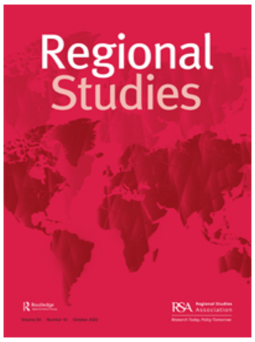
Research versus development: global cities and the location of MNCs' cross-border R&D investments



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Research versus development: global cities and the location of MNCs' cross-border R&D investments

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ABSTRACT
Large, internationally connected cities are important hubs of innovative activity, yet research on the attractiveness of such 'global' cities for research and development (R&D) activities by multinational corporations (MNCs) is scarce. We posit that factors determining cities' potential to attract R&D investments by MNCs differ depending on the type of R&D investments: research or development. We investigate the heterogeneous determinants of location choices for 1537 cross-border R&D investments by 633 MNCs in 55 global cities during the period 2003–12. The findings suggest that cities' technological and university strengths are stronger attracting factors for research activities, while global cities' market potential and intellectual property rights protection attract investments in development activities. Implications are discussed.

KEYWORDS
foreign research and development; global cities; location choice; research versus development

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INTRODUCTION

Cities are viewed as engines of growth (Henderson, 2007; McKinsey & Co., 2013) in the world economy. So-called 'global cities', characterized by a high degree of interconnectedness to local and global markets, a cosmopolitan cultural environment, and a high level of advanced producer services (Goerzen et al., 2013), serve as 'command and control' nodes in the world economy (Clark, 2016; Derudder et al., 2015; Friedmann, 1986; Taylor et al., 2009) and are important locations for the activities of multinational corporations (MNCs) (Belderbos et al., 2016, 2017a; Blevins et al., 2016; Du, 2016; Somers, 2016). Metropolitan areas are also increasingly important as locations of knowledge creation (Organisation for Economic Co-operation and Development (OECD), 2011). For example, the literature has documented that many innovations originated in cities (Bairoch, 1991; Jacobs, 1969). Global cities play an important role in knowledge creation, since they host many world-leading universities, offer connectedness embedded in global knowledge networks of the global economy (Bathelt et al., 2004; Breschi & Lenzi, 2015; Lorenzen et al., 2020; Sassen, 2001, 2006; Wall & van der Knaap, 2011), host skilled workers and scientists (Matthiessen et al., 2010; Verginer & Riccaboni, 2021), and represent hubs of sophisticated demand for innovative products. Notable examples of such global cities are Hong Kong, London, New York, Paris and Singapore.

Despite global cities' important role in innovation and knowledge creation, and the world economy, prior studies have not specifically examined the role of global cities as locations and attractors of innovative activities of MNCs. Given the characteristics of global cities, they are also expected to be strong attractors of global research and development (R&D) investments of MNCs. Prior work has examined R&D location decisions at the country level (e.g., Bas & Sierra, 2002; Belderbos et al., 2017b, 2017c; Kumar, 2001), at the level of regions or cities within specific countries (Abramovsky et al., 2007; Autant-Bernard, 2006; Belderbos et al., 2020; Li & Bathelt, 2018), at the level of regions within Europe (Basile et al., 2008; Belderbos & Somers, 2015; Belderbos et al., 2014;

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Siedschlag et al., 2013), or in cities in the context of manufacturing–R&D collocation propensities (Castellani & Lavoratori, 2020), but has not specifically examined R&D investments in global cities.[1] In this paper, we contribute an analysis of the R&D investment location choices of multinational firms among the world's major global cities. We argue that even given their general attractiveness as location of MNC activities, there is substantial heterogeneity in the strength of locational factors attracting R&D investments across global cities, with cities heterogeneously positioned to serve as hotspot of innovation.

We argue that there is also substantial heterogeneity in the nature of the R&D investments, which leads to differential strength of location drivers attracting such investments. We distinguish R&D investments between those focusing on research and those focusing on development (e.g., Barge-Gil & López, 2015; Karlsson et al., 2004; Leifer & Triscari, 1987; Von Zedtwitz & Gassmann, 2002). Research and development differ in motivations, objectives, people and management (Barge-Gil & López, 2015). Research involves the discovery and creation of new knowledge, while development is related to applying technologies to commercial products and manufacturing processes (Karlsson et al., 2004; Wheelwright & Clark, 1992). In the context of foreign R&D investments by MNCs, development activities have been termed 'home-base exploiting' with the aim to commercialize and adapt technologies and knowledge developed at home to foreign manufacturing and marketing activities, while research activities have been termed 'home-base augmenting' aiming to augment existing firm technologies, to absorb knowledge from foreign local research and scientific communities, and to create new knowledge (Ivarsson et al., 2017; Kuemmerle, 1997). We posit that city-level locational drivers for investments in research are more related to technological strength and university knowledge creation, while locational drivers for investments in development are more related to local market opportunities and commercialization and appropriation potential linked to the local intellectual property right regime.

Empirically, we examine the location choices (2003–12) for 1537 cross-border R&D investments across 55 global cities by 633 multinational firms in the manufacturing industry. We differentiate R&D investments by their main research or development mandate. Estimating conditional logit (discrete choice) models, we find broad support for a strong heterogeneity of the location drivers of R&D investments. Our findings suggest that global cities are in competition to attract R&D investments and that their heterogeneous attractiveness may lead to a specialization in development- or research-oriented local innovation systems.

Our paper contributes insights at the intersection of the international business literature on foreign R&D and location decisions, and the regional economics literature on regional innovation clusters and global cities (McCann, 2011; Papanastassiou et al., 2019). We contribute to the literature on global cities (Asmussen et al., 2019; Belderbos et al., 2020, 2017a; Blevins et al., 2016; Clark, 2016; Derudder et al., 2015; Derudder & Taylor, 2018; Goerzen et al., 2013; Sassen, 2001, 2006; Wall & van der Knaap, 2011) by highlighting their heterogeneous roles in global innovation and as hotspots of multinational R&D activity. We contribute to the stream of literature on regional R&D investments and regional innovation performance (Abramovsky et al., 2007; Autant-Bernard, 2006; Basile et al., 2008; Belderbos et al., 2014, 2016; Belderbos & Somers, 2015; Breschi & Lenzi, 2015; Cantwell & Piscitello, 2005; Essletzbichler, 2015; Li & Bathelt, 2018; Rigby, 2015; Siedschlag et al., 2013; Verginer & Riccaboni, 2021) by showing the important and systematic heterogeneity in the city-level drivers of R&D investments and the differences between R&D investments.

BACKGROUND AND HYPOTHESES

A growing literature has investigated the locational determinants of foreign R&D investments by multinational firms. While several studies have been conducted at the country level (e.g., Bas & Sierra, 2002; Belderbos et al., 2017b, 2017c; Kumar, 2001), other studies have taken a regional perspective (Abramovsky et al., 2007; Autant-Bernard, 2006; Belderbos et al., 2014; Belderbos & Somers, 2015). Attention has been devoted to the role of the cost and abundance of local R&D manpower (Kumar, 2001), market size (Kuemmerle, 1999), intellectual property rights (IPR) (Branstetter et al., 2006; Kumar, 2001), corporate tax rate and tax incentives (Hall & Van Reenen, 2000), and government investment policies (Head et al., 1999; Mudambi & Mudambi, 2005). Other studies have taken account of the role of local technological strength (Bas & Sierra, 2002), and the strength of local universities (Belderbos et al., 2014, 2017b, 2017c; Cantwell & Piscitello, 2005; Thursby & Thursby, 2006).

Scant attention has been given to the role of global cities as preferred locations of R&D investments, and to the potential differences in the location drivers of research versus development activities. Global cities are important locations for R&D activities, as they host academic and innovation activities, function as hubs in international knowledge exchange (Carlino, 2001) and feature concentrated and sophisticated demand. In the current study, we examine the drivers of MNEs' choice to locate R&D activities in specific global cities, distinguishing between R&D activities.

The distinction between research and development

Two main motivations to conduct international R&D have been identified in the international business literature: 'home-base exploiting' and 'home-base augmenting' foreign R&D (Belderbos et al., 2015; Kuemmerle, 1997). The traditional 'home-base exploiting' foreign R&D is to exploit, commercialize and adapt technologies and knowledge developed at the company's home base to the laboratory site abroad and to foreign local manufacturing and marketing sites. 'Home-base augmenting' foreign R&D is to augment existing firm technologies, to absorb knowledge from foreign local research and scientific communities, and to create new knowledge (Florida, 1997; Kuemmerle, 1997; Siedschlag et al., 2013).

The difference in motivations corresponds to the differences between R&D activities that have been well documented in the literature (e.g., Barge-Gil & López, 2015; Belderbos et al., 2009, 2017c; Karlsson et al., 2004; Leifer & Triscari, 1987; Von Zedtwitz & Gassmann, 2002; Wheelwright & Clark, 1992). Research activities are characterized as aiming to acquire or generate new knowledge and to expand the scope of technologies, involving more non-routine tasks than development (Karlsson et al., 2004; Leifer & Triscari, 1987), maintaining close links with universities (Van Ark et al., 2008), and being relatively independent of the rest of the organization apart from headquarters (Leifer & Triscari, 1987). In contrast, development activities are characterized as aiming at technology exploitation and introducing new products or processes to fit market and manufacturing circumstances (Wheelwright & Clark, 1992). They involve more routine tasks (Leifer & Triscari, 1987), are more closely controlled and supervised, and require intensive communication with other units within the organization such as marketing and manufacturing (Allen et al., 1979).

In line with the different characteristics between R&D, locations of R&D activities are often different (Von Zedtwitz & Gassmann, 2002). Development activities for local adaptation are more likely than research activities to be located closer to manufacturing plants (Ivarsson et al., 2017). Decisions for R&D activities can be expected to be subject to different location drivers (Belderbos et al., 2009). Following the different purposes of R&D, we expect that knowledge strengths (technological and academic strength) and market opportunities (market size, market growth, and IPR protection) will exert different influences on R&D investment location decisions.

Local knowledge strengths

Knowledge generated by local firms and universities is an important source of geographically bounded knowledge spillovers benefitting R&D activities of foreign firms. Agglomeration advantages tend to be strongest for firms' R&D activities, leading to patterns of strong geographic concentration (Alcacer, 2006; Audretsch & Feldman, 1996; Hilber & Voicu, 2010; Jofre-Monseny et al., 2011; Li & Bathelt, 2018; McCann & Mudambi, 2004; Rosenthal & Strange, 2003). Co-location facilitates knowledge spillovers and the creation of knowledge networks (Maggioni et al., 2007) through formal interactions and informal encounters in which tacit knowledge is exchanged (Boschma, 2005; McCann, 2011), allowing cities to develop new knowledge often based on existing strengths (Essletzbichler, 2015; Rigby, 2015). Studies have shown that firms can improve their innovative performance by benefitting from knowledge spillovers in R&D clusters (e.g., Baptista & Swann, 1998; Beaudry & Breschi, 2003) and that the technological strength of host countries in the field in which the MNC is active is a factor that influences location decisions (Bas & Sierra, 2002; Belderbos et al., 2013; Chung & Alcacer, 2002; Patel & Vega, 1999). 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.

In addition to R&D and technology development activities by firms, the importance of academic research as a source of knowledge spillovers and facilitator of R&D has been widely acknowledged (Cassiman et al., 2008; Cohen et al., 2002; Fleming & Sorenson, 2004; Mansfield, 1995, 1998). There are several mechanisms through which universities may have an impact on firms' R&D activities. Universities supply firms with a skilled labour force of scientists and engineers, act as collaboration partners, and transfer new and embryonic technologies to firms (e.g., Cassiman et al., 2008). Universities 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 a deeper understanding of the technological landscape (Fleming & Sorenson, 2004) and help them to pursue the right research path avoiding wasteful experimentation costs. Also, scientific knowledge may help firms to better evaluate their applied research activities and estimate their economic implications. Universities conduct not only research activities but also more commercialization-oriented development activities (Cohen et al., 2002). A good understanding of academic research and an effective translation into specific applications can lead to first-mover advantages (Fabrizio, 2009; Rosenberg, 1990). These benefits of academic research to firms' innovation performance also tend to be localized (Anselin et al., 1997; Autant-Bernard, 2001; Belderbos et al., 2014, 2017b, 2017c; Del Barrio-Castro & García-Quevedo, 2005; Fischer & Varga, 2003), implying that R&D activities are required to be in the vicinity of universities to reap the benefits.

It follows that global cities hosting relevant R&D activities (technological strength) by firms and strong research universities (university strength) are attractive environments for multinational firms' R&D investments. However, the magnitude of the effects of technological and university strength will be heterogeneous, depending on whether firms decide on the location of research or development activities. Research activities are characterized as aiming to acquire or generate new knowledge and technologies (Karlsson et al., 2004; Leifer & Triscari, 1987) and draw on external sources of knowledge, while often building on and maintaining close links with universities (Van Ark et al., 2008). Research in the vicinity of agglomerations of strong R&D activities and excellent universities allows access to local engineering and scientific communities, centres of innovation, and local talent pools. In contrast, development activities draw more on existing internal sources of knowledge, with the aim to adapt or exploit the knowledge in the local environment, which renders local technological and university strengths less salient. This leads to the following hypothesis.

Hypothesis 1: A global city's local knowledge strength has a stronger influence on multinational firms' choice in which global city to invest in research activities than it has on the decision where to invest in development activities.

Local market opportunities

Development activities are characterized as aiming at technology exploitation and introducing adapted products or processes. Von Zedtwitz and Gassmann (2002) define development as a 'market-driven' activity, as the internationalization of development typically follows the call of foreign markets. Foreign development activities correspond to the traditional 'home-base exploiting' motivation for foreign R&D: to exploit and adapt technologies developed at (mostly) at home in foreign markets (Kuemmerle, 1997). Effective development for local markets requires close interaction with the MNC's local manufacturing and marketing activities and proximity to local customers (e.g., Belderbos et al., 2009). In particular, if the local market is large and growing, investments in local development activities are likely to be instrumental in increasing sales prospects. This is likely to play an important role in global cities, given their sizes, growth (McKinsey & Co., 2013) and concentration of relative sophisticated consumers and business clients (Goerzen et al., 2013).

While these arguments hold for development activities, research activities have less of a direct link with market opportunities, as they focus on technology development without direct commercialization and market expansion opportunities. The outcomes of research activities may also be transferred back to R&D laboratories at home and may be an input into development for other markets than the local market of the R&D unit. This suggests that market opportunities are a much weaker driver of the location of research activities, suggesting the following hypothesis:

Hypothesis 2: A global city's market opportunities has a stronger influence on multinational firms' choice in which global city to invest in development activities than it has on the decision where to invest in research activities.

Local intellectual property rights protection

A strong intellectual property rights protection regime has been shown to be an important factor in attracting R&D investments (e.g., Branstetter et al., 2006). However, no prior study has investigated the heterogeneous effects on location choices of R&D activities. Development activities focusing on releasing new products to local markets or improvements in products are 'market driven' and commercialization oriented (Von Zedtwitz & Gassmann, 2002). Since they are strongly focusing on knowledge appropriation through commercialization and receiving a return on R&D investments, protection of the firm's technologies is a key concern (Leten et al., 2013). Firms have strong incentives to avoid disclosure of knowledge to local rivals and to prevent the misappropriation of this intellectual property (Belderbos et al., 2021). A strong intellectual property rights regime in the host country of the global city will help the multinational firm in these efforts. In contrast, research activities focusing on knowledge creation are less commercialization oriented and further from the market, such that knowledge outflows have less direct consequences for a firm's technology position. If the firm collaborates with universities in the context of research activities, it will partially adhere to an open science logic with substantial knowledge diffusion (Belderbos et al., 2017b). It follows that the strength of the IPR environment is less likely to be important for research activities. This leads to the following hypothesis:

Hypothesis 3: A global city's intellectual property rights protection regime has a stronger influence on multinational firms' choice in which global city to invest in development activities than it has on the decision where to invest in research activities.

DATA, VARIABLES AND EMPIRICAL MODEL

We draw on an extensive database on cross-border greenfield investments compiled by Financial Times Ltd (FDI Markets). The version of the database we had access to records over 120,000 cross-border investment projects between 2003 and 2012, covering activities such as headquarters, R&D, design, development and testing, manufacturing, and sales and service. This dataset identifies the investing firm, source country, type of project, host country, host city and sector in which the investing firm operates. The accuracy and validity of this database have been confirmed by several studies (e.g., Castellani et al., 2013; Crescenzi et al., 2014; D'Agostino et al., 2013).

From this database, we extracted all projects classified as either 'research & development' or 'design, development and testing' industry activities. We categorized the R&D projects in 12 two-digit NACE manufacturing industries based on the industry of the investing firm. For these industries we can construct measures of industry-specific technological strength (based on patents) of each global city. Each R&D project in the database was classified as a research or a development project. All projects of the 'design, development and testing' category are classified as development. Projects of the 'R&D' category were classified as either research or development based on the text description accompanying each R&D investment project in the FDI Market database. We classified an investment project as research if from the text description it was clear that the investment was in activities involving research (including basic, fundamental, and scientific research). We classified a project as a development investment if no such reference to research activities were made, and the text referred to activities such as development, adaptation, solutions, and technical services.[2] We provide two illustrative descriptions of a research and a development investment project, respectively.

Table 1. Distribution of foreign research and development (R&D) investments over 55 global cities, 2003–12.

Global city	R&D projects	Research projects	Development projects
Shanghai	320	92	228
Singapore	189	63	126
Bangalore	116	41	75
Beijing	113	53	60
Seoul	53	15	38
Barcelona	43	21	22
London	42	12	30
Tokyo	41	9	32
Paris	34	14	20
Hong Kong	28	2	26
Dublin	27	16	11
Munich	27	7	20
Boston	26	11	15
Budapest	25	12	13
Mumbai	24	7	17
Melbourne	21	8	13
Los Angeles	18	4	14
Milan	18	7	11
Toronto	18	6	12
Madrid	17	8	9
Montreal	17	10	7
San Francisco	17	5	12
Stockholm	17	5	12
Brussels	16	6	10
Moscow	16	5	11
Copenhagen	14	6	8
Edinburgh	14	4	10
Mexico City	14	1	13
Prague	14	5	9
Taipei	14	3	11
Vienna	14	8	6
Sydney	12	2	10
New York	11	0	11
Warsaw	11	2	9
Dallas	10	4	6
Dubai	10	1	9
Dusseldorf	9	3	6
Hamburg	9	2	7
Houston	9	2	7
Bangkok	8	3	5
Berlin	8	2	6
Chicago	8	0	8
Frankfurt	8	2	6
Rio de Janeiro	8	2	6
Amsterdam	6	2	4
Atlanta	6	3	3

(*Continued*)

Table 1. Continued.

Global city	R&D projects	Research projects	Development projects
Vancouver	6	2	4
Philadelphia	5	2	3
Santiago	5	2	3
Washington	5	2	3
Miami	4	1	3
Zurich	4	1	3
Geneva	3	0	3
Rome	3	2	1
Lisbon	2	0	2
Total	1537	508	1029

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.

September 2011 – 3M India [Subsidiary of 3M] (United States) is investing €15.97 m in the city of Bangalore (Karnataka), India in the Chemicals sector in a Research & Development project. 3M India has opened its new R&D facility in Bangalore, India. The Rs1bn R&D centre has a floor area of 13,935 sq m and houses more than 25 labs for product and technology development. The new facility will initially focus on developing products for key industry segments as infrastructure, automotive, healthcare and construction for the Indian market. The company intends to increase its R&D personnel to 300 by 2016.

The differences between development-oriented R&D activities and research-based R&D activities have been confirmed in prior case study research (Kuemmerle, 1998, 1999; Von Zedtwitz & Gassmann, 2002) and are the cornerstone of the 'home-base exploiting' versus 'home-base augmenting' foreign R&D framework (Ivarsson et al., 2017; Kuemmerle, 1997) used frequently in extant research on the internationalization of R&D (e.g., Belderbos et al., 2015; Siedschlag et al., 2013).

We identify global cities by using the ranking of MasterCard (2008) and the Globalization and World Cities (GaWC) maintained at Loughborough University (GaWC, 2021). The ranking of MasterCard is of interest because it provides a comprehensive ranking of 75 global cities based on seven city characteristics, that is, the legal and political frameworks, economic stability, the ease of doing business, financial flows, the business centre, knowledge creation, information flow, and liveability. The GaWC dataset classifies cities as so-called 'alpha' world cities if they exhibit a strong international connectivity in advanced producer services and knowledge flows.[3]

The intersection of the two rankings, and a number of data limitations concerning the availability of city characteristics, led us to include 55 of these global cities in our analysis. The included cities are located in 32 countries.

Instead of using legal boundaries for metropolitan areas, we define the boundaries of global cities on the basis of economic integration of the area. We apply the OECD methodology to define functional urban areas (OECD, 2011) based on population density and travel-to-work flows. A metropolitan region consists of a densely populated 'urban core' and 'hinterlands' whose labour markets are highly integrated with the core. For example, the Paris functional urban area includes not only the 2 million inhabitants of the core city but also the 8 million inhabitants of the wider metropolitan area. We were able to define the boundaries of 48 global cities in OECD countries. In addition, we included seven other cities for which we could apply the OECD functional urban area methodology to determine metropolitan boundaries: Bangalore and Mumbai (India), Bangkok (Thailand), Dubai (United Arab Emirates – UAE), Moscow (Russia), Rio de Janeiro (Brazil) and Taipei (Taiwan).

From the FDI Market database we extracted 1537 investments in 55 global cities made by 633 multinational firms during the period 2003–12.[4] There are 1029 development investments and 508 research investments. US MNCs are responsible for the largest share of the R&D projects (42.8%), followed by German (11.5%), Japanese (9.5%), French (6.4%) and British (5.5%) firms. The distribution of these R&D investments across the 55 global cities during the period 2003–12 is presented in Table 1. Shanghai attracted most foreign R&D projects, that is, 320 projects (20.8%), followed by Singapore and Bangalore with 189 (12.2%) and 116 (7.5%) projects, respectively. In contrast, no R&D investment has been observed for Athens, while Geneva, Rome and Lisbon received fewer than four investments during the period.[5]

Dependent and hypothesis testing variables

The dependent variable, R&D investment location choice, is a binary variable that takes the value 1 if a foreign firm chose a particular global city to locate its R&D investment, and 0 for the other (54) global cities in the choice set.

Local knowledge strengths providing knowledge sourcing opportunities are measured by two variables: technological strength of the local R&D cluster and the presence of top universities. Our measure of technological strength draws on patent data. We draw on the OECD's REGPAT Database, which provides the regions and geographical coordinates of the addresses of inventors on each patent, to allocate patents to cities. A patent with at least one inventor located within a city's metropolitan boundaries is allocated to that city.

We use patents filed under the Patent Co-operation Treaty (PCT). The PCT offers a single, unified, procedure to file for protection in each of the jurisdictions of the PCT. PCT patents are thus filed for inventions that are important enough for firms to seek protection in several countries and markets (e.g., the United States, European Union and Japan). This feature has the advantage that patents are less likely to exhibit a country or city bias.

We matched inventions to global cities based on available concordance tables linking NUTS-3/TL-3 regions and geographical coordinates to metropolitan areas. We allocated patents to industries through the technology class (IPC code) to industry (two-digit NACE) concordance developed by Schmoch et al. (2003). The variable *technological strength* of the global city is calculated as the number of patented inventions originating in the city in technologies relevant to the firms' industry. This variable measures the availability of local technological knowledge and potential R&D spillovers relevant for the investing firm.

To measure *university strength*, we gathered information on the presence of leading universities in each city, defined as universities listed in the Shanghai 500 list of top universities in the year located in each city. The presence of top universities will also represent the availability of highly qualified scientists, postdoctoral researchers, and doctorates. To arrive at a university strength indicator that is not conflated with city size, we scaled this number by the city's population.[6] *Technological strength* and *university strength* test for Hypothesis 1.

We include two variables measuring market potential (Hypothesis 2) of a global city: gross domestic product (GDP) of the city and the growth rate of city GDP. City market size measured as GDP is expressed in purchasing power parity terms. The GDP growth rate is the yearly proportional growth in GDP of the global city. Data on city GDP are taken from the Citymayors data repository and the OECD's metropolitan database. These variables are test Hypothesis 2.

Data on *intellectual property rights protection* (IPR protection) are drawn from the Global Competitiveness Report of the World Economic Forum (WEF) (2015). IPR protection measures the strength of patents, trademarks and copyright protection in the country. It is based on a survey among managers of (multinational) firms. The index takes values between 0 and 10. This variable tests Hypothesis 3.

Control variables

We include a series of control variables found to affect location decisions (of foreign investment) in prior studies (e.g., Arauzo-Carod & Viladecans-Marsal, 2009; Arauzo-Carod et al., 2010; Autant-Bernard, 2006; Belderbos et al., 2014, 2016; Castellani & Lavoratori, 2020; Moncada-Paternò-Castello et al., 2011; Nielsen et al., 2017), or suggested by extant research on global cities (e.g., Asmussen et al., 2019; Belderbos et al., 2017a; Lorenzen et al., 2020).

International knowledge connectivity of a city refers to the extent to which knowledge created in the city is connected to knowledge sources residing abroad. It can increase the attractiveness of the city for R&D investments, as an international knowledge network can foster access to wider knowledge inflows (e.g., Asmussen et al., 2019; Belderbos et al., 2017a; Cano-Kollmann et al., 2016; Lorenzen et al., 2020). 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 (Bell & Zaheer, 2007; Berman et al., 2020; Breschi & Lenzi, 2015; Malmberg & Maskell, 2002). Empirical work has also confirmed the importance of extra-local knowledge sources on firms' innovative performance (Gertler & Levitte, 2005; Gittelman, 2007; Owen-Smith & Powell, 2004; Rosenkopf & Almeida, 2003). To measure the international knowledge connectivity of the global city, 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. The connectivity measure is calculated at the industry level.

The analysis also takes into account the *population density* of the city. Population density is the population of the city divided by its surface area. Data on population are taken from the Citymayor data repository and the OECD's metropolitan database; surface areas are retrieved from city websites. Greater population density may on the one hand represent stronger agglomeration benefits of the city. On the other hand, high density may imply congestion costs.

Apart from the presence of universities, cities also differ in the level of education of the population. However, there is no systematic information available on higher education and human capital – such as the number of science and technology graduates or employment in R&D and technology related services – available across all cities. Instead, we include city level information on educational spending. Educational expenditure at the city level will be correlated with tertiary education level in the cities, and is likely to reflect human capital availability that is relevant for multinational firms deciding where to locate their R&D facilities. Specifically, we include the share of the city's household expenditure on education in total household spending in the cities. Data are obtained from Oxford Economics.

We control for two cost-related local investment factors, i.e., the global city wage level and the corporate tax rate. 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 Price & Earning reports. The c*orporate tax rate* is taken from KPMG reports. Corporate tax rates are only available at the country level, but in general show little variation across regions within a country. Prior studies have found ambiguous effects of corporate tax rates on foreign R&D investment locations, with some studies suggesting negative effects (e.g., Hines, 1995; Mudambi & Mudambi, 2005), while others did not find a significant influence (e.g., Cantwell & Mudambi, 2000).

There is prior evidence that financial incentives given by local and national governments affect R&D location decisions (Head et al., 1999; Mudambi & Mudambi, 2005). The effective tax burden on R&D projects can differ due to various financial regulations and special tax treatment of R&D. The so-called B-index measures the net cost for the firm to invest in R&D (Bösenberg & Egger, 2017; Warda, 2006). It is defined as the net present value of before-tax income required to cover the cost of R&D expenditures, including applicable taxes. The index is reduced due to R&D tax credits, cost allowance deductions, and depreciation allowances for R&D (Belderbos et al., 2016; Warda, 2006). Unfortunately, systematic information on R&D taxation and incentives is not available for all countries and regions represented in our sample and inclusion of the variable leads to the omission of four cities (Dubai, Bangkok, Hong Kong and Warsaw) from the analysis, reducing the number of investments by 65 and the number of observations by about 9000, and rendering the analysis less representative in this regard. We therefore estimate separate models and report the results of these models with the B-index in a separate table.[7]

The analysis also controls for the quality of the infrastructure of the global city. Data on this measure were provided by the Economist Intelligence Unit (EIU). Global cities are given an overall score based on criteria such as the quality of the road network, public transport, telecommunications and housing quality. The maximum score is 100.

We include GDP of the country in which the city is located and GDP density of the broader region in which the city is located as additional control variables, since location in a global city is also likely to provide market access to the broader region and the country as a whole. Country and region level GDP data come from the World Development Indicators compiled by the World Bank, and the OECD regional database. The measure of GDP of the region surrounding the global city is the broader region for which the city can play an integrator role. This is the focal and/or adjacent TL-2 region and can also extend to neighbouring countries: for London this is South East England, for Hong Kong this is Guangdong province, and for Singapore we take the Malaysian peninsula. Since in contrast with the functional urban area (FUA) methodology, there are no established perimeters for what these larger surrounding regions are, and because we have to work with established administrative boundaries, in some cases the surrounding region is substantially larger than in other cases. We therefore normalize the size of the regional economy by dividing its GDP by its surface area and include regional GDP density.

We also include control variables that vary with the investing firm. Cities may be a more likely location candidate if the firm faces fewer setup costs and operational issues. MNCs are likely to face greater coordination and control challenges when operating foreign units if they have to operate in an unfamiliar language environment. One factor influencing this is the language distance between the home country and the country of the global city. We measure language distance using the indicator of Dow and Karunaratna (2006) that takes into account the 'closeness' of languages, the incidence of languages spoken in a country, and the heterogeneity of spoken languages in the countries.

English language proficiency in the host country can reduce communication costs (Cuypers et al., 2015; Slangen, 2011). We include the average Test of English as a Foreign Language (TOEFL) scores as recorded for examinees in the host country by ETS (Educational Testing Services) as an indicator of such proficiency.

We also control for geographical distance between the city and the city of incorporation the investing firm. Geographical distance can negatively influence investment location decisions as it can increase coordination costs (Castellani et al., 2013; Ghemawat, 2001). We calculated the geographical distance from the geographical coordinates of cities as the great circle distance (the shortest distance between two points on the surface of a sphere).

Firms will be more likely to invest in R&D in a global city if they have previous manufacturing investments in the city and can benefit from closer interaction with other units (e.g., Castellani & Lavoratori, 2020; Ivarsson et al., 2017). To control for earlier investments in the global city, we calculated the number of affiliates in the city prior to the investment project. We identified each firm's affiliates in the city by using the ORBIS database developed by Bureau Van Dijk and included the total number of affiliates located in the global city prior to the investment project.

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., 1995). 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. The correlation coefficients do not raise multicollinearity concerns.

Empirical model: conditional logit

In order to analyse which global city is chosen as an investment location for multinational firms' foreign R&D, the conditional logit model is used (McFadden, 1974). The conditional logit model has been the most commonly used in the literature focusing on the location choice of foreign direct investment (e.g., Alcacer & Chung, 2007; Belderbos et al., 2014). The probability that a multinational firm chooses a global city for its R&D project can be expressed by the following equation:

$$P_{i,j,t} = \frac{\exp(\alpha C_{j,\,t-1} + \beta S_{s,j,t-1} + \gamma F_{i,j,t-1})}{\sum_j \exp(\alpha C_{j,\,t-1} + \beta S_{s,j,t-1} + \gamma F_{i,j,t-1})}$$

where $P_{i,j,t}$ represents the probability of firm i to locate its R&D in a global city j, rather than in any other global city, at time t; $C_{j,t-1}$ defines the characteristics of a global city j at time $t-1$ (e.g., GDP, population density, wage levels); $S_{s,j,t-1}$ are the characteristics of a global city j at time $t-1$ that vary by sector (e.g., technological strength); and $F_{i,j,t-1}$ defines the characteristics of a global city j at time $t-1$ that vary by firm (e.g., the multinational firm's number of prior affiliates in the global city).

As the coefficients of the conditional logit model are not directly interpretable as marginal effects, it is preferred to execute a logarithmic transformation on the exploratory variables in the conditional logit model times $(N-1)/N$ (where N is the total number of alternatives in the choice set) (Head et al., 1995). By doing so, the coefficients represent the average elasticity of the probability of the location choice with regard to the variable. In practice, this means that we multiply the coefficient on a logarithmic transformed exploratory variable by 0.98 since the locational choice set consists of 55 global cities.

The conditional logit assumes the independence of irrelevant alternatives (IIA), a condition which is not always met in practice. A solution is to estimate a random coefficient mixed logit version of the model that allows for heterogeneity in investor preferences and relaxes the IIA assumption. Estimation of mixed logit models delivered highly similar results.

EMPIRICAL RESULTS

The results of the conditional logit models are reported in Table 4. Model 1 is estimated on all investments. Model 2 is estimated for research investments only, while model 3 includes only development investments. Coefficients indicated in bold in models 2 and 3 indicate that the difference between the coefficients between the research and the development model is significant at the 5% level.

In the overall and research models, university strength has a significant and positive effect on R&D location choice, but this is not the case in the development model. In model 1, the coefficient suggests that a 10% increase in university strength, results in a probability increase of approximately 3.7% that the city gets selected as a location for R&D activities. The coefficient for research investments in model 2 is almost twice as large. Although the coefficient of university strength in the development model is small and insignificant, a relatively high standard error of the coefficient in the development model renders the Wald test of the difference in coefficients in the development and research models insignificant.

Technological strength has a significant and positive effect on R&D location choice in all models. In model 1, the coefficient shows that a 10% increase technological strength leads to an increase in the probability that the city gets chosen by approximately 1.7%. The comparative elasticity for research investments is 2.8%, while it is 1.3% for development investments. A Wald test confirms that the effect of technological strength for research investments is significantly larger than for development investments ($p < 0.05$). Overall, these results provide support for Hypothesis 1.

Table 2. Definition and summary statistics of explanatory variables.

Variable	Definition	Mean	SD	Minimum	Maximum
Number of top universities per capita	Number of top universities in the global city divided by the population of the city	0.75	0.65	0	3.30
Technological strength	Number of patents in the global city at the industry level	206	645	0	7867
City GDP	Gross domestic product (GDP) of the global city (US$ millions)	201,925	214,123	17,828	1,327,852
City GDP growth rate	Annual GDP growth rate of the global city (percentage)	3.05	3.43	−15.29	21.47
IPR protection	Intellectual property rights (IPR) protection index taken from global competitiveness index	7.3	1.6	2.2	9.6
International knowledge connectivity	Share of patents with external international linkages in the total number of patents in the city at the industry level	0.23	0.19	0	1
Population density	Population density of the global city (thousand persons/km^2)	6.91	9.34	0.26	50.89
Share of educational expenditure in consumer expenditure	Percentage of educational expenditure in total consumer expenditure	2.49	1.67	0.30	8.90
Wage level	Wage level of the global city, index relative to Zurich (100)	49.0	26.7	3.1	108.4
Corporate tax rate	Corporate tax rate of the global city's country (%)	29.8%	7.9%	0.0%	45.0%
Infrastructure	Infrastructure score of the global city	88.8	12.0	46.4	100.0
English proficiency	English language proficiency scores, measured by the Test of English as a Foreign Language (TOEFL) (full marks = 100)	80.5	11.8	48.3	95.0
Country GDP	GDP of the country of the global city (US$ billions)	2793	4232	30	15,534
Regional GDP density	GDP of the global city's broader region (at adjusted OECD TL-2 level) divided by the region area (US$ millions/km^2)	9.3	11.3	0.1	61.2
Language distance	Language distance between home country and the global city's country	5.2	1.3	1.7	6.1
Geographic distance	Geographical distance (km) between the source city and global city	7329	4123	31	19,620
Firm's prior affiliates	Firm's number of prior affiliates of in the global city	0.4	1.28	0	45
B-index (tax burden on R&D)	Relative tax burden on research and development (R&D) in the global city's country	0.90	0.12	0.56	1.05

Both city market opportunity variables show important differences in effects depending on the type of R&D investments. City GDP has a positive and significant effect on development activities (model 3), while we observe no significant effect (and even a negative sign) for research activities (model 2). The city GDP growth rate is significant and positive in both models 2 and 3, but its magnitude for research investments is more than twice as large as for development investments. Wald tests suggest that effects of city GDP and city GDP growth rate are significantly different between research activities and development activities. These results provide strong support for Hypothesis 2. IPR protection has a significant and positive effect on development activities, but no significant effect on research activities, in support of Hypothesis 3. Although the coefficient in the research model is more than four times as large as the coefficient in the development model, a relatively high standard error of the coefficient in the development model renders the Wald test insignificant.

Table 3. Correlation coefficients.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Location choice																		
2. Number of top universities per capita	−0.06																	
3. Technological strength	0.03	0.10																
4. City GDP	0.05	−0.31	0.21															
5. City GDP growth rate	0.08	−0.20	−0.11	−0.05														
6. IPR protection	−0.04	0.51	0.25	−0.08	−0.24													
7. International knowledge connectivity	0.03	0.06	0.28	−0.36	0.06	−0.03												
8. Population density	0.00	0.03	−0.06	0.06	−0.01	−0.01	−0.04											
9. Share of educational expenditure	0.07	−0.47	−0.16	0.31	0.23	−0.22	−0.20	−0.13										
10. Wage level	−0.09	0.61	0.28	0.05	−0.36	0.69	−0.14	−0.03	−0.40									
11. Corporate tax rate	0.00	0.11	0.27	0.16	−0.20	0.05	0.00	0.29	−0.21	0.09								
12. Infrastructure	−0.04	0.52	0.31	0.02	−0.16	0.54	−0.02	−0.14	−0.33	0.78	0.04							
13. English proficiency	−0.04	0.38	0.07	−0.07	−0.24	0.41	−0.02	−0.17	−0.03	0.47	0.30	0.35						
14. Country GDP	0.02	−0.09	0.21	0.47	−0.17	0.19	−0.33	−0.10	0.04	0.35	0.34	0.12	0.28					
15. Regional GDP density	−0.01	0.21	0.13	0.14	−0.11	0.02	−0.09	0.40	−0.30	0.19	0.04	0.05	−0.31	0.05				
16. Language distance	0.00	−0.11	−0.06	0.06	0.08	−0.23	−0.04	0.15	−0.16	−0.16	−0.08	−0.07	−0.44	−0.12	0.31			
17. Geographic distance	0.02	−0.23	−0.04	0.15	0.12	−0.07	−0.10	−0.08	0.32	−0.18	−0.06	−0.14	−0.03	0.05	−0.17	0.04		
18. Firm's prior affiliates	0.08	0.00	0.02	0.06	0.05	−0.05	0.03	0.04	0.04	−0.09	−0.07	0.01	−0.06	−0.14	0.05	0.02	−0.07	
19. B-index	−0.08	0.33	0.05	−0.15	−0.14	0.26	−0.01	0.00	−0.33	0.37	−0.08	0.32	0.22	0.05	0.16	0.00	−0.06	−0.06

Note: B-index correlations are for a subset 52 (out of 55) cities for which the indicator is available. GDP, gross domestic product; IPR, intellectual property rights.

Table 4. Conditional logit analysis of the location choices of foreign research and development (R&Ds) investments in global cities.

	Model 1 (all)	Model 2 (research)	Model 3 (development)
Number of top universities per capita	0.377**	0.648**	0.252
	(0.175)	(0.305)	(0.183)
Technological strength	0.172***	**0.280***	**0.135***
	(0.037)	(0.076)	(0.039)
City GDP	0.189***	**−0.122**	**0.325***
	(0.069)	(0.117)	(0.080)
City GDP growth rate	0.061***	**0.038***	**0.073***
	(0.009)	(0.014)	(0.011)
IPR protection	0.474***	**0.144**	**0.661***
	(0.150)	(0.226)	(0.184)
International knowledge connectivity	0.275***	0.241***	0.295***
	(0.045)	(0.080)	(0.049)
Population density	0.115***	0.109	0.127***
	(0.039)	(0.069)	(0.046)
Share of educational expenditure	0.398***	0.475***	0.369***
	(0.068)	(0.102)	(0.081)
Wage level	−0.949***	−1.196***	−0.846***
	(0.082)	(0.138)	(0.092)
Corporate tax rate	−0.163*	−0.127	−0.187*
	(0.088)	(0.139)	(0.105)
Infrastructure	1.544***	2.832***	1.001***
	(0.311)	(0.523)	(0.363)
English proficiency	0.152	−0.382	0.405
	(0.286)	(0.514)	(0.345)
Country GDP	0.287***	0.300***	0.279***
	(0.038)	(0.063)	(0.047)
Regional GDP density	0.003	−0.029	0.015
	(0.028)	(0.048)	(0.034)
Language distance	−0.129	−0.419*	0.011
	(0.126)	(0.216)	(0.145)
Geographic distance	−0.024	−0.069	0.002
	(0.043)	(0.060)	(0.055)
Firm's prior affiliates	0.964***	1.063***	0.908***
	(0.069)	(0.122)	(0.082)
Observations	76,994	25,514	51,480
Number of R&D investment projects	1537	508	1029
Wald test of model significance	1194***	621.6***	767.7***

Note: Robust standard errors clustered by firm are shown in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Coefficients shown in bold are for focal variables that are significantly different between the research and development (R&D) models. GDP, gross domestic product; IPR, intellectual property rights.

A number of control variables are also found to exert significant influences on R&D location choices. We observe that international knowledge connectivity, educational expenditures, infrastructure, country GDP, and the number of existing affiliates of the firm in the city have a positive and significant effects on both R&D activities. Wage costs discourage both types of R&D investments, confirming similar findings in previous studies (e.g., Belderbos et al., 2014; Kumar, 1995). Population density is positive and significant in the overall R&D and development models, but not in the research model. Language distance has a marginally significant negative effect ($p < 0.10$) on research activities, but no significant effect on development. Perhaps research activities need more intensive communication with corporate headquarters (Howells, 1990) and thus are more likely to be located at places with linguistic proximity to corporate headquarters. The corporate tax rate has a marginally significant negative effect in the R&D and development models. English proficiency, regional GDP density, and geographical distance do not appear to have a further significant effect on R&D location choice.

Table 5 reports results of models with the B-index included. Results on the hypothesis testing variables are generally similar, with the exception of higher estimated standard errors for the university strength variable in the full and research investment models. This may be related to a relatively high correlation between university strength and the B-index (33%) combined with the loss in degrees of freedom in this smaller subsample. The B-index itself is negative and highly significant, suggestion that tax and financial incentives do play an important role in R&D location decisions.

DISCUSSION AND CONCLUSIONS

Global cities are increasingly important global hubs for knowledge intensive activities and multinational firms but are also heterogeneous in their attractiveness for multinational R&D investments. In contrast with prior studies on R&D location, this study considers R&D as heterogeneous activities and investigates the differential drivers of locational choice for the two types R&D activities. We hypothesize that global cities' technological and university strengths are a stronger attracting factor for research activities of multinational firms aiming to source technological and scientific knowledge. In contrast, global cities' market potential and intellectual property rights protection are more important for the location of development activities benefitting from large and growing markets and commercialization opportunities. Examining MNCs location decisions for 1537 R&D projects in 55 global cities, our results provide broad support for these hypotheses.

Our paper contributes insights at the intersection of the international business literature on foreign R&D and location decisions, and the regional economics literature on regional innovation and global cities (McCann, 2011; Papanastassiou et al., 2019). Our analysis shows that disaggregating R&D into R&D is required to identify differential locational drivers for different types of R&D activities. Prior studies treating R&D as a homogenous activity have missed the nuances of distinctive location patterns for R&D. Here our study contributes to the stream of literature on regional R&D investments and regional innovation performance (Abramovsky et al., 2007; Autant-Bernard, 2006; Basile et al., 2008; Belderbos et al., 2014, 2016; Belderbos & Somers, 2015; Cantwell & Piscitello, 2005; Li & Bathelt, 2018; Siedschlag et al., 2013).

Second, we examine R&D location decisions at a fine-grained geographical level of analysis, that is, at the global city level. The analysis shows that characteristics at this detailed level of analysis are strong drivers of R&D location decisions and are consistent with the notion that multinational firms compare opportunities for R&D investments globally, with cities increasingly competing to attract investments. Our findings on the significant influence of difference in financial (tax) incentives for R&D attest to such competition. The global perspective on R&D investments is in line with the increasing trend of internationalization of R&D. We show that across global cities in different regions of world, systematic drivers of R&D location decisions can be identified and generalized. In this manner, our paper contributes to the growing literature on global cities (e.g., Belderbos et al., 2017a, 2020; Blevins et al., 2016; Clark, 2016; Derudder et al., 2015; Goerzen et al., 2013; Sassen, 2006; Wall & van der Knaap, 2011) by highlighting their heterogeneous roles in global innovation and as hotspots of multinational R&D activity. By combining a fine-grained regional location perspective with the global R&D investment perspective of multinational firms, we respond to the call to contribute to the integration of international business and economic geography in studying innovation (Cano-Kollmann et al., 2016; McCann, 2011; Papanastassiou et al., 2019, p. 648).

Our findings have important implications for regional and city innovation and development policies. Cities can present an attractive environment for R&D investments due to the concentration of knowledge creating firms and universities as well as relatively sophisticated customers and potential client firms. Yet our research suggests that cities may be competing with other comparable cities around the world to attract R&D investments, suggesting that city administrators should be aware of the city's relative strengths and weaknesses.

Our results suggest that cities, depending on their characteristics, may come to exhibit a stronger degree of specialization in either research- or development-oriented innovation systems, driven by the heterogeneous preferences of investing firms. The difference in the role of knowledge- and market-based drivers depending on the type of R&D investment predicts that different city profiles facilitate different types of industrial R&D clusters, either focusing on research, or on development. The global R&D investment decisions of multinational firms may strengthen such city specialization – an implication that is in line with the conclusion of Mudambi and Santangelo (2016) and Papanastassiou et al. (2019, p. 648) that investments by multinational firms can play an important role in the development of regional innovation clusters. Our findings may also underscore the usefulness of smart specialization strategies for local development (Boschma et al., 2019), with policies to strengthen knowledge clusters preferably building on local related capabilities in development or in research.

We would like to point out several avenues for future research, which can help to address some of the limitations of our study. First, we distinguished R&D investment projects between R&D based on their mandates. While development projects only focus on development, adaptation, and technical services, the research projects also have often a development component. In our sample, pure investments in basic research laboratories are relatively rare. Future research could focus on pure research

Table 5. Conditional logit analysis of the location choices of foreign research and development (R&D) investments in global cities: subsample of cities with an R&D tax burden available.

	Model 1 (all)	Model 2 (research)	Model 3 (development)
Number of top universities per capita	0.145	0.493	0.012
	(0.182)	(0.341)	(0.199)
Technological strength	0.197***	**0.321*****	**0.151*****
	(0.041)	(0.085)	(0.042)
City GDP	0.084	**−0.205***	**0.221*****
	(0.071)	(0.123)	(0.082)
City GDP growth rate	0.061***	**0.035****	**0.074*****
	(0.009)	(0.015)	(0.012)
IPR protection	0.371**	0.041	0.551***
	(0.167)	(0.262)	(0.203)
International knowledge connectivity	0.268***	0.199**	0.305***
	(0.045)	(0.083)	(0.049)
Population density	0.119***	0.111	0.129***
	(0.042)	(0.071)	(0.049)
Share of educational expenditure	0.336***	0.246**	0.376***
	(0.068)	(0.110)	(0.081)
Wage level	−0.702***	−0.963***	−0.580***
	(0.096)	(0.167)	(0.112)
Corporate tax rate	−1.083***	−1.317***	−1.003***
	(0.192)	(0.322)	(0.241)
Infrastructure	1.051***	1.910***	0.601
	(0.333)	(0.559)	(0.395)
English proficiency	0.389	−0.030	0.543
	(0.370)	(0.682)	(0.433)
Country GDP	0.311***	0.331***	0.300***
	(0.037)	(0.062)	(0.044)
Regional GDP density	0.040	0.000	0.051
	(0.030)	(0.054)	(0.035)
Language distance	−0.151	−0.434*	−0.027
	(0.131)	(0.232)	(0.150)
Geographic distance	−0.012	−0.052	0.014
	(0.042)	(0.064)	(0.053)
Firm's prior affiliates	0.918***	0.988***	0.875***
	(0.070)	(0.125)	(0.084)
B-index	−2.048***	−2.684***	−1.729***
	(0.175)	(0.297)	(0.206)
Observations	67,946	22,445	45,501
Number of R&D investment projects	1472	484	988
Wald test of model significance	1288***	625.1**	802.0***

Note: Robust standard errors clustered by firm are shown in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. Coefficients shown in bold are for focal variables that are significantly different between the R&D models. GDP, gross domestic product; IPR, intellectual property rights.

versus development investments for a greater contrast, once better information sources become available.

Second, although we control for firm's prior affiliates in the city, due to data limitations, we are unable to disaggregate firm's existing activities into individual value chain activities, and we are thus unable to examine specific value chain collocation effects (e.g., Alcacer & Delgado, 2013; Defever, 2006). Future work may consider this and examine, for instance, if development laboratories are likely to be proximate to firms' marketing units.

Third, our analysis focused on R&D investments by manufacturing firms. A major advantage of focusing on firms active in manufacturing industries, in comparison to service industries, is that industry-specific technological strength data are available across cities based on patents and patent–industry concordances. However, R&D

investments by service firms are gaining in importance and future research should aim to extend analysis to include service industries.

Finally, data limitations restricted our analysis to R&D projects in 55 global cities and did not allow us to include precise city-level measures of human capital or financial incentives for R&D. The challenge for future research is to embark on an even broader systematic data collection exercise to examine whether more refined sets of locational determinants of R&D exert similar patterns influences across broader sets of cities. We hope that future research can address these challenges.

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DISCLOSURE STATEMENT

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NOTES

1. An exception is the OECD report by Belderbos et al. (2016).
2. Research investments can also include a development component, which is perhaps to be expected given the ultimate commercialization goals of the firms.
3. One of the section criteria of MasterCard is knowledge creation, which to an extent may lead to the selection of the cities that are most attractive to R&D investments. If we omit the five top cities on the knowledge ranking (London, New York, Tokyo, Paris and Seoul) from the empirical model, we find similar results, though with a somewhat weaker significance of the top university variable. It is conceivable that taking out top cities, by reducing relevant variation in the sample, may introduce rather than mitigate selection bias.
4. We had to exclude 30 R&D investments by firms that we could not link to the ORBIS database (to identify prior affiliates of the firms in the global cities).
5. Tables on the distribution across industries and source countries can be obtained from the authors upon request.
6. Patents applied for by universities in the city are an alternative measure of university strength, but may not be unbiased if the propensity to patent may differ across universities due to legislation on publicly funded research, such as the Bayh Dole Act in the United States (e.g., Mowery & Ziedonis, 2002).
7. We thank Simon Bösenberg for provision of the B-index data. Other financial incentives that local (city) governments may provide, such as the provision of land and infrastructure, may also play a role, but that information on such incentives is not available.

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REFERENCES

Abramovsky, L., Harrison, R., & Simpson, H. (2007). University research and the location of business R&D. *The Economic Journal*, *117*(519), C114–C141. https://doi.org/10.1111/j.1468-0297.2007.02038.x

Alcacer, J. (2006). Location choices across the value chain: How activity and capability influence collocation. *Management Science*, *52*(10), 1457–1471. https://doi.org/10.1287/mnsc.1060.0658

Alcacer, J., & Chung, W. (2007). Location strategies and knowledge spillovers. *Management Science*, *53*(5), 760–776. https://doi.org/10.1287/mnsc.1060.0637

Alcacer, J., & Delgado, M. (2013). *Spatial organization of firms and location choices through the value chain* (Working Paper No.13-025). Harvard Business School.

Allen, T. J., Tushman, M. L., & 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. https://doi.org/10.2307/255809

Anselin, L., Varga, A., & Acs, Z. (1997). Local geographic spillovers between university research and high technology innovations. *Journal of Urban Economics*, *42*(3), 422–448. https://doi.org/10.1006/juec.1997.2032

Arauzo-Carod, J.-M., Liviano-Solis, D., & Manjón-Antolin, M. (2010). Empirical studies in industrial location: An assessment of their methods and results. *Journal of Regional Science*, *50*(3), 685–711. https://doi.org/10.1111/j.1467-9787.2009.00625.x

Arauzo-Carod, J.-M., & Viladecans-Marsal, E. (2009). Industrial location at the intra-metropolitan level: The role of agglomeration economies. *Regional Studies*, *43*(4), 545–558. https://doi.org/10.1080/00343400701874172

Asmussen, C. G., Nielsen, B. B., Weatherall, C. D., & Lyngemark, D. H. (2019). Foreign ownership and global city characteristics: Unpacking the connectivity of micro-locations. *Regional Studies*, *54*(3), 352–365. https://doi.org/10.1080/00343404.2019.1623391

Audretsch, D. B., & Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *The American Economic Review*, *86*(3), 630–640.

Autant-Bernard, C. (2001). Science and knowledge flows: Evidence from the French case. *Research Policy*, *30*(7), 1069–1078. https://doi.org/10.1016/S0048-7333(00)00131-1

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. https://doi.org/10.1080/09654310600933314
Bairoch, P. (1991). *Cities and economic development: From the Dawn of history to the present*. University of Chicago Press.
Baptista, R., & Swann, P. (1998). Do firms in clusters innovate more? *Research Policy*, *27*(5), 525–540. https://doi.org/10.1016/S0048-7333(98)00065-1
Barge-Gil, A., & López, A. (2015). R versus D: Estimating the differentiated effect of research and development on innovation results. *Industrial and Corporate Change*, *24*(1), 93–129. https://doi.org/10.1093/icc/dtu002
Bas, C. L., & 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. https://doi.org/10.1016/S0048-7333(01)00128-7
Basile, R., Castellani, D., & Zanfei, A. (2008). Location choices of multinational firms in Europe: The role of EU cohesion policy. *Journal of International Economics*, *74*(2), 328–340. https://doi.org/10.1016/j.jinteco.2007.08.006
Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, *28*(1), 31–56. https://doi.org/10.1191/0309132504ph469oa
Beaudry, C., & Breschi, S. (2003). Are firms in clusters really more innovative? *Economics of Innovation and New Technology*, *12*(4), 325–342. https://doi.org/10.1080/10438590290020197
Belderbos, R., Du, H. S., & Goerzen, A. (2017a). Global cities, connectivity, and the location choice of MNC regional headquarters. *Journal of Management Studies*, *54*(8), 1271–1302. https://doi.org/10.1111/joms.12290
Belderbos, R., Du, H. S., & Slangen, A. (2020). When do firms choose global cities as foreign investment locations within countries? The roles of contextual distance, knowledge intensity, and target-country experience. *Journal of World Business*, *55*(1), 101022. https://doi.org/10.1016/j.jwb.2019.101022
Belderbos, R., Fukao, K., & Iwasa, T. (2009). Foreign and domestic R&D investment. *Economics of Innovation and New Technology*, *18*(4), 369–380. https://doi.org/10.1080/10438590802172404
Belderbos, R., Leten, B., & Suzuki, S. (2013). How global is R&D? Firm-level determinants of home-country bias in R&D. *Journal of International Business Studies*, *44*(8), 765–786. https://doi.org/10.1057/jibs.2013.33
Belderbos, R., Leten, B., & Suzuki, S. (2017b). Scientific research, firm heterogeneity, and foreign R&D locations of multinational firms. *Journal of Economics and Management Strategy*, *26*(3), 691–711. https://doi.org/10.1111/jems.12205
Belderbos, R., Lokshin, B., & Sadowski, B. (2015). The returns to foreign R&D. *Journal of International Business Studies*, *46*(4), 491–504. https://doi.org/10.1057/jibs.2014.63
Belderbos, R., Park, J. J., & Carree, M. (2021). Do R&D investments in weak IPR countries destroy market value? The role of internal linkages. *Strategic Management Journal*, *42*(8), 1401–1431. https://doi.org/10.1002/smj.3268
Belderbos, R., & Somers, D. (2015). Do technology leaders deter inward R&D investments? Evidence from regional R&D location decisions in Europe. *Regional Studies*, *49*(11), 1805–1821. https://doi.org/10.1080/00343404.2015.1018881
Belderbos, R., Somers, D., Sleuwaegen, L., & De Backer, K. (2016). *Where to locate innovative activities in global value chains: Does co-location matter?* (OECD Science, Technology and Industry Policy Papers No. 30). OECD Publ. https://doi.org/10.1787/5jlv8zmp86jg-en
Belderbos, R., Suzuki, S., & Kwon, H. U. (2017c). The location of multinational firms' R&D activities abroad: Host country university research and R&D heterogeneity. *Advances in Strategic Management*, *36*, 127–162. https://doi.org/10.1108/S0742-332220170000036005
Belderbos, R., Van Roy, V., Leten, B., & Thijs, B. (2014). Academic research strengths and multinational firms' foreign R&D location decisions: Evidence from R&D investments in European regions. *Environment and Planning A: Economy and Space*, *46*(4), 920–942. https://doi.org/10.1068/a45536
Bell, G. G., & Zaheer, A. (2007). Geography, networks, and knowledge flow. *Organization Science*, *18*(6), 955–972. https://doi.org/10.1287/orsc.1070.0308
Berman, A., Marino, A., & Mudambi, R. (2020). The global connectivity of regional innovation systems in Italy: A core–periphery perspective. *Regional Studies*, *54*(5), 677–691. https://doi.org/10.1080/00343404.2019.1672865
Blevins, D. P., Moschieri, C., Pinkham, B. C., & Ragozzino, R. (2016). Institutional changes within the European Union: How global cities and regional integration affect MNE entry decisions. *Journal of World Business*, *51*(2), 319–330. https://doi.org/10.1016/j.jwb.2015.11.007
Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, *39*(1), 61–74. https://doi.org/10.1080/0034340052000320887
Boschma, R., Crespo, J., Balland, P. A., & Rigby, D. L. (2019). Smart specialization policy in the European Union: Relatedness, knowledge complexity and regional diversification. *Regional Studies*, *53*(9), 1252–1268. https://doi.org/10.1080/00343404.2018.1437900
Bösenberg, P., & Egger, H. (2017). R&D tax incentives and the emergence and trade of ideas. *Economic Policy*, *32*(89), 39–80. https://doi.org/10.1093/epolic/eiw017
Branstetter, L., Fisman, R., & Foley, C. F. (2006). Do stronger intellectual property rights increase international knowledge transfer? Empirical evidence from US firm-level data. *Quarterly Journal of Economics*, *121*(1), 321–349. https://doi.org/10.1162/003355306776083482
Breschi, S., & Lenzi, C. (2015). The role of external linkages and gatekeepers for the renewal and expansion of US cities' knowledge base, 1990–2004. *Regional Studies*, *49*(5), 782–797. https://doi.org/10.1080/00343404.2014.954534
Cano-Kollmann, M., Cantwell, J., Hannigan, T., Mudambi, R., & Song, J. (2016). Knowledge connectivity: An agenda for innovation research in international business. *Journal of International Business Studies*, *47*(3), 255–262. https://doi.org/10.1057/jibs.2016.8
Cantwell, J., & Mudambi, R. (2000). The location of MNE R&D activity: The role of investment incentives. *Management International Review*, *40*(1), 127–148.
Cantwell, J., & 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. https://doi.org/10.1080/0034340052000320824
Carlino, G. A. (2001). Knowledge spillovers: Cities' role in the new economy. *Business Review*, *4*, 17–24.
Cassiman, B., Veugelers, R., & Zuniga, P. (2008). In search of performance effects of (in)direct industry science links. *Industrial and Corporate Change*, *17*(4), 611–646. https://doi.org/10.1093/icc/dtn023
Castellani, D., Jimenez, A., & Zanfei, A. (2013). How remote are R&D labs? Distance factors and international innovative activities. *Journal of International Business Studies*, *44*(7), 649–675. https://doi.org/10.1057/jibs.2013.30
Castellani, D., & Lavoratori, K. (2020). The lab and the plant: Offshore R&D and co-location with production activities. *Journal of International Business Studies*, *51*(1), 121–137. https://doi.org/10.1057/s41267-019-00255-3

Chung, W., & Alcacer, J. (2002). Knowledge seeking and location choice of foreign direct investment in the United States. *Management Science*, *48*(12), 1534–1554. https://doi.org/10.1287/mnsc.48.12.1534.440
Clark, G. (2016). *Global cities: A short history*. Brooking Institution Press.
Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, *48*(1), 1–23. https://doi.org/10.1287/mnsc.48.1.1.14273
Crescenzi, R., Pietrobelli, C., & Rabellotti, R. (2014). Innovation drivers, value chains and the geography of multinational corporations in Europe. *Journal of Economic Geography*, *14*(6), 1053–1086. https://doi.org/10.1093/jeg/lbt018
Cuypers, I. R. P., Ertug, G., & Hennart, J. (2015). The effects of linguistic distance and lingua franca proficiency on the stake taken by acquirers in cross-border acquisitions. *Journal of International Business Studies*, *46*(4), 429–442. https://doi.org/10.1057/jibs.2014.71
D'Agostino, L., Laursen, K., & Santangelo, G. (2013). The impact of R&D offshoring on the home knowledge production of OECD investing regions. *Journal of Economic Geography*, *13*(1), 145–175. https://doi.org/10.1093/jeg/lbs012
Defever, F. (2006). Functional fragmentation and the location of multinational firms in the enlarged Europe. *Regional Science and Urban Economics*, *36*(5), 658–677. https://doi.org/10.1016/j.regsciurbeco.2006.06.007
Del Barrio-Castro, T., & García-Quevedo, J. (2005). Effects of university research on the geography of innovation. *Regional Studies*, *39*(9), 1217–1229. https://doi.org/10.1080/00343400500389992
Derudder, B., Hoyler, M., Taylor, P. J., & Witlox, F. (2015). *International handbook of globalization and world cities*. Edward Elgar.
Derudder, B., & Taylor, P. J. (2018). Central flow theory: Comparative connectivities in the world-city network. *Regional Studies*, *52*(8), 1029–1040. https://doi.org/10.1080/00343404.2017.1330538
Dow, D., & Karunaratna, A. (2006). Developing a multidimensional instrument to measure psychic distance stimuli. *Journal of International Business Studies*, *37*(5), 578–602. https://doi.org/10.1057/palgrave.jibs.8400221
Du, H. S. (2016). *Global cities and multinational firms' FDI location decisions* [Doctoral dissertation]. Faculty of Economics and Business, KU Leuven.
Essletzbichler, J. (2015). Relatedness, industrial branching and technological cohesion in US metropolitan areas. *Regional Studies*, *49*(5), 752–766. https://doi.org/10.1080/00343404.2013.806793
Fabrizio, K. R. (2009). Absorptive capacity and the search for innovation. *Research Policy*, *38*(2), 255–267. https://doi.org/10.1016/j.respol.2008.10.023
Fischer, M. M., & Varga, A. (2003). Spatial knowledge spillovers and university research: Evidence from Austria. *The Annals of Regional Science*, *37*(2), 303–322. https://doi.org/10.1007/s001680200115
Fleming, L., & Sorenson, O. (2004). Science as a map in technological search. *Strategic Management Journal*, *25*(8–9), 909–928. https://doi.org/10.1002/smj.384
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. https://doi.org/10.1016/S0048-7333(97)00004-8
Friedmann, J. (1986). The world city hypothesis. *Development and Change*, *17*(1), 69–83. https://doi.org/10.1111/j.1467-7660.1986.tb00231.x
Gertler, M. S., & Levitte, Y. M. (2005). Local nodes in global networks: The geography of knowledge flows in biotechnology innovation. *Industry and Innovation*, *12*(4), 487–507. https://doi.org/10.1080/13662710500361981
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. https://doi.org/10.1287/orsc.1070.0249
Globalization and World Cities (GaWC) Research Network. (2021). *The world according to GaWC*. https://www.lboro.ac.uk/gawc/gawcworlds.html
Goerzen, A., Asmussen, C. G., & Nielsen, B. B. (2013). Global cities and multinational enterprise location strategy. *Journal of International Business Studies*, *44*(5), 427–450. https://doi.org/10.1057/jibs.2013.11
Hall, B., & Van Reenen, J. (2000). How effective are tax incentives for R&D? A review of the evidence. *Research Policy*, *29*(4–5), 449–469. https://doi.org/10.1016/S0048-7333(99)00085-2
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*(3–4), 223–247. https://doi.org/10.1016/0022-1996(94)01351-R
Head, K., Ries, J., & Swenson, D. (1999). Attracting foreign manufacturing: Investment promotion and agglomeration. *Regional Science and Urban Economics*, *29*(2), 197–218. https://doi.org/10.1016/S0166-0462(98)00029-5
Henderson, J. (2007). Understanding knowledge spillovers. *Regional Science and Urban Economics*, *37*(4), 497–508. https://doi.org/10.1016/j.regsciurbeco.2006.11.010
Hilber, C. A. L., & Voicu, I. (2010). Agglomeration economies and the location of foreign direct investment: Empirical evidence from Romania. *Regional Studies*, *44*(3), 355–371. https://doi.org/10.1080/00343400902783230
Hines, J. (1995). Taxes, technology transfer, and the R&D activities of multinational firms. In M. Feldstein, J. R. Hines, Jr., & R. G. Hubbard (Eds.), *The effects of taxation on multinational corporations* (pp. 51–62). University of Chicago Press.
Howells, J. (1990). The location and organisation of research and development: New horizons. *Research Policy*, *19*(2), 133–146. https://doi.org/10.1016/0048-7333(90)90043-6
Ivarsson, I., Alvstam, C., & Vahlne, J. E. (2017). Global technology development by collocating R&D and manufacturing: The case of Swedish manufacturing MNEs. *Industrial and Corporate Change*, *26*(1), 149–168. https://doi.org/10.1093/icc/dtw018
Jacobs, J. (1969). *The economies of cities*. Random House.
Jofre-Monseny, J., Marín-López, R., & Viladecans-Marsal, E. (2011). The mechanisms of agglomeration: Evidence from the effect of inter-industry relations on the location of new firms. *Journal of Urban Economics*, *70*(2–3), 61–74. https://doi.org/10.1016/j.jue.2011.05.002
Karlsson, M., Trygg, L., & Elfstrom, B. O. (2004). Measuring R&D productivity: Complementing the picture by focusing on research activities. *Technovation*, *24*(3), 179–186. https://doi.org/10.1016/S0166-4972(03)00111-1
Klevorick, A., Levin, R. C., Nelson, R. R., & Winter, S. G. (1995). On the sources and significance of inter-industry differences in technological opportunities. *Research Policy*, *24*(2), 185–205. https://doi.org/10.1016/0048-7333(93)00762-I
Kuemmerle, W. (1997). Building effective R&D capabilities abroad. *Harvard Business Review*, *75*, 61–72.
Kuemmerle, W. (1998). Optimal scale for research and development in foreign environments – An investigation into size and performance of research and development laboratories abroad. *Research Policy*, *27*(2), 111–126. https://doi.org/10.1016/S0048-7333(98)00030-4

Kuemmerle, W. (1999). The drivers of foreign direct investment into research and development: An empirical investigation. *Journal of International Business Studies*, *30*(1), 1–24. https://doi.org/10.1057/palgrave.jibs.8490058

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. https://doi.org/10.1016/S0048-7333(99)00102-X

Leifer, R., & Triscari, T. (1987). Research versus development: Differences and similarities. *IEEE Transactions on Engineering Management*, *EM-34*(2), 71–78. https://doi.org/10.1109/TEM.1987.6499029

Leten, B., Vanhaverbeke, W., Roijakkers, N., Clerix, A., & Van Helleputte, J. (2013). IP models to orchestrate innovation ecosystems. *California Management Review*, *55*(4), 51–64. https://doi.org/10.1525/cmr.2013.55.4.51

Li, P., & Bathelt, H. (2018). Location strategy in cluster networks. *Journal of International Business Studies*, *49*(8), 967–989. https://doi.org/10.1057/s41267-017-0088-6

Lorenzen, M., Mudambi, R., & Schotter, A. (2020). International connectedness and local disconnectedness: MNE strategy, city-regions and disruption. *Journal of International Business Studies*, *51*(8), 1199–1222. https://doi.org/10.1057/s41267-020-00339-5

Maggioni, M. A., Novelli, M., & Uberti, T. E. (2007). Space versus networks in the geography of innovation: A European analysis. *Papers in Regional Science*, *86*(3), 471–493. https://doi.org/10.1111/j.1435-5957.2007.00130.x

Malmberg, A., & Maskell, P. (2002). The elusive concept of localization economies: Towards a knowledge-based theory of spatial clustering. *Environment and Planning A: Economy and Space*, *34*(3), 429–449. https://doi.org/10.1068/a3457

Mansfield, E. (1995). Academic research underlying industrial innovations: Sources, characteristics, and financing. *The Review of Economics and Statistics*, *77*(1), 55–65. https://doi.org/10.2307/2109992

Mansfield, E. (1998). Academic research and industrial innovation: An update of empirical findings. *Research Policy*, *26*(7), 773–776. https://doi.org/10.1016/S0048-7333(97)00043-7

Mastercard. (2008). *Worldwide centres of commerce index*.

Matthiessen, C. W., Schwarz, A. W., & Find, S. (2010). World cities of scientific knowledge: Systems, networks and potential dynamics. An analysis based on bibliometric indicators. *Urban Studies*, *47*(9), 1879–1897. https://doi.org/10.1177/0042098010372683

McCann, P. (2011). International business and economic geography: Knowledge, time, and transaction costs. *Journal of Economic Geography*, *11*(2), 309–317. https://doi.org/10.1093/jeg/lbq035

McCann, P., & Mudambi, R. (2004). The location behavior of the multinational enterprise: Some analytical issues. *Growth and Change*, *35*(4), 491–524. https://doi.org/10.1111/j.1468-2257.2004.00259.x

McFadden, D. (1974). Conditional logit analysis of qualitative choice behaviour. In P. Zarembka (Ed.), *Frontiers in econometrics* (pp. 105–142). Academic Press.

McKinsey & Co. (2013). *Urban world: The shifting global business landscape*.

Moncada-Paternò-Castello, P., Vivarelli, M., & Voigt, P. (2011). Drivers and impacts in the globalization of corporate R&D: An introduction based on the European experience. *Industrial and Corporate Change*, *20*(2), 585–603. https://doi.org/10.1093/icc/dtr005

Mowery, D. C., & Ziedonis, A. A. (2002). Academic patent quality and quantity before and after the Bayh–Dole act in the United States. *Research Policy*, *31*(3), 399–418. https://doi.org/10.1016/S0048-7333(01)00116-0

Mudambi, R., & Mudambi, S. M. (2005). Multinational enterprise knowledge flows: The effect of government inward investment policy. *Management International Review*, *45*(2), 155–178. https://doi.org/10.1007/978-3-322-91003-5_8

Mudambi, R., & Santangelo, G. D. (2016). From shallow resource pools to emerging clusters: The role of multinational enterprise subsidiaries in peripheral areas. *Regional Studies*, *50*(12), 1965–1979. https://doi.org/10.1080/00343404.2014.985199

Nielsen, B. B., Asmussen, C. G., & Weatherall, C. D. (2017). The location choice of foreign direct investments: Empirical evidence and methodological challenges. *Journal of World Business*, *52*(1), 62–82. https://doi.org/10.1016/j.jwb.2016.10.006

Organisation for Economic Co-operation and Development (OECD). (2011). *Regions at a glance*.

Owen-Smith, J., & 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. https://doi.org/10.1287/orsc.1030.0054

Papanastassiou, M., Pearce, R., & Zanfei, A. (2019). Changing perspectives on the internationalization of R&D and innovation by multinational enterprises: A review of the literature. *Journal of International Business Studies*, *51*(4), 623–664. https://doi.org/10.1057/s41267-019-00258-0

Patel, P., & Vega, M. (1999). Patterns of internationalisation of corporate technology: Location vs. home country advantages. *Research Policy*, *28*(2–3), 145–155. https://doi.org/10.1016/S0048-7333(98)00117-6

Rigby, D. L. (2015). Technological relatedness and knowledge space: Entry and exit of us cities from patent classes. *Regional Studies*, *49*(11), 1922–1937. https://doi.org/10.1080/00343404.2013.854878

Rosenberg, N. (1990). Why do firms do basic research (with their own money)? *Research Policy*, *19*(2), 165–174. https://doi.org/10.1016/0048-7333(90)90046-9

Rosenkopf, L., & Almeida, P. (2003). Overcoming local search through alliances and mobility. *Management Science*, *49*(6), 751–766. https://doi.org/10.1287/mnsc.49.6.751.16026

Rosenthal, S. S., & Strange, W. C. (2003). Geography, industrial organization, and agglomeration. *Review of Economics and Statistics*, *85*(2), 377–393. https://doi.org/10.1162/003465303765299882

Sassen, S. (2001). *The global city*. Princeton University Press.

Sassen, S. (2006). *Cities in a world economy*. Pine Forge.

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

Siedschlag, I., Smith, D., Turcue, C., & Zhang, X. (2013). What determines the location choice of R&D activities by multinational firms? *Research Policy*, *42*(8), 1420–1430. https://doi.org/10.1016/j.respol.2013.06.003

Slangen, A. (2011). A communication-based theory of the choice between greenfield and acquisition entry. *Journal of Management Studies*, *48*(8), 1699–1726. https://doi.org/10.1111/j.1467-6486.2011.01013.x

Somers, D. (2016). *Essays on the location of FDI of multinational firms* [Doctoral dissertation]. Faculty of Economics and Business, KU Leuven.

Taylor, P. J., Ni, P., Derudder, B., Hoyler, M., Huang, J., Lu, F., Pain, K., Witlox, F., Yang, X., Bassens, D., & 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: Economy and Space*, *41*(1), 7–12. https://doi.org/10.1068/a41318

Thursby, J., & 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.

Van Ark, B., Dougherty, S., Inklaar, R., & 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. https://doi.org/10.1504/IJFIP.2008.016904

Verginer, L., & Riccaboni, M. (2021). Talent goes to global cities: The world network of scientists' mobility. *Research Policy*, *50*(1), 104–127. https://doi.org/10.1016/j.respol.2020.104127

Von Zedtwitz, M., & 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. https://doi.org/10.1016/S0048-7333(01)00125-1

Wall, R. S., & van der Knaap, G. A. (2011). Sectoral differentiation and network structure within contemporary worldwide corporate networks. *Economic Geography*, *87*(3), 267–308. https://doi.org/10.1111/j.1944-8287.2011.01122.x

Warda, J. (2006). *Tax treatment of business investments in intellectual assets: An international comparison* (OECD Science, Technology and Industry Working Papers No. 2006/04). https://doi.org/10.1787/672304513676

Wheelwright, S. C., & Clark, K. B. (1992). *Revolutionizing product development*. Free Press.

World Economic Forum (2015). *The global competitiveness index historical dataset*. https//www3.weforum.org>docs>GCR2014-15.