Location of R&D abroad – An analysis on global cities

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Abstract

This chapter investigates the determinants of the location of MNEs' overseas R&D activities, by focusing on two major drivers. On the one hand, external location factors lead the firm to separate its activities along the value chain and geographically disperse these activities in different locations. On the other hand, the R&D location choice may be driven by the existence of internal (within-firm) linkages that motivate firms to locate their value chain activities in the same location (co-location within-firm).

Using data from the *fDi Markets* database, the study examines 2,580 location decisions of new R&D greenfield investments made by MNEs in 110 *global cities* worldwide, over the period 2003-2014. Results from Conditional and Mixed Logit econometric models reveal that both external and internal factors matter. Findings confirm the strong role of external agglomeration economies. Furthermore, evidence suggests that previous R&D and production activities of the same MNE increase the probability to locate R&D in a given global city.

Keywords: location of international R&D, empirical methodology

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Introduction

The last decades have witnessed an increasing internationalisation of research and development (R&D) activities by multinational enterprises (MNEs), initially to developed economies and then also to emerging countries (OECD, 2008; WTO, 2008). The increasing involvement in internationalisation process of R&D activities worldwide motivate the interest about where MNEs locate their R&D activities and which factors drive their location choices.

On the one hand, *external factors* lead firms to disperse geographically R&D activities to exploit the attractiveness of locations. In particular, firms may want to locate close to other firms (co-location between firms). On the other hand, *internal factors* may drive firms to co-locate their value chain activities (e.g. production and R&D) in the same location (co-location within firm). In order to preserve and benefit from intra-firm linkages related to the internal proximity between own activities, the firm need to concentrate its activities in a same location. The R&D internationalisation process may present a trade-off to the firm between dispersing geographically their activities in search for the best external location factors and concentrating their activities along the value chain in a same location to preserve these internal linkages (Blanc and Sierra 1999; Mariani 2002; Alcácer and Delgado 2016).

The importance of external factors on foreign R&D location decision is a rather well-established fact, and many empirical studies reinforce this view. Instead, while the existence of within-firm linkages between different activities of the same firm, influencing the R&D location decision is not a new concept, it still lacks large-scale supporting evidence.

This study investigates the determinants of R&D internationalisation process, analysing the role of external and internal factors as drivers on firms' location strategy, with a multi-country and multi-sector approach.

Traditionally, location studies focus the analysis at a country or regional level, this study takes a finer grained unit of location analysis, the global city. This approach is in line with some recent contribution in the International Business and Economic Geography (Iammarino and McCann 2013). Indeed, cities are a particularly interesting unit of analysis, since they are a fundamental engine of economic growth and are particularly attractive locations for MNEs investments, due to their specific characteristics and their degree of global connectivity (Jacobs 1970; Sassen 1991; Goerzen et al. 2013, Castellani and Santangelo, 2016).

The reminder of chapter is organized as follows. The next section discusses a conceptual framework about the location of MNEs innovation activities. Section three describes the data. Section four presents the econometric strategy and specification. Section five describes the empirical findings. Section six concludes.

Location of International R&D

Several factors may contribute to explain the localization patterns of R&D activities. The discussion of them distinguishes factors external to the firm and those internal to the firm.

The role of factors external to the firm

The foreign R&D location decision may be influenced by factors external to the firm and related to the endowment of a specific geographical area.

Agglomeration economies are a key driver for the attraction of MNEs investments. These are the positive externalities generated from the geographical presence of different firms co-located in a given location (Alcácer and Chung 2006). Two main different types of external agglomerations economies exist (Glaeser et al. 1992). Economies associated with the co-presence of firms in the same sector, that generate intra-industry spillovers (called "localisation" or "specialisation" externalities), thanks to the knowledge flows among competitors, specialized labour created by industry demand and specialized suppliers (Marshall, 1920). Whereas, the second type is associated with the inter-industry spillovers (“urbanisation” or “diversification” externalities) created by the co-presence of firms active in different industries, based on the idea that knowledge may arise between complementary rather than similar activities (Jacobs, 1970). A complementary classification, introduced by Duranton and Puga (2004), recognises three different sources of externalities: “sharing” includes advantages from sharing indivisible goods and facilities, suppliers, customers and risks; “matching”, a source of agglomerations may be the improved matching of labour or firms, an increasing number of agents trying to match is able to improve the quality of each match; “learning” advantages are related to the generation, diffusion and accumulation of knowledge.

Studies on FDIs location decisions generally find strongly positive effects of agglomeration economies (Nielsen et al. 2017). However, when firm are heterogeneous, they may have different preferences in terms of “coagglomeration” strategies, presenting an adverse selection. Firms may differ in the net benefits they receive from locating close to others. Shaver and Flyer (2000) show that firms possessing the “best technologies, human capital, training programs, suppliers, or distributors benefit less from access to competitors' technologies, human capital, training programs, suppliers, or distributors”, whereas “less-capable” firms have a higher propensity to collocate (Alcácer 2006). At the same time, a firm leader in its industry may locate close to other leaders and the “stickiness” of local knowledge maintains the cluster in a central position as a global centre of innovative excellence in the automotive industry (Hannigan et al. 2015).

At the same time, the activities along the value chain may present different collocation patterns. Alcácer (2006) finds that R&D activities are more likely to be collocated close to other firms because they benefit more from agglomeration economies through knowledge spillovers, rather than sales or production activities that benefit less from agglomerations. Manufacturing activities tend to be more geographically dispersed close to the final market respect to R&D activities that tend to be more concentrated.

When the knowledge is local bounded and embedded, the geographical proximity reduces the cost of information and knowledge transfer and the tacit knowledge embedded in a specific area, constituting a potential attractiveness of that location (Jaffe et al. 1993; Lawson and Lorenz 1999).

Location characteristics. Most studies of foreign investment location decisions emphasize the “basic” characteristics of destination location as drivers attracting FDIs. These factors may be demand and market size, productivity and wage levels, corporate tax rates, developed formal institution, but also physical infrastructures and advanced human capital, in terms of education and skills (Nielsen et al. 2017).

The foreign R&D activities are also influenced by the presence of natural advantages and external source of knowledge in a specific location. Human capital and a pool of quality R&D personnel, university and adequate education systems, research centres and public knowledge stocks, as well as the specific industrial structure may influence the firms’ location decision (Cantwell and Piscitello 2005; Siedschlag et al. 2013).

Geographic distance is generally negatively associated with the location of MNE activities. This is due to the fact that some intermediate inputs need to be transferred between headquarters and subsidiaries, thus locating more distant from the home country may increase transport costs, and to the fact that more geographic distant location tend also to be less familiar, thus increasing sunk costs associated with MNEs’ activities. In case of innovative activities, geographical distance is a lesser obstacle on location of R&D activities abroad respect to other functions (such as manufacturing plants), due to the decreasing of trade costs for codified information. The latter is the result of increased agglomeration and geographic concentration of tacit knowledge, driving the MNEs to set-up R&D labs in distant locations in order to access knowledge (Castellani et al. 2013).

The role of global cities as preferred locations of MNEs activities has been recently highlighted (Goerzen et al. 2013; Castellani and Santangelo, 2016). These cities allow to reduce the *liability of foreignness* (Zaheer 1995), thanks to their high degree of interconnectedness to local and global market, cosmopolitan environment and high levels of advanced producer services.

Arauzo-Carod and Viladecans-Marsal (2013) find that the preferred location of high-technology activity (as R&D) is in the centre of the metropolitan area, where there is a higher presence of skilled people and other high-technology firms. Castellani and Santagelo (2016) qualify this finding by showing that R&D is relatively more attracted towards moderately global cities, which can combine connectivity, quality of (technical and scientific) infrastructure and good quality of life, which attracts (among others) young talented researchers. Manufacturing plants instead tend to be located in rural areas and small metro areas (Henderson et al. 2008; Castellani and Santangelo, 2016), in order to facilitate the access to raw materials, suppliers and distributors, but also gain access to lower wages and larger physical spaces.

Given the increasing role played by global cities in the attraction of foreign FDIs, this study focuses on the R&D locations at the global cities level, following previous insights of Belderbos et al. (2016) based on a small subset of 57 global cities.

The role of factors internal to the firm

In addition, the foreign R&D location choice may be driven by the existence of internal (within-firm) linkages that motivate firms to locate different activities along the value chain close to each other.

In an intra-functional perspective, a firm decides to establish a new R&D investment in a location where it is already present with its other activities. This choice may be motivated by the aim to generate economies of scale and scope (Parr 2002; Belderbos et al. 2013). Proximity to other same-firm establishments facilitates local knowledge transfer because new establishments learn from pre-existing establishments' experience and *vice versa*, with a positive influence on establishment-level productivity (Rawley and Seamans 2015). At the same time, the co-location may be motivated by the reduction of information costs and the uncertainty to operate in a foreign market, in order to reduce the *liability of foreignness* (Zaheer 1995). The co-location of different investments doing similar activities may also be discouraged when firms perceive the risk of redundancy. In other words, it may be too costly for a firm to set-up further R&D labs in a given location.

In an inter-functional perspective, the existence of internal linkages between R&D and production activities arises the need of co-location within firm. Internal location factors, as geographical proximity to headquarters and main corporate production units, are important in the R&D location (Howell 1984). A survey conducted by Warrant (1991) shows that 35,7% of responding firms indicate "proximity to manufacturing plant" as the most important factor influencing the choice of R&D location. The literature of multinational enterprises highlights that the own R&D activity may be located abroad where other own production plants are already in place (Pearce and Singh 1992; Cantwell and Piscitello 2002), if the benefits from innovation are strongly incorporated into the production processes (Cantwell 1989).

The global value chain fragmentation and the dispersion of R&D activity makes it more difficult to preserve the control on core competencies and the integrity of firm knowledge, causing a "fragmentation of capabilities" (Blanc and Sierra 1999). Despite the improvement in managing communication among units thanks to the development in information and communication technologies (ICT), the complexity of technological learning and high level of tacit process knowledge maintain strong importance to face-to-face contact, as a communication technology particularly when much of the information are not codifiable (Storper and Venable 2003).

The interdependence between R&D and production enhances when inter-functional communication, sharing of non-standardized information, transfer of tacit knowledge and joint problem-solving are needed (Gray at al. 2015). The proximity may be an alternative mechanism of coordination and control, both within and across activities.

Ketokivi and Ali-Yrkko (2009) exam the conditions under which R&D and production require physical co-location. The complexity of products and processes, the increasing rate of industry change and new product introduction ("clockspeed" industry), low maturity of production process and low degree of modularity are factors that may increase the need of proximity. Buciuni and Finotto (2016), through multi-case study analysis of six Italian firms in low-tech industries, suggest that controlling a few key development functions (such as prototype development) that require distinct manufacturing competences, ensures the constant generation of innovation and maintains the control of innovative activities.

The empirical studies investigating co-location between production and R&D are conducted mainly in two fields. First, some studies investigate the effect of co-location between R&D and production on firm's performance. Gray et al. (2015) highlight that manufacturing plants co-located with R&D labs tend to have better conformance quality of products reducing the probability of obtaining an adverse inspection outcome, in pharmaceutical industry. Tecu (2013) shows that a chemicals firm is more than twice as productive in R&D activities in a metropolitan area where the firm is already present with production units than another firm without plants. In line with these findings, Adams and Jaffe (1996) show that the effects of parent firm R&D on plant-level productivity diminishes with the increasing of geographic and technological distance between R&D labs and production plants. Other studies show that firm's existing operations have a positive effect on the establishment's performance, in terms of probability of survival (Shaver and Flyer 2000; Alcácer and Delgado 2016).

Second, recent empirical studies on location choice investigate the extent to which R&D activities co-located with other activities of the same firm. These studies underline that prior firm's investment in a location increases the probability to choose that location for a new investment, both in the same function (e.g. among R&D labs) and between functions (e.g. R&D and production). In a study focused on biopharmaceutical industry in US, Alcácer and Delgado (2016) show that the positive effect of intra-firm linkages on location varies between activities along the value chain, the need to co-locate R&D and manufacturing is greater than the need to co-locate R&D and sales, or sales and manufacturing. Another important result is that not considering the internal factors ("internal agglomeration") tends to overestimate the effects of external ones on firm location decisions.

Defever (2012), through a multi-country and multi-sector analysis, investigates the spatial organization of value chain activities and the incentives for the firms to locate their activities close to each other, analysing the location choice of non-European MNEs in 224 European regions over the period 1997-2002. He finds that prior service or production investments located in the 75-mile area around a location have a positive effect on location decision of a new investment in that location. Belderbos et al. (2016) analyses the location choice of 1,908 cross-border greenfield projects in R&D made by MNEs over the period 2003-2011 at a city level, selecting a choice set of 57 world global cities. Their results confirm the positive effect of prior core investment, in manufacturing or service activities, on the probability of "follow up" R&D investment in the same location.

Various contributions in the literature highlight that there may be a heterogeneous firm behaviour in terms of need of internal proximity.

Heterogeneity in the scientific content of R&D activities. The interdependence between production and R&D activities may be influenced by the scientific content of R&D investments. Some empirical studies, through survey conducted on small samples of firms, highlight a stronger co-location between production and R&D in case of applied research, with the aim to adapt the product or to create new product for the local market (Pearce and Singh 1992), R&D subsidiaries support the adaptation of manufacturing process to host-country condition and the products adaptation to local markets (Papanastassiou and Pearce 2009). Demand-driven R&D investments are more likely located close to the final market and the production plants. Instead, the probability to separate R&D activities increases when the research investment is basic or science-intensive, because the link with the production is relatively less important. Mariani (2002) analyses the geographical organization in the European regions of research activities made by 799 Japanese MNEs, of which 236 affiliates performing both R&D and production in the chosen region. She underlines that the possibility of separating R&D from production is influenced by the scientific content of research: the higher the science-intensity of firm sector, the less important is the linkages with production.

Heterogeneity across industries. In the last century, large manufacturing firms with "in-house" R&D labs was the dominant source of technical change, but the increasing standardization of production through automation and developments in ICT reduced the costs of vertical disintegration, creating a growing modular production system (Sturgeon 2002). The complete disintegration of innovation and manufacturing has not yet been achieved. Some specialized firms need to maintain and develop technological competencies, thus the association between research and production activities remains a strategic resource (Pavitt 2003). The need to inter-functional proximity may vary across industries, because the interdependence between production and R&D could be stronger in some industries than in others. Geographical proximity is more important in industries like engineering where the product properties are closely related to the production activities (Ivarsson et al. 2016), when the development of new technologies depends on familiarity with the product process and the innovation follows the manufacturing (Pisano and Shih 2009) and the production is an important source of ideas. A survey conducted by Florida (1997) shows that around of 5% of US biotechnological firms consider manufacturing plants as a significant source of innovation, 17% in case of chemicals/materials and around 37% in automotive industries. In engineering-intensive industries, the firms co-locate their R&D and production units in order to develop new technologies and products for the global and regional market, not to locally adapt existing products and processes, as a result of the analysis conducted on 146 R&D units of 17 largest manufacturing Swedish MNEs (Ivarsson et al. 2016).

Determining when manufacturing is critical to innovation and when it could be located far away is difficult. Pisano e Shih (2012) introduce an industry classification based on the degree (high or low) of modularity and maturity production processes' technology ("Modularity-Maturity Matrix"). In their conceptualisation, the proximity between production and R&D is not needed in sectors like consumer electronics and semiconductors, where the technology process may be more or less mature but with a high degree of modularity. Instead, in sectors with low degree of modularity the risk of separating design and production is significant (e.g. chemicals and pharmaceutical). These underline industrial specificities in terms of co-location pattern.

Heterogeneity in firm characteristics. The heterogeneity of proximity preferences could be related also to firm characteristics. The size of the firm may have an important role on the need of co-location. Larger firms have structured and developed capabilities, organizational and managerial, able to coordinate operations across distance and manage knowledge transfer across geographically dispersed units, while smaller firms may need co-location in order to coordinate activities due to the lack of structured organizational processes (Gray et al. 2015). Leader firms more likely locate away from cluster in order to avoid the negative effects of knowledge outflows to competitors (Shaver and Flyer 2000) and they may choose locations with own operations or where the firms have never been located. Alcácer and Delgado (2016), separating small and large firms, find that intra-firm linkages matter for both subsamples, but the effect is higher for small firms. While in larger firms the innovative activity is more formalized and performed into R&D labs, in smaller firms this is more informal and incremental and performed within the production plants. Thus, co-location of production and R&D may be stronger for the latter (Paci and Usai 1999).

Finally, a high degree of internationalisation creates the experience for reducing the coordination problems and costs of decentralised R&D (Lall 1979; Pearce and Singh 1992). Alcácer and Delgado (2016) explore the role of geographical diversification of firms. The effects of internal linkages are higher for firms operating in few locations, geographically diversified firms have better managerial capabilities to disperse value chain activities across distant locations reducing the potential effect of co-location.

Data

The empirical analysis relies on data on international investment projects from *fDi Markets*, a database produced by fDi Intelligence, a division of the Financial Times Ltd., which tracks cross-border greenfield investments across different industries and countries worldwide[1].

The database contains about 143,000 investment projects referring to the period 2003-2014, in 184 different countries. For each one of these projects *fDi Markets* reports information about the parent company name, home country and city, the industry and the business activity involved in the project, as well as the location of project destination (host country and city). The database contains projects in different types of business activity, such as Research & Development, manufacturing, business service, logistics, marketing & sales, headquarters, ICT, education & training and technical support.

This study focuses the analysis on 2,580 new R&D greenfield investments made by 1,316 MNEs over the period 2003-2014. In particular, 738 of 2,580 (28.60%) identify projects in

[1] For more details, see http://www.fdimarkets.com/.

Research & Development (R&D) activity**,** while 1,842 (71.40%) identify projects in Design, Development and Testing (DDT). It is expected that R&D-related projects represent the basic (or science-intensive) type of research, whereas DDT projects represent the applied/adaptive type of research, but a causal inspection of the description does not allow to clearly gauge the difference between the two. Therefore, R&D and DDT projects are considered jointly.

Figure X.1 shows the geographical distribution of DDT and R&D projects, by destination city.

Insert **Figure X.1** about here

These investment projects take place in 110 global cities around the word. Table X.1 reports the distribution of R&D/DDT investment projects and cities across geographical areas. While the 50% of our sample of global cities is situated in Europe and North America, they receive only about 30% of all R&D-related projects. On the contrary, around 30 global cities in Asia (about 30% of the sample) attract around of 60% of the projects.

Insert **Table X.1** about here

Moreover, the table X.2 shows the geographical distribution of R&D/DDT investments projects by origin area of MNEs. The 46.32% (1,195 out of 2,580) comes from North America and 30.74% (793) from European countries, while around 17% from East and South Asia (448).

Insert **Table X.2** about here

Empirical Methodology

Location Choice Models

In order to provide a robust test of theoretical arguments, a location choice model is estimated, investigating the effect of external and internal factors on the location decision of new foreign investments in R&D activities.

The literature on firm's location choice has mainly estimated Conditional Logit (CLM) and Nested Logit (NLM) models (Arauzo-Carod et al. 2010; Nielsen et al. 2017).

A strong assumption of CLM (McFadden, 1974) is the property of independence of irrelevant alternatives (IIA), according to which the relative odds ratio of choosing between two alternatives is independent of the characteristics of any other alternative in the choice set. Adding a new alternative or changing the characteristics of a third one, cannot change the odds ratio between pairs of alternatives. This assumption may prove to be too restrictive in location choice analysis, especially with a large location choice set as in this analysis (110 global cities). Recent empirical studies of location choices of multinational firms introduce individual random effects estimating a Mixed Logit (MLM) model (Train 2003), in order to capture less restrictive substitution patterns between choices than the Conditional and Nested Logit models (Basile et al. 2008; Defever 2012; Belderbos et al. 2016) and to overcome the restrictive assumption of IIA, but also to use more flexible models taking into account the firms' heterogeneity (Rasciute and Downward 2016).

The random coefficients could be decomposed in its *mean*, the average effect common to all the firms, and its *standard deviation*, which captures the deviation from the average effect for each observation. A statistically significant standard deviation reveals a presence of heterogeneous preferences across firms. The CLM specification is a special case of MLM, where β is a fixed term that does not vary over firms.

A Conditional Logit model is estimated. Furthermore, a Mixed Logit model is estimated as a robustness check.

Model Specification

Dependent variable. The dependent variable is the location choice of the new R&D/DDT investment project. The variable assumes value 1 if a given R&D/DDT project is located in the global city c^* and value zero for all possible alternative cities $c \neq c^*$.

Intra-firm co-location. This variable measures the intra-firm linkages between activities that captures the effect of firms' prior investment in a given global city, as an internal driver on firm location decisions. First, the firm cumulated investments in the city *c* at time t-1 in R&D/DDT activity capture the effect of within-firm and intra-functional co-location. Second, the firm cumulated investments in the city *c* at time t-1 in production activity capture the effect of within-firm and inter-functional co-location, between R&D and production. A control for the firm's investments in other activities in the same city, for example in sales, marketing, headquarters, logistics and business services, is included.

External agglomeration. The cumulated number of foreign investments by all MNEs in the sample in the city c (at time t-1), in production, R&D and other activities respectively, are measures of external agglomerations. The overall number of investments received by a city may be correlated with city characteristics and other external factors attracting firms to certain locations, so the effects of these variables may be overstated on a positive side, the lack of a number of city characteristics should not significantly affect the estimates of intra-firm co-location effects.

Geographic distance to home city. A control for the geographical distance is included, calculating the ellipsoidal distance between the home city of the firm and the host cities.

The variables definitions are reported in table X.3.

Results

This section presents the results of Conditional Logit model (CLM) and Mixed Logit model (MLM) regressions, which estimate the effect of external and internal factors on multinational firms' new R&D investment location choices, at the global city level.

Table X.4 reports the results of two different specifications. Mod. 1 controls for prior investments in R&D and production at the firm-city level (measuring the role of intra-firm linkages) and both for prior investments in production and R&D activities at the overall city level (measuring the importance of external agglomerations). Mod. 2 also controls for prior investments in all other activities included in the *fDi Market* database (e.g. HQs, sales & marketing, logistics, etc.). In both specifications, the control for the geographical distance between home and destination city is included.

The results show that the external agglomeration economies have a positive effect on R&D location choices. R&D tends to collocate close to other firms, supporting the idea that R&D may benefit more from agglomeration economies compared to other activities, such as manufacturing and sales (Alcácer, 2006) and that this agglomeration force is higher in case of other R&D-related activities (*'External Agglomeration-R&D'*).

Results also underline a positive effect of distance between home and destination city, suggesting that in case of R&D-related activities the geographical distance is not an obstacle, in order to acquire specific knowledge located far away from the home country (Castellani et al, 2013).

Controlling for the other activities, results highlight a reduction in the role of external factors. Findings are consistent with the idea that Mod. 1 is not adequately capturing external factors. The overall amount of investments that a city attracts is probably correlated with a number of city characteristics that make them attractive for MNEs location. While there may be a number of additional city characteristics that may affect the location of R&D, we are confident that the specification in Mod. 2 can account for a large proportional of the variance explained by city characteristics.

These first results confirm the positive role of external factors on R&D location choice. Furthermore, a firm's prior investment in a global city has a positive and significant effect on the probability that an MNE will locate a new R&D investment in that city, both in an intra-functional and inter-functional perspective. This is consistent with the idea that internal linkages matter and they increase the probability of co-location, with a higher effect in case of co-location with production activity[2].

This suggests that the argument of uncertainty reduction, economies of scale and scope and knowledge transfers across activities dominates over the redundancy argument.

Interestingly, co-location with other business activities does not seem to occur to the same extent, and having previous investments in other business activities do not have a strong effect on the location of R&D.

In the third column (Mod. 3), the model is estimated considering the R&D investments made during the period 2008-2014. Due to data limitations, flows of investments are used and it is not possible to know whether a firm had R&D or manufacturing activities in a given global city before 2003. In order to take into account this problem, the prior investments made during the period 2003-2007 are computed as a measure of stock. The main results persist.

Finally, Mixed Logit model is estimated in order to control for the Independence of Irrelevant Alternatives (IIA) assumption. Results are reported in the last column (Mod. 4) of table X.4.

The independent variables of intra-firm co-location are included as random parameters. The mean coefficients and the standard deviations are reported.

Also in this case, the main results persist. These findings underline that with a larger location choice set composed by homogeneous cities (global cities) the Conditional Logit model does not produce biased estimates and the IIA property is respected.

Conclusion

This study examines the determinants of R&D internationalisation process. In particular, it investigates the role of external and internal factors in the firms' location decision of R&D

[2] This conclusion is also confirmed by the coefficients calculated as odds ratio in order to facilitate comparisons, available under request to the authors.

activities abroad, looking at intra-functional and inter-functional interdependences across activities along the value chain, especially between R&D and production.

On the one hand, external factors (e.g. external agglomeration economies) lead firms to disperse geographically their activities in search for the best location (we observe co-location between firms in the same location). On the other hand, internal factors drive firms to concentrate their activities along the value chain close to each other in a same location, to preserve intra-firm linkages (thus leading to co-location of different activities within the same firm).

The empirical literature of multinational firms is focused mainly on the external factors driving the location decision of multinational enterprises' R&D activities. Although the existence of internal linkages, which require co-location, is not new in the literature, strong empirical evidence has been lacking. This study contributes to filling this gap.

Recent empirical studies attribute a crucial role to *global cities* as preferred locations for MNEs activities thanks to their degree of global interconnectedness, a cosmopolitan environment and for the presence of high levels of advanced producer services, especially in the attraction of R&D-related activities (Goerzen et al. 2013; Castellani and Santangelo, 2016; Belderbos et al. 2016).

Following these insights, this study investigates the determinants of location decisions, using data on R&D foreign direct investments in 110 global cities worldwide. Results confirm the positive role of external agglomeration economies. Additionally, findings suggest that previous R&D and production activities of the same MNEs increase the probability to locate R&D in a given global city. The effect of co-location is higher with production activity, confirming the role of intra-firm linkages between R&D and production.

This study has several limitations. First, the analysis exploits an unprecise geographical boundary, the city. In further investigations, more well-defined administrative boundaries (e.g. metropolitan area or functional urban area) could be adopted. Second, there is clearly a trade-off between considering a comprehensive set of fine-grained locations and gathering a rich set of characteristics for these locations. This study has chosen the former route and some of the city characteristics used should be able to capture a significant portion of the variance, but it is not possible to exclude that some omitted variables may affect the results. Third, by considering co-location at a very geographically disaggregated level of analysis, some actions going on at a slightly more aggregated level could be missed. A disaggregated unit of analysis should make more difficult detecting co-location. This makes the results like a lower bound. For example, R&D may be located closer to city centres, while production may take place in the outskirts. In order to address this issue, a further investigation could move to the metropolitan area level.

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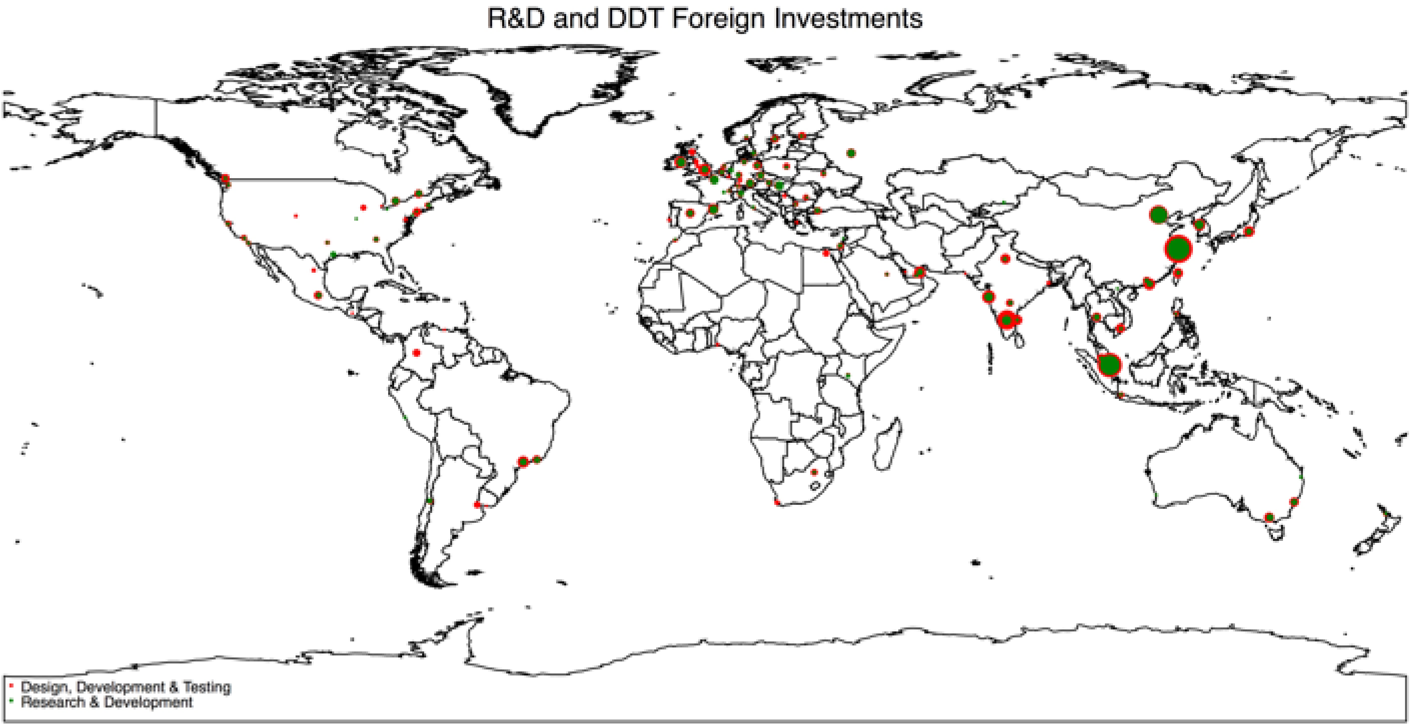
Figure X.1: Geographical distribution of R&D and DDT FDIs, by destination area.



Source: our elaboration on *fDi Markets*

Table X.1: Geographical distribution of R&D/DDT projects and Global Cities, by destination area.

	No. Projects in R&D/DDT		No. of Cities	
	Freq.	**Percent.**	**Freq.**	**Percent**
East Asia & Pacific	1,236	47.91	21	19.09
EU	529	20.5	33	30
South Asia	284	11.01	7	6.36
North America	181	7.02	18	16.36
Latin America & Caribbean	146	5.66	12	10.91
Middle East & North Africa	93	3.6	8	7.27
Non-EU Europe	46	1.78	5	4.55
Central Asia	38	1.47	2	1.82
Sub-Saharan Africa	27	1.05	4	3.64
Total	**2,580**	**100**	**110**	**100**

Source: our elaboration on *fDi Markets*

Table X.2: Geographical distribution of R&D/DDT projects, by origin area of MNEs.

	No. Projects in R&D/DDT	
	Freq.	**Percent.**
North America	1,195	46.32
EU	793	30.74
East Asia & Pacific	375	14.53
Non-EU Europe	97	3.76
South Asia	66	2.56
Middle East & North Africa	30	1.16
Latin America & Caribbean	12	0.47
Central Asia	7	0.27
Sub-Saharan Africa	5	0.19
Total	**2,580**	**100**

Source: our elaboration on *fDi Markets*

Table X.3: Variable List and Description.

Variables	Descriptions	Source	Type
Location	R&D location choice among 110 cities over the period 2003-2014; it assumes value 1 if the firm choose the global city *c*; 0 otherwise.	fDi Markets	Firm-City
Previous R&D	Firm cumulated investments in R&D/DDT, in the city *c* at time (t-1)	fDi Markets	Firm-City
Previous Prod.	Firm cumulated investments in Production, in the city *c* at time (t-1)	fDi Markets	Firm-City
Previous Other	Firm cumulated investments in other activities (e.g. logistics, sales & marketing, HQs, etc) in the city *c* at time (t-1)	fDi Markets	Firm-City
External Agglomerations			
R&D	log of the cumulated number of R&D investments made by MNEs in the city *c* at time (t-1)	fDi Markets	City
Prod.	log of the cumulated number of Production investments made by MNEs in the city *c* at time (t-1)	fDi Markets	City
Other	log of the cumulated number of investments made by MNEs in the city *c* at time (t-1), in other activities	fDi Markets	City
Distance	Geographical distance between firm home city and the potential host cities (in log)	fDi Markets	Firm-City

Table X.4: Results of Conditional and Mixed Logit Models.

	Dependent Variable: foreign R&D location choice			
	Mod. 1	**Mod. 2**	**Mod. 3**	**Mod. 4**
Mean				
Internal factors				
Previous R&D (firm-city)	0.0948***	0.0813***	0.0851***	0.1132***
	(0.0308)	(0.0258)	(0.0263)	(0.0362)
Previous Prod (firm-city)	0.2064***	0.1820***	0.1562***	0.2143***
	(0.0612)	(0.0650)	(0.0601)	(0.0719)
Previous Other (firm-city)		0.1306	0.1514*	0.056
		(0.0850)	(0.0828)	(0.0639)
External factors				
External Agglomerations				
R&D (log) (city)	0.7293***	0.6200***	0.6235***	0.6183***
	(0.0281)	(0.0353)	(0.0394)	(0.0301)
Prod. (log) (city)	0.1232***	0.0620**	0.0235	0.0608**
	(0.0253)	(0.0264)	(0.0312)	(0.0246)
Other (log) (city)		0.2781***	0.2397***	0.2776***
		(0.0351)	(0.0417)	(0.0340)
Distance (log)	0.0454**	0.0634***	0.0975***	0.0650***
	(0.0212)	(0.0217)	(0.0281)	(0.0219)
Standard Deviation				
Previous R&D (firm-city)				-0.0834
				(0.1618)
Previous Prod (firm-city)				-0.5309
				(0.4242)
Previous Other (firm-city)				0.7142***
				(0.1240)
No. obs	231,785	231,785	175,575	231,785
No. Cities	110	110	110	110
No. MNEs	1,316	1,316	975	1,316
Period	2003-2014	2003-2014	2008-2014	2003-2014
Pseudo-R2	0.1556	0.1592	0.1499	
Simulated Log-L MXL				-9667.103
Conditional vs. Mixed Model	CLM	CLM	CLM	MLM

Note: The dependent variable is equal to 1 if firm f is set in city c and zero for all city different from c. Standard error in parenthesis. Asterisks denote confidence levels: *p<0.10, **p<0.05 and ***p<0.01.

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