city is not significant, although it is positive in Model 1 and Model 2, which indicates no support for Hypothesis 3.

GDP and GDP growth rate have a positive and significant effect on development activities (Model 3), while we observe no significant effect for research activities. Furthermore, while university strength is significant in the research and development models, its coefficient is more than twice as large in the research equation. These results are consistent with our Hypothesis 5 predicting that market potential is more important for development activities than for research activities, while university strength is more important for research.

Turning to the control variables, we observe that socio-political stability exerts a positive and significant effect on both research and development activities. Both activities are also attracted to cities in which the investing firm operates existing subsidiaries.

Consistent with previous studies (e.g. Kumar, 1995; Belderbos et al. 2013), wage costs discourage R&D investments. The coefficient on corporate tax rate is negative, but not significant, while neither language similarity or geographic distance neither has a significant effect on R&D location choice.

The estimates for the random parts of the coefficients in model 1 show that there exists some heterogeneity in the effects of international knowledge connectivity, collaboration intensity, GDP growth rate, existing subsidiaries, language similarity and geographic distance. When the model is split in the subsamples of research and development, on the other hand, this significant heterogeneity is substantially reduced. For the research equation only the connectivity has a significant random part, while the occurrence of significant variation is also reduced, though to a lesser extent, in the development equation. These results further demonstrate that it is important to distinguish between research and development activities to arrive at more consistent and precise estimates of locational determinants.

5. CONCLUSION

We investigate the locational drivers of international R&D investment activities in global cities by multinational enterprises. We argue that specific characteristics of the innovation system in global cities attract R&D investments, while the impact may be different between research and development projects. We estimate mixed logit models relating the probability that a global city hosts an R&D investment to a set of city, industry- and firm-specific factors.

Our empirical analysis confirms the important roles of technological strength (measured as patent activity in relevant technology fields), international knowledge connectivity (cities' participation in international inventor networks) and university strength (the importance of universities as inventors) in attracting cross-border R&D investments. The role of university strength is substantially larger for research investments, while market potential (GDP and GDP growth) only attract development projects. High wage levels discourage R&D investments while social and political stability and prior investments by the firms Encourage investments.

Our study makes several contributions to the literature. First, we examine R&D location decisions at a more fine-grained geographic level of analysis, i.e. at the global city level, compared to prior work taking the country or region as the level of analysis. The focus on global cities follows the increasing importance of global cities as global innovation hubs, but the role of cities has been underexposed. Second, we take a global perspective in examining foreign R&D decisions in relationship with the role of global knowledge networks, while prior work has been confined to R&D investments within a country or in a subset of countries. Third, our analysis shows that disaggregating R&D into research and development respectively is necessary to identify differential locational drivers for different types of foreign R&D activities, while prior work has treated R&D as a homogenous activity.

We aim to pursue several lines of further research. First, our measure of inter-firm collaboration in cities is not optimal. Co-patenting picks up only a fraction of actual collaborative activities and is also influenced by the legal environment concerning joint property rights. In future efforts, we aim to establish collaborative research by identifying inventors on a firm's patents, who are associated with other firms (as they appear as inventors on other firms' patents). Another line of research we aim to pursue is to examine the occurrence and effects of breakthrough inventions. Breakthrough inventions hold to promise to increase a firm's profitability and competitive advantage substantially (Tushman and Anderson 1986). It has been suggested that they increase the region's productivity growth by generating knowledge spillovers to neighbouring firms (Edquist and Henrekson 2006). Patterns of reallocation of industries to cities are related to past breakthrough inventions (Duranton 2007; Kerr 2010) and high-tech industries relocate across US cities and states particularly quickly (Beardsell and Henderson 1999; Black and Henderson 1999; Wallace and Walls 2004). It follows that breakthrough inventions, to be identified by examining forward citation patterns of patented inventions, may constitute another typical characteristic of global cities attracting R&D investments.

References

Abramovsky, L., Harrison, R and Simpson, H. (2007). "University Research and the Location of Business R&D." The Economic Journal, **117**(519): C114-C141.

Acs, Z. J., Anselin, L., and Varga, A. (2002). "Patents and innovation counts as measures of regional production of new knowledge." Research Policy, **31**(7): 1069-1085.

Aharonson, B. S., Baum, J. A. C. and Feldman, M.P. (2007). "Desperately seeking spillovers? Increasing returns, industrial organization and the location of new entrants in geographic and technological space." Industrial and corporate change**, 16**(1): 89-130.

Ahuja, G. and Lampert, C. (2001). "Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions." Strategic Management Journa,l **22**(6-7): 521-543.

Alcácer, J. and Chung, W. (2007). "Location Strategies and Knowledge Spillovers." Management Science 53(5), pp. 760-776.

Allen, T.J., Tushamn, M.L. and Lee, D.M.S. (1979). "Technology transfer as a function of position in the spectrum from research through development to technical services." Academy of Management Journal, 22(4): 694-708.

Allred, B. B. and Park, W. G. (2007). "Patent rights and innovative activity: evidence from national and firm-level data." Journal of International Business Studies**, 38**(6): 878-900.

Anselin, L., Varga, A and Acs, Z. (1997). "Local Geographic Spillovers between University Research and High Technology Innovations." Journal of urban economics, **42**(3): 422-448.

Asheim, B. T. and Coenen, L. (2006). "Contextualising regional innovation systems in a globalising learning economy: On knowledge bases and institutional frameworks." The Journal of Technology Transfer, **31**(1): 163-173.

Autant-Bernard, C. (2001). "The geography of knowledge spillovers and technological proximity." Economics of innovation and new technology, **10**(4): 237-254.

Autant-Bernard, C. (2001). "Science and knowledge flows: evidence from the French case." Research Policy, **30**(7): 1069-1078.

Autant-Bernard, C. (2006). "Where do firms choose to locate their R&D? A spatial conditional logit analysis on French data." European Planning Studies**, 14**(9): 1187-1208.

Bairoch, P. (1991). “Cities and economic development: from the dawn of history to the present.” University of Chicago Press.

Bania, N., Calkins, L.N., and Dalenberg, D.R. (1992). "The effects of regional science and technology policy on the geographic distribution of industrial R&D laboratories." Journal of Regional science, **32**(2): 209-228.

Baptista, R. and Swann, P. (1998). "Do firms in clusters innovate more?" Research Policy, **27**(5): 525-540.

Bas, C. L. and Sierra, C. (2002). "Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies." Research Policy, **31**(4): 589-609.

Basile R, Castellani D, and Zanfei A. (2008), “Location choices of multinational firms in Europe: The role of EU cohesion policy” Journal of International Economics, 74: 328-340

Bathelt, H., Malmberg, A., and Maskell, P. (2004). "Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation." Progress in human geography, **28**(1): 31-56.

Beardsell, M. and Henderson, V. (1999). "Spatial evolution of the computer industry in the USA." European Economic Review, **43**(2): 431-456.

Beaudry, C. and Breschi, S. (2003) "Are firms in clusters really more innovative?" Economics of innovation and new technology, **12**(4): 325-342.

Beaverstock, J., Doel, M.A., Hubbard, P.J., and Taylor, P.J. (2002). "Attending to the world: competition, cooperation and connectivity in the World City network." Global Networks, **2**(2): 111-132.

Becker, W. and Dietz, J. (2004). "R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry." Research Policy, **33**(2): 209-223.

Belderbos, R., Leten, B., and Suzuki, S. (2009). Does excellence in academic research attract foreign R&D? Woking paper at UNU-MERIT, Maastricht Economic and Social Research and Training Centre on Innovation and Technology.

Belderbos, R. (2001). "Overseas innovations by Japanese firms: an analysis of patent and subsidiary data." Research Policy**, 30**(2): 313-332.

Belderbos, R. (2003). "Entry mode, organizational learning, and R&D in foreign affiliates: Evidence from Japanese firms." Strategic Management Journal, **24**(3): 235-259.

Belderbos, R., Carree, M., and Loksin, B. (2004). "Cooperative R&D and firm performance." Research Policy**, 33**(10): 1477-1492.

Belderbos, R., Fukao, K., and Iwasa, T. (2009). "Foreign and domestic R&D investment." Economics of innovation and new technology, **18**(4): 369-380.

Belderbos, R., Leten, B., and Suzuki, S. (2013) (Forthcoming). "How Global is R&D? Determinants of the Home Country Bias in R&D." Journal of International Business Studies.

Belderbos R., Van Olffen, W. and Zou, J. (2011). “General and specific learning mechanism in foreign investment location choice”. Strategic Management Journal, 31: 224-236.

Belderbos, R., Van Roy, V., Leten, B., and Thijs, B. (2013). "Academic research strengths and multinational firms’ foreign R&D location decisions: Evidence from R&D investments in European regions." Environment and Planning A.

Bell, G. G. and Zaheer, A.(2007). "Geography, networks, and knowledge flow." Organization Science, **18**(6): 955-972.

Black, D. and Henderson, V. (1999). "Spatial evolution of population and industry in the United States." The American Economic Review, **89**(2): 321-327.

Boschma, R. (2005). "Proximity and innovation: a critical assessment." Regional Studies **39**(1): 61-74.

Boschma, R. and Frenken, K. (2010). "The spatial evolution of innovation networks. A proximity perspective." Handbook of evolutionary economic geography: 120-135.

Branstetter, L. and Kwon, H. (2004). "The restructuring of Japanese research and development: The increasing impact of science on Japanese R&D." Unpublished manuscript.

Buettner, T. and Wamser, G. (2009). “The Impact of Non-profit Taxes on Foreign Direct Investment: Evidence from German Multinationals”. International Tax and Public Finance, 16(3):298-320.

Callaert, J., Du Plessis, M. Grouwels, J., Lecocq, C., Magerman, T., Peeters, B., Song, X., Van Looy, B., and Vereyen, C. (2011). “Patent statistics at Eurostat: Methods for regionalization, sector allocation and name harmonization.” Eurostat Methodologies and Working Papers.

Camagni, R. (1991). “Innovation networks”, John Wiley & Sons, Inc.

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

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

Cantwell, J. and Mudambi, R. (2000). 'The Location of MNE R&D Activity: The Role of Investment Incentives.' Management International Review, 40(1): 127-148.

Carlino, G. A. (2001). "Knowledge spillovers: cities' role in the new economy." Business Review, **4**: 17-24.

Cassiman, B., Veugelers, R and Zuniga, P. (2008). "In search of performance effects of (in) direct industry science links." Industrial and corporate change**, 17**(4): 611-646.

Castellani, D., Palmero, A.J. and Zanfei, A. (2011). The Gravity of R&D FDIs. Working paper.

Castells, M. (2002). "Local and global: cities in the network society." Tijdschrift voor Economische en Sociale Geografie, **93**(5): 548-558.

Chesbrough, H. W. (2003). Open innovation: The new imperative for creating and profiting from technology, Harvard Business Press.

Chung, W. and Alcácer, J. (2002). "Knowledge seeking and location choice of foreign direct investment in the United States." Management Science: 1534-1554.

Cohen, W. M., Nelson, R.R. and Walsh, J.P. (2002). "Links and impacts: the influence of public research on industrial R&D." Management Science: 1-23.

Czarnitzki, D., Ebersberger, B., and Fier, A. (2007). "The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany." Journal of Applied Econometrics, **22**(7): 1347-1366.

Deeds, D. L. and Hill, C.W. (1996). "Strategic alliances and the rate of new product development: an empirical study of entrepreneurial biotechnology firms." Journal of Business Venturing, **11**(1): 41-55.

Del Barrio-Castro, T. and García-Quevedo, J. (2005). "Effects of university research on the geography of innovation." Regional Studies, **39**(9): 1217-1229.

Deyle, H. G. and Grupp, H. (2005). "Commuters and the regional assignment of innovative activities: A methodological patent study of German districts." Research Policy**, 34**(2): 221-234.

Duranton, G. (2007). "Urban evolutions: The fast, the slow, and the still." The American Economic Review: 197-221.

Dyer, J. H. and Singh, H. (1998). "The relational view: Cooperative strategy and sources of interorganizational competitive advantage." Academy of Management Review, **23**(4): 660-679.

Edquist, H. and Henrekson, M. (2006). Technological breakthroughs and productivity growth, Emerald Group Publishing Limited.

Fabrizio, K. R. (2009). "Absorptive capacity and the search for innovation." Research Policy, **38**(2): 255-267.

Fischer, M. M. and Varga, A. (2003). "Spatial knowledge spillovers and university research: evidence from Austria." The Annals of Regional Science, **37**(2): 303-322.

Fleming, L. (2001). "Recombinant uncertainty in technological search." Management Science: 117-132.

Fleming, L. and Sorenson, O. (2004). "Science as a map in technological search." Strategic Management Journal, **25**(8 ‐ 9): 909-928.

Florida, R. (1997). "The globalization of R&D: Results of a survey of foreign-affiliated R&D laboratories in the USA." Research Policy**, 26**(1): 85-103.

Friedmann, J. (1986). "The world city hypothesis." Development and change, **17**(1): 69-83.

Fujita, M., Krugman, P., and Venables, A.J. (1999). The spatial economy: cities, regions and international trade, Wiley Online Library.

Gertler, M. S. and Levitte, Y.M. (2005). "Local nodes in global networks: the geography of knowledge flows in biotechnology innovation." Industry and Innovation**, 12**(4): 487-507.

Ghemawat, P. (2001). "Distance still matters." Harvard Business Review**, 79**(8): 137-147.

Gittelman, M. (2007). "Does geography matter for science-based firms? Epistemic communities and the geography of research and patenting in biotechnology." Organization Science**, 18**(4): 724-741.

Goerzen, A., Asmussen, C.G. and Nielsen, B.B. (2013). "Global cities and multinational enterprise location strategy." Journal of International Business Studies**, 44**(5): 427-450.

Grabher, G. (1993). The Embedded Firm: On The Socioeconomic of Industrial Networks, Routledge, London.

Griliches, Z. (1998). Patent statistics as economic indicators: a survey, University of Chicago Press.

Guellec. D. and Van Pottelsberghe B. (2001). The internationalization of technology analysed with patent data. Research Policy, 30(8), 1256-1266.

Hagedoorn, J. (1993). "Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences." Strategic Management Journal, **14**(5): 371-385.

Hagedoorn, J. and Cloodt, M. (2003). "Measuring innovative performance: is there an advantage in using multiple indicators?" Research Policy, **32**(8): 1365-1379.

Head K, Ries J, Swenson D, 1995, “Agglomeration benefits and location choices: Evidence from Japanese manufacturing investments in the United States” Journal of International Economics 38 223-247

Head K, Ries J, Swenson D, 1999, “Attracting foreign manufacturing: Investment promotion and agglomeration” Regional Sciences and Urban Economics 29 197-218.

Henderson, J. (2007). "Understanding knowledge spillovers." Regional Science and Urban Economics, **37**(4): 497-508.

Hilber, C. A. L. and Voicu, I. (2010). "Agglomeration economies and the location of foreign direct investment: Empirical evidence from Romania." Regional Studies**, 44**(3): 355-371.

Hines, J. R. Jr., 1995. Taxes, Technology Transfer, and the R&D Activities of Multinational Firms. Extracted from: ‘The Effects of Taxation on Multinational Corporations.’ (Feldstein, M.; Hines, J. R. Jr. and Hubbard, R. G., 1995). University of Chicago Press

Hoekman, J., Frenken, K and van Oort, F. (2008). "Collaboration networks as carriers of knowledge spillovers." Working paper.

Jacobs, J. (1969). The economies of cities, New York: Random House.

Karlsson, M., Trygg, L and BO, E. (2004). "Measuring R&D productivity: complementing the picture by focusing on research activities." Technovation, **24**(3): 179-186.

Kenney, M. and Florida, R. (1994). "The organization and geography of Japanese R&D: results from a survey of Japanese electronics and biotechnology firms." Research Policy, **23**(3): 305-322.

Kerr, W. R. (2010). "Breakthrough inventions and migrating clusters of innovation." Journal of urban economics, **67**(1): 46-60.

Kleinknecht, A. and Reijnen, J.O. (1992). "Why do firms cooperate on R&D? An empirical study." Research Policy**, 21**(4): 347-360.

Klevorick, A., Levin, R.C., Nelson, R.R. and Winter, S.G. (1995). "On the sources and significance of inter-industry differences in technological opportunities." Research Policy, **24**: 342-349.

Kuemmerle, W. (1997). "Building effective R&D capabilities abroad." Harvard Business Review, **75**: 61-72.

Kumar, N., 1995. “Changing Character of Foreign Direct Investment From Developing Countries: Case Studies from Asia.” The United Nations University, Institute for New Technologies.

Kumar, N. (2001). "Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations." Research Policy, **30**(1): 159-174.

Lambooy, J. G. and Boschma, R.A. (2001). "Evolutionary economics and regional policy." The Annals of Regional Science, **35**(1): 113-131.

Landry, R., Amara, N. and Lamari, M. (2002). "Does social capital determine innovation? To what extent?" Technological forecasting and social change, **69**(7): 681-701.

Laursen, K. and Salter, A. (2006). "Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms." Strategic Management Journal**, 27**(2): 131-150.

Leifer, R. And Triscari, T.(1987). "Research versus development: differences and similarities." Engineering Management, IEEE Transactions, (2): 71-78.

Levinthal, D. A. and March, J.G. (1993). "The myopia of learning." Strategic Management Journal, **14**(S2): 95-112.

Maggioni, M. A., Nosvelli, M., and Uberti, T.E. (2007). "Space versus networks in the geography of innovation: A European analysis." Regional science**, 86**(3): 471-493.

Maillat, D. (1998). "Innovative milieux and new generations of regional policies." Entrepreneurship & Regional Development, **10**(1): 1-16.

Malmberg, A. and Maskell, P. (2002). "The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering." Environment and Planning A, **34**(3): 429-450.

Mansfield, E. (1995). "Academic research underlying industrial innovations: sources, characteristics, and financing." The Review of Economics and Statistics: 55-65.

Mansfield, E. (1997). "Academic research and industrial innovation: An update of empirical findings." Research Policy**, 26**(7): 773-776.

Mastercard (2008). "Worldwide Centres of Commerce Index."

McFadden, D. (1974). “Conditional logit analysis of qualitative choice behaviour In: Zarembka P., Frontiers in Econometrics.” Academic Press, New York, 105-142.

McFadden D, Train K. (2000), “Mixed MNL models for discrete response” Journal of Applied Econometrics 15(5) 447-470

Miguélez, E. and Moreno, R. (2012). "Skilled labour mobility, networks and knowledge creation in regions: a panel data approach." The Annals of Regional Science: 1-22.

Mudambi, R. and Mudambi, S. M. (2005). Multinational enterprise knowledge flows: The effect of government inward investment policy. Management International Review 45(2), pp. 155-178.

OECD (2011). “Regions at a glance.” Paris, OECD.

Oinas, P. and Malecki, E.J. (2002). "The evolution of technologies in time and space: from national and regional to spatial innovation systems." International regional science review, **25**(1): 102-131.

Orlando, M. J. (2004). "Measuring spillovers from industrial R&D: On the importance of geographic and technological proximity." RAND Journal of Economics: 777-786.

Owen-Smith, J. and Powell, W.W. (2004). "Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community." Organization Science, **15**(1): 5-21.

Piergiovanni, R., Santarelli, E., and Vivarelli, M. (1997). "From which source do small firms derive their innovative inputs? Some evidence from Italian industry." Review of Industrial Organization, **12**(2): 243-258.

Powell, W. W., Koput, K.W., and Smith-Doerr, L. (1996). "Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology." Administrative Science Quarterly: 116-145.

Revelt D, Train K, 1998, “Mixed Logit with Repeated Choices: Households’ Choice of Appliance Efficiency Level” Review of Economics and Statistic 53(4) 647-657

Rosenberg, N. (1990). "Why do firms do basic research (with their own money)?" Research Policy, **19**(2): 165-174.

Rosenkopf, L. and Almeida, P. (2003). "Overcoming local search through alliances and mobility." Management Science: 751-766.

Rosenthal, S. S. and Strange, W.C. (2003). "Geography, industrial organization, and agglomeration." Review of Economics and Statistics**,** **85**(2): 377-393.

Sassen, S. (2001). “The Global City”, Princeton University Press.

Sassen, S. (2006). “Cities in a World Economy.” CA, Thousand Oaks, Pine Forge Press.

Schmoch, U., Laville, F., Patel, P., and Frietsch, R. (2003). "Linking technology areas to industrial sectors." Final Report to the European Commission, DG Research.

Solocha, A. and M. D. Soskin (1994). "Canadian direct investment, mode of entry, and border location." MIR: Management International Review, **34**(1): 79-95.

Taylor, P. J. (2004). "World city network: a global urban analysis."

Taylor, P. J., Ni, P., Derudder, B., Hoyler, M., Huang, J., Lu, F., Pain, K., Witlox, F., Yang, X., Bassens, D., and Shen, W. (2009). "The way we were: command-and-control centres in the global space-economy on the eve of the 2008 geo-economic transition." Environment and Planning A**, 41**(1): 7-12.

Thursby, J. and Thursby, M. (2006). Here Or There?: A Survey of Factors in Multinational R & D Location. Report to the Government-university-industry Research Roundtable, National Academy of Sciences.

Tushman, M.L. (1978). “Work characteristics and subunit communication structure: A contingency analysis.” Administrative Science Quarterly, 24:82-98

Tushman, M. L. and Anderson, P. (1986). "Technological discontinuities and organizational environments." Administrative Science Quarterly: 439-465.

Uzzi, B. (1996). "The sources and consequences of embeddedness for the economic performance of organizations: The network effect." American Sociological Review: 674-698.

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

Van Ark, Dougherty, S., Inklaar, R. and McGuckin, R. (2008). The structure and location of business R&D: recent trends and measurement implications. International Journal of Foresight and Innovation Policy, 4(1/2): 8-28.

Von Zedtwitz, M. and Gassmann, O. (2002). "Market versus technology drive in R&D internationalization: four different patterns of managing research and development." Research Policy, **31**(4): 569-588.

Wallace, N. and Walls, D. (2004). “Agglomeration economies and the high-tech computer cluster.” Unpublished.

Yamin, M. and Otto, J. (2004). "Patterns of knowledge flows and MNE innovative performance." Journal of International Management**, 10**(2): 239-258.

Table 1: The distribution of foreign R&D investments over 50 global cities, 2003-2012

Global city	Number of R&D projects (all)	Number of research projects	Number of development projects
Shanghai	274	74	200
Singapore	169	59	110
Beijing	102	50	52
Seoul	32	9	23
Hong Kong	31	3	28
Paris	22	7	15
London	20	5	15
Barcelona	19	8	11
Tokyo	19	7	12
Budapest	17	8	9
Melbourne	17	6	11
Munich	16	6	10
Dublin	14	8	6
Milan	14	6	8
Toronto	14	4	10
Copenhagen	13	5	8
Madrid	12	5	7
Mexico City	12	1	11
Sydney	12	1	11
Prague	11	4	7
Berlin	9	2	7
Stockholm	9	2	7
Edinburgh	8	2	6
Hamburg	8	1	7
Montreal	7	5	2
Warsaw	7	1	6
Atlanta	6	2	4
Boston	6	2	4
Dusseldorf	6	3	3
Frankfurt	6	0	6
Houston	6	3	3
San Francisco	6	1	5
Vienna	6	2	4
Santiago	5	2	3
Vancouver	5	2	3
Amsterdam	4	1	3
Brussels	4	2	2
Osaka	4	1	3
Chicago	3	0	3
Geneva	3	0	3
Los Angeles	3	2	1
Dallas	2	0	2
Rome	2	1	1
Washington	2	0	2
Zurich	2	1	1
Lisbon	1	0	1
Philadelphia	1	1	0
Athens	0	0	0
Miami	0	0	0
New York	0	0	0
Total	971	315	656

Table 2: Definition and summary statistics of explanatory variables

Name	Definition	Mean	Stdev.
Technological strength	Natural logarithm of number of patents in the global city at the industry level	4.212	1.725
International knowledge connectivity	share of patents with extra-local international knowledge linkage(s) in the total number of patents in the city at the industry level	0.224	0.156
Collaboration intensity	Share of co-patents in the global city in the total number of patents invented in the city at the industry level	0.024	0.037
University strength	Natural logarithm of number of university patents in the global city	3.180	1.338
GDP	Natural logarithm of GDP of the global city	11.873	0.842
GDP growth rate	Annual GDP growth rate of the global city (percentage)	4.238	39.953
Socio-political stability	Natural logarithm of socio-political stability ranking of the global city	4.437	0.106
Existing subsidiaries	Natural logarithm of number of exisiting subsidiaries in the global city	0.136	0.415
Wage cost	Natural logarithm of wage ranking of the global city	3.828	0.645
Corporate tax rate	Natural logarithm of corporate tax rate of the global city (percentage)	3.425	0.255
Language similarity	Dummy variable indicating that the source city and the global city share at least one language	0.195	0.396
Geographic distance	Natural logarithm of geographic distance in km between source city and the global city	6.263	1.000

Table 3: Correlation table

	1	2	3	4	5	6	7	8	9	10	11	12
1. Technological strength	1											
2. International knowledge connectivity	0.074	1										
3. Collaboration intensity	0.524	0.125	1									
4. University strength	0.581	-0.133	0.339	1								
5. GDP	0.483	-0.230	0.272	0.622	1							
6. GDP growth rate	-0.002	0.010	0.003	-0.035	0.000	1						
7. Socio-political stability	0.177	0.094	0.208	0.083	-0.170	0.002	1					
8. Existing subsidiaries	-0.037	0.034	-0.020	-0.029	0.026	-0.002	-0.051	1				
9. Wage cost	0.396	-0.015	0.195	0.372	-0.021	-0.001	0.423	-0.132	1			
10. Corporate tax rate	0.281	-0.084	0.206	0.181	0.177	-0.012	-0.010	-0.150	0.297	1		
11. Language similarity	0.051	0.092	0.026	0.149	-0.041	-0.011	0.209	0.042	0.136	-0.098		
12. Geographic distance	0.102	-0.061	0.023	0.127	0.189	-0.007	-0.017	-0.074	-0.092	-0.047	-0.130	1

Table 4: Mixed logit analysis of location choices for foreign R&D investment projects, 2003-2012

	Model 1 (All)	Model 2 (Research)	Model 3 (Development)
Technological strength	0.250***	0.230**	0.300***
	(0.062)	(0.112)	(0.082)
International knowledge connectivity	0.536***	0.400**	0.609***
	(0.090)	(0.167)	(0.109)
Collaboration intensity	0.004	0.031	-0.015
	(0.028)	(0.051)	(0.033)
University strength	0.289***	0.481***	0.200***
	(0.048)	(0.084)	(0.058)
GDP	0.250***	-0.065	0.406***
	(0.089)	(0.153)	(0.109)
GDP growth rate	0.001	-0.000	0.002**
	(0.001)	(0.001)	(0.001)
Socio-political stability	3.274***	4.150***	2.985***
	(0.463)	(0.812)	(0.543)
Existing subsidiaries	0.539***	0.676***	0.394**
	(0.121)	(0.138)	(0.190)
Wage cost	-1.626***	-1.762***	-1.559***
	(0.073)	(0.122)	(0.076)
Corporate tax rate	-0.22	-0.287	-0.17
	(0.174)	(0.314)	(0.213)
Language similarity	0.061	-0.043	0.67
	(0.179)	(0.257)	(0.244)
Geographic distance	0.026	-0.031	0.054
	(0.073)	(0.084)	(0.159)
Standard errors of random parts coefficients			
International knowledge connectivity		0.495***	0.540***
Collaboration intensity	-0.237**		
GDP growth rate	0.002***		0.001*
Existing subsidiaries	0.992***		1.341***
Language similarity	-0.813*		-0.976*
Geographic distance	0.342**		
No. of observations	42573	13862	28711
No. of cross-border R&D investments	971	315	656
Wald chisquare	719.22***	338.55***	641.44***

Notes: Error terms are clustered by investing firm. Significance levels: *** p < 0.01; ** p < 0.05; * p < 0.10. Only significant random components of the coefficients are reported.