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EVIDENCE FROM REGIONAL R&D LOCATION DECISIONS IN EUROPE

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ABSTRACT

Leading technology intensive firms have incentives to protect knowledge outflows to collocated firms in order to enhance the returns to R&D (Alcácer and Zhao, 2012). In this paper we argue that leading firms' knowledge protection strategies are likely to discourage other firms from setting up new R&D establishments in their vicinity. Knowledge protection is facilitated by an R&D organization emphasizing internal knowledge flows drawing on complementary contributions by dispersed R&D units. We examine whether the presence and R&D organization of local technology leaders discourages inward R&D investments in an analysis of the (NUTS-1) regional location of 196 cross-border R&D investment projects in EU-15 countries during 2003-2008. While the strength of the local relevant technology clusters attracts inward R&D investments, investors are generally discouraged by the concentration of technology activities due to the presence of regional technology leaders in the industry. This discouraging effect occurs specifically in case the leaders exhibit an internally oriented R&D organization drawing on cross-border intra-firm knowledge flows in their technology development activities. Our study challenges the common notion in the literature on clusters and innovation that agglomeration is generally associated with greater knowledge spillovers.

Keywords: Multinational firms; R&D; location choice;

JEL codes: *F230; O320; R39*

INTRODUCTION

Foreign multinational firms are responsible for a sizeable share of R&D investment in most European countries (OECD, 2007). Host country governments seek to attract these R&D investments since they provide numerous benefits to their region, such as highly skilled employment and knowledge spillovers to local firms (e.g. Carlsson, 2006). Such knowledge spillovers resulting from clustered R&D activities favourably affect knowledge accumulation and economic growth of regions (Audretsch and Feldman, 1996) and attract R&D investments by firms seeking to benefit from local knowledge networks (Belderbos et al., 2009, Del Barrio-Castro and García-Quevedo, 2005, Cantwell and Piscitello, 2005).

Recent studies have pointed out that the presence in R&D clusters is not beneficial for all firms (Alcácer and Zhao, 2012). While in general the agglomeration of R&D generates potential benefits due to increased knowledge spillovers, for technological leading firms there is a potentially important downside. Although incoming knowledge flows provide benefits, firms also face the risk that firm-specific valuable knowledge and technologies spill over to collocated firms, potentially undermining efforts to appropriate technologies and to earn returns on internal R&D efforts. The strong technology position of technologically leading firms creates an asymmetry: they have less to learn from incoming knowledge spillovers and at the same time face greater risks that valuable knowledge and frontier technologies are appropriated by neighbouring firms.

Although prior studies have confirmed the role of heterogeneity in the benefits of collocation in empirical models, by showing that leaders are less likely to choose agglomerated areas for new investments (Shaver and Flyer, 2000, Chung and Alcácer, 2002b, Alcácer and Chung, 2007), the position and strategies of incumbent leading firms with existing R&D facilities have not received due attention. The asymmetry in knowledge spillovers implies that technology leaders with existing R&D facilities have to face the possibility that firms set up new R&D establishments in their vicinity to benefit from knowledge spillovers. To prevent this, leading firms are likely to have incentives to discourage new R&D establishments in their locality. Extant literature has suggested that firms indeed employ a number of strategies in attempts to limit knowledge outflows, such as limiting personnel mobility by using non-compete clauses (e.g. Marx et al., 2009, Marx, 2011), aggressive patent enforcement strategies (e.g. Agarwal et al., 2009), and geographically dispersed but interrelated internal R&D activities that ensure that technological knowledge developed in one location is of little use without complementary knowledge developed in other locations (Zhao, 2006, Alcácer and Zhao, 2012). Such strategies, while often intended to prevent knowledge flows to collocated firms, will also render new R&D investments less attractive to firms wishing to benefit from knowledge spillovers.

In this paper, we address this issue by examining whether concentration of technological activities by local technology leaders displaying knowledge protection strategies discourages inward R&D investments, controlling for other relevant locational features. Our focus here is on knowledge internalization strategies as a potential means to prevent outgoing spillovers. By utilizing information on local and cross-border self-citations in technology leaders' patents, we examine whether the dependence of local inventions on the leaders' internal technology development activities and in particular on internal R&D abroad, makes regions relatively less attractive for investments. Since the presence of industry and regional R&D leaders has generally be seen as encouraging entry through agglomeration effects (Agrawal and Cockburn, 2003), a potentially discouraging effects of the presence of technology leaders on multinational firms' R&D location choices provides an important qualification to such assessments - with related policy implications.

We examine the role of technology leaders in a R&D location study at the regional level across multiple countries in the EU-15. Most previous R&D studies have been conducted at the national level (e.g. Belderbos et al., 2009, Kumar, 2001) or focused on regions within one country (Autant-Bernard, 2006, Hilber and Voicu, 2010). It has however been shown that multinational firms take regions across multiple countries into consideration when they decide to locate foreign R&D investments (Thursby and Thursby, 2009, McCann and Mudambi, 2004). We analyse the location of 196 foreign R&D investment projects drawing on data provided by the Financial Times' Cross-border Investment Monitor (2003-2008). We examine firms' location choices at the regional (NUTS-1) level and identify the strength of industry technology leaders as dominant players in regional R&D from the concentration of regional patenting activity among local firms. We analyse investment locations and the relationship with technology clusters and technology leaders at the relevant industry level. Our results suggest that, while the strength and quality of local relevant technology development activities attract cross-border R&D investments, investors are discouraged by concentrated technology development activities due to the dominance of regional industry leaders. This discouraging effect occurs specifically in case the leaders exhibit an internally oriented R&D organization drawing on cross-border intra-firm knowledge flows in their technology development activities.

Our results challenge the common premise in the literature on clusters (e.g. Storper, 1995, Porter, 2000, Cooke, 2001) that firms will generally benefit from knowledge spillovers when locating in regions with clustered industrial activity. Our study highlights that geographical clustering and knowledge spillovers do not necessarily co-occur, but that knowledge spillovers are conditional on incumbent firms' strategic behaviour.

LITERATURE REVIEW AND PROPOSITIONS

We provide a brief review of two relevant literature streams: the literature on agglomeration economies and firms' location decisions, and the literature on strategies to prevent knowledge spillovers. We proceed by suggesting a base proposition on the negative correlation between concentrated technology ownership and location choice, after which we derive two propositions on the effects of knowledge internalization strategies of technology leaders.

Agglomeration Economies

Agglomeration theory has been a dominant theory in explaining why firms tend to co-locate in the same region. The theory argues that firms can increase their profitability by locating in the proximity of other economic activities and related production facilities due to positive externalities that might stem from industry localization (Marshall, 1920). Several studies have shown that agglomeration economies are indeed an important factor in explaining foreign multinational location choices (e.g. Belderbos and Carree, 2002, Chang and Park, 2005). Marshall (1920) highlighted three positive externalities that favour geographic concentration of industries: (1) industry demand that creates a pool of specialized labour, (2) industry demand that creates a pool of specialized inputs, and (3) knowledge spillovers among firms in an industry. Of all activities in the value chain, R&D activities benefit the most from knowledge spillovers among competing firms and consequently show the highest level of concentration (Audretsch and Feldman, 1996, McCann and Mudambi, 2004, Alcácer, 2006).

Empirical studies have shown that firms can improve their innovative performance by benefitting from knowledge spillovers in clusters (e.g. Beaudry and Breschi, 2003), although it is worth noting that some studies obtained contrasting or no effects in this regard (e.g. Lee and Lim, 2001). Less attention has been given to the notion that firms not only benefit from knowledge spillovers, but that they also contribute to these externalities. Knowledge outflows may hinder the firm from appropriating the value from its own inventions. Furthermore, as firms are heterogeneous, they will differ in the net benefits they receive from agglomeration economies (Chung and Kalnins, 2001, Shaver and Flyer, 2000, Alcácer and Chung, 2013). Firms with the best technological capabilities, employees, distributors or suppliers will gain little from incoming spillovers, but may competitively suffer when their employees are hired by other firms and information on their technologies spills over to competing firms. In this context, a number of studies have found that larger or more R&D intensive firms are less likely to invest in agglomerated areas (e.g. Shaver and Flyer, 2000). However, once technology leaders have established their R&D facilities, they will have to face the possibility that other firms set up new R&D establishments in their vicinity to benefit from knowledge spillovers and they cannot easily avoid collocation. This is likely to provide leading firms with the incentives to adopt knowledge protection strategies discouraging new R&D establishments in their vicinity.

Strategies to prevent knowledge spillovers

Technology leaders can make use of several strategies to prevent outgoing knowledge spillovers from their existing R&D facilities. In general, one can distinguish between two types of knowledge protection strategies (de Faria and Sofka, 2010). One type of knowledge protection strategies relies on organizational processes within the firm to prevent knowledge spillovers, while the other relies on legal forms of protection based on formal applications or contracts.

Firms can adopt specific organizational practices to limit the risk of outgoing knowledge spillovers. As most technology leaders are large companies with R&D activities in multiple locations, they can take advantage of their geographically dispersed, but closely integrated innovation networks. Studies have shown that technology leading firms can make use of strong internal linkages across multiple locations to leverage knowledge for competitive advantage, without risking critical knowledge outflows to competing firms (Alcácer and Zhao, 2012, Feinberg and Gupta, 2004, Zhao and Alcácer, 2007). Feinberg and Gupta (2004) for instance documented that firms can minimize outgoing knowledge spillovers by integrating their global network of subsidiaries. As specialized complementary assets are essential for the commercialization of an invention (Teece, 1986), it follows that competing firms that lack such an integration mechanisms are unable to benefit from the incoming knowledge spillovers (Zhao, 2006). Technology leading firms may also reduce outgoing knowledge flows by allocating less vulnerable projects to industrial clusters, by incorporating local innovation quickly into its global knowledge base and by the use of cross-cluster teams to strengthen control over locally developed technologies. The finding by Alcácer and Zhao (2012) that firms indeed make use of these mechanisms when they are surrounded by direct competitors shows that the internal organization of R&D is often part of a well considered strategy to limit outgoing knowledge transfers. Given that these cross-cluster R&D teams can be costly to manage (Frost et al., 2002), firms will implement an internal linkage strategy when the benefits outweigh the costs, which is more likely under the threat of knowledge dissipation.

Another means to prevent harmful knowledge spillovers is the use of legal instruments such as patents and contracts. On the one hand, outgoing knowledge spillovers may be difficult to prevent through legal mechanisms, because knowledge spillovers are mostly tacit and often occur through interpersonal interactions. On the other hand, studies have documented that firms effectively make use of legal instruments aiming to reduce employee mobility (Almeida and Kogut, 1999, Rosenkopf and Almeida, 2003, Song et al., 2003) and that non-compete contracts and employers' patent litigiousness significantly reduce employee mobility (Marx et al., 2009, Agarwal et al., 2009).

Propositions

The extant literature suggests that technology leading firms can effectively use mechanisms to prevent outgoing knowledge spillovers. Although prior studies have generally seen the presence of technology leading firms as encouraging entry (e.g. Agrawal and Cockburn, 2003), we examine whether the presence of regional technology leading firms could have a potential entry deterring effect on foreign firms' R&D location choices. As firms take the potential for incoming knowledge spillovers into account when they locate their R&D facilities (Chung and Alcácer, 2002a, Cantwell and Piscitello, 2005), they may refrain from locating their R&D activities in regions where technology leading firms have incentives to prevent outgoing knowledge flows.

There are various reasons why the actual opportunities to benefit from spillovers may be reduced if there is a strong concentration of technology activities in one or a few firms (McCann and Mudambi, 2005). Dispersion of R&D activities in a region among a larger number of R&D performing firms may fail to provide greater spillovers for prospective investors even in the absence of specific strategic behaviour to prevent outgoing knowledge flows. Chinitz (1961) for instance contended that networking intensity between firms will be lower in highly concentrated industry structures. A smaller dispersion of R&D activities will also be associated with less diversity and a poorer content of the regional knowledge base (Feinberg and Gupta, 2004), rendering a close match between the knowledge generated by incumbents and the knowledge base of entrants less likely (Alcácer and Chung, 2013). Cantwell and Mudambi (2011) similarly suggest that industrial concentration reflects a relative closeness of the local innovation system. Finally, studies in the entrepreneurship literature suggest that the dispersion of technology activities among smaller incumbent firms might provide greater agglomeration benefits (Chen and Hambrick, 1995, Rosenthal and Strange, 2003), as small firms tend to be more open and entrepreneural (Baum and Oliver, 1991).

We conclude that there is a range of arguments in prior studies suggesting that concentrated technology activities in regions provide fewer knowledge spillover benefits to entrants, such that these regions are less likely to attract R&D investments. This leads to the following baseline proposition:

Baseline Proposition 1. *A high concentration of technology activities in a region among incumbent local firms reduces the probability that foreign R&D investors locate in the region.*

The negative correlation between concentration of technology ownership and the attractiveness of regions for R&D projects may vary, or depend on, the presence of technology protection strategies of incumbents. Here we focus on R&D internalization strategies used by technology leading firms to prevent valuable knowledge outflows (Zhao, 2006, Alcácer and Zhao, 2012).[1] These strategies imply that firms build on their own internal knowledge stock and complementary knowledge assets when developing new technologies. By developing technologies that require complementary knowledge and resources which are not readily available to potential imitators, technology leading firms can limit valuable knowledge outflows, preventing imitation (Teece, 1986, Alcácer and Zhao, 2012). For instance, James (2011) finds a negative relationship between the patent self-citation ratio of technology leaders and the number of patent applications by competing firms. Alácer and Zhao (2012) show that technology leading firms are more often making use of internal linkages when they are surrounded by rival firms and suggest that this behavior is part of a strategy to prevent outgoing knowledge flows and to enhance appropriation. Indeed, adoption of such strategies was correlated with reduced citations of other firms to the focal firm's patent base. Zhao's (2006) finding that firms are internalizing their technologies developed in countries with weak IPR protection to a greater extent provides additional evidence that this internalization is part of a well considered strategy to prevent knowledge expropriation.[2] If firms succeed in R&D internalization strategies, this can enhance competitive advantage (Hall et al., 2003) and increase the firm's lead-time over competitors (Cohen et al., 2000).

In summary, R&D internalisation strategies as indicated by the importance of intra-firm knowledge flows, are expected to reduced knowledge spillovers. As investing firms take the potential for incoming spillovers into account when they decide on the location of their foreign R&D activities, it follows that firms are discouraged to enter regions in which the leading firm adopted such strategies:

Proposition 2. *A strong degree of internalization of technology development activities by local technology leaders reduces the probability that foreign R&D investors locate in the region.*

Regional technology leaders are often multinational firms operating multiple dispersed R&D facilities across a variety of countries. This allows them to assimilate, generate and integrate knowledge on a worldwide basis (Ghoshal and Bartlett, 1990, Frost et al., 2002). It also offers the opportunity to internalize knowledge flows across borders (e.g. Zhao, 2006). When technology leaders develop inventions that build upon prior internally developed technologies in R&D facilities abroad, this may present additional difficulties for competing firms to benefit from these leading firms' local R&D activities. Competing firms that seek to benefit from knowledge outflows and imitation strategies will face much greater difficulties to obtain needed complementary knowledge residing in several locations across national borders. This presents a much greater challenge than in case leading firms' internalization strategies are restricted to internal development of technologies in the same location. This leads to the next proposition:

Proposition 3. *A strong degree of cross-border internalization of technology development activities by local technology leaders reduces the probability that foreign R&D investors locate in the region - more so than internalization strategies restricted to domestic technology development activities.*

DATA, VARIABLES and METHOD

We obtained information on cross-border R&D investments from the Financial Times' Cross-border Investment Monitor database for the years 2003 through 2008. This database is developed by the Financial Times Ltd and tracks global cross border investments drawing on public information sources and information from local and national investment agencies. It includes information on the investing firms, the city and country of investment, the sector of investment and the type of activity (R&D, manufacturing, logistics, distribution, etc.). For our purpose we only retrieved information on R&D projects located in EU-15 countries. Due to the limited availability of regional information required to construct our independent variables, in particular regional R&D intensity, our sample for analysis consists of 301 R&D investments made by 218 firms.[3] From among these projects, we selected those for which the detailed press releases and company reports suggested that the mandate of the project extended to research. For these projects we can be sure that knowledge spillovers and knowledge sourcing are important, while projects focusing solely on development often imply limited activities focusing on application of technologies in the local context or design activities. Consequently, we focus on a sample of 196 R&D investments by 152 firms.[4] Firms based in the US were responsible for the largest share of R&D projects (49%), followed by firms based in the UK (8%), France (8%), Germany (7%) and Japan (6%). Based on the information on the industry of the investment project we categorized the projects in twelve 2-digit NACE manufacturing industries, for which we can also construct measures of industry-specific patent activity (see below). We complemented this dataset with information about the characteristics of the NUTS-1 regions in EU-15 countries using various data sources.

Dependent variable

The dependent variable is a binary variable, which indicates in which NUTS-1 region in the EU-15 the R&D investment is made. This variable takes the value one if a foreign firm made its R&D investment in host region j and zero otherwise. Our analysis includes 64 NUTS-1 regions.[5] Table 1 shows the distribution of R&D projects over industries. Most of R&D investments are made in the electronics and pharmaceutical industries with respectively 40 and 38 percent of the R&D investments. The chemicals, transport and machinery industries are each responsible for about 5 percent of the investments, while the remaining industries are less well represented. No cross-border R&D investments are reported for the textiles, paper and mineral industries. Table 2 shows the distribution of the projects over NUTS-1 regions. From the table, we can observe that most R&D investments are made in Catalunya (ES5) and Ireland (IE0) with respectively 23 and 21 R&D projects.

INSERT TABLES 1 and 2

Technology concentration

To measure the level of concentration of technology development activities among firms based in the region, we calculate the Herfindahl-Hirschman index of company patent ownership.[6] This technology concentration index measures the concentration of patents among firms applied for by inventors based in the region and relevant to the industry. It is the sum of squares of the patent shares of individual firms with patents invented in the region and ranges between just over zero (highly dispersed activities) to 1 (one company is responsible for all the region's relevant patents). We use patent information from the European patent office to characterize technology concentration and technological strength (see below) because the advantages of patent data are given by their consistent availability over time and their detailed information on technological content and location of inventive activity (Griliches, 1998). Patent data have been very frequently used in prior research on international R&D and as indicator of innovative activities (Belderbos, 2001, Cantwell and Piscitello, 2005, Allred and Park, 2007).

Patents are assigned to NUTS-1 regions based on the addresses of the inventors that are listed on the patents (Deyle and Grupp, 2005). In order to allocate patents to industries, we make use of the patent technology class to industry concordance table developed by Schmoch et al. (2003). This concordance table links the technology codes (IPC) of the patents to their corresponding NACE code at the two-digit level. If a patent lists multiple inventors and IPC classes, we use fractional counts to assign the patent to the region and industry. Patents are allocated to firms at the consolidated level including firm's majority-owned subsidiaries.

As these data operations, which we had to implement across regions and industries, are likely to introduce measurement error in the data, we used a dummy variable indicating whether the region is characterized by an above or below the median Herfindhal-Hirschman index rather than the detailed index itself. The dummy variable *high technology concentration* takes the value one if patent ownership in the industry and region is highly concentrated. Proposition 1 suggested that this variable has a negative effect on R&D location choice.

Internalisation (patent self-citations)

To measure the internalization strategy of the regional technology leader, we calculated the patent self-citation ratio of this leader in the year prior to the investment. The technological leader is the firm that applied for the most patents in the NUTS-1 region and sector of the investing firm. The self-citation ratio is a measure of intra-firm knowledge transfers and represents the extent to which firms retain the value of R&D within internal boundaries (James and Shaver, 2008, Zhao, 2006, Trajtenberg et al., 1997, Hall et al., 2001, Hall et al., 2003). The self-citation ratio is measured as the ratio of self-citations over total citations of a leading firm's patents invented in the region and related to the focal industry. A citation is considered a self-citation if the citing and cited patents are both assigned to the same firm (at the consolidated level).

We constructed three dummy variables indicating combinations of technology concentration and internalization. One dummy takes the value one if the region shows a strong (above median) technology concentration and if the technology leading firm is strongly internalizing its knowledge (the technology leader has an above median self-citation ratio). A second dummy variable takes the value 1 if the region exhibits strong technology concentration but when the technology leading firm is not strongly internalizing its knowledge flows (the firm has a below the median self-citation ratio). A third dummy variable takes the value 1 in case of weak technology concentration combined with strong internalization. The omitted reference dummy is the situation where there is neither strong technology concentration nor strong internalization. Proposition 2 suggests the strongest negative effect of the combination of high concentration and high internalization: strong local technology leaders with pronounced internalization strategies.

To test whether cross-border internalization strategies have a stronger effect than domestic internalization, we calculated cross-border and domestic self-citation ratios separately, by identifying the country of the inventors of the cited patents. The foreign self-citation ratio is measured as the ratio of foreign self-citations over total citations of a leading firm's patents in the region and sector. The domestic self-citation ratio is calculated in a similar way by dividing domestic self-citations by total citations of all patents of the technology leader in the region and sector. Based on these ratios and the dummy variable identifying high technology concentration, we constructed 7 combined dummy variables to examine what the roles are of technology concentration, domestic self-citations and foreign self-citations in discouraging R&D. The reference category is the case where a low technology concentration is combined with a low domestic and a low foreign self-citation ratio. Proposition 3 suggests a the strongest negative effects in case of high technology concentration combined with a high foreign self-citation ratio, but less so for combinations of high concentration and high domestic self-citations.

Table 3 shows examples of regions with high technology concentration and high (foreign) self-citation ratios. Technology leaders are often large multinationals firms such as Bayer, Philips, Shell and Monsanto. These firms have large R&D budgets and operate R&D affiliates across many countries, opening up opportunities to internalize (cross-border) knowledge flows, which are reflected in high self-citation ratios. Still, there is ample heterogeneity in the intensity of self citations, with, for example, AstraZeneca showing stronger internalization strategies than Bayer in the pharmaceutical industry.

INSERT TABLE 3

Other explanatory variables

As control variables we included a range of host region characteristics that have been found to influence R&D location choices in prior studies. As not all location factors differ within a country across regions, or are available at the regional level, we also include a number of host country characteristics in addition to a full set of host country dummies.

The presence of clustered technology activities, proxied by patent activity, has been found to attract R&D investments in earlier studies (e.g. Belderbos et al., 2009). We include the variable *technological strength*, which is the share of the region in the number of patent applications in the EU-15 allocated to the industry of the investing firms. It measures the availability of technological knowledge and potential R&D spillovers relevant for the industry. By constructing this variable at the industry level, we control for differences in the propensity to patent across industries. In addition, we control for differences in *patent quality* across regions. The number of citations a patent receives (forward citations) mirrors the technological importance of the patent for the development of subsequent technologies and also reflects the economic value of inventions (Trajtenberg, 1990, Hall et al., 2005, Harhoff et al., 2003). We collected forward citations received by the regional patents at the patent family level and constructed *patent quality* as the average number of forward citations received by regional patents in an industry in the year prior to investment.[7] We also include the *backward citation intensity* of patents invented in the region to control for general characteristics of technology development in the region. This variable is measured as the average number of backward citations on patents in the NUTS-1 region and industry. Several studies have suggested that this backward citation frequency is an indicator of patent impact, as inventions using a wider array of prior art tend to be more valuable (Lanjouw and Schankerman, 2004). Finally, we include the *R&D intensity* of the host region (Shimizutani and Todo, 2008) to control for R&D spillovers at the broader regional level. This variable is the ratio of the total intramural R&D expenditure in the business sector of the host region over total GDP of that region.

Several studies have also found that academic research has a positive impact on the innovative performance of firms (e.g. Cohen et al., 2002, Fleming and Sorenson, 2004, Mansfield, 1995). As research has shown that these effects are highly localized (e.g. Del Barrio-Castro and García-Quevedo, 2005, Piergiovanni and Santarelli, 2001), firms may locate in the close vicinity of academic research institutions. We include the variable *academic research strength*, which is the share of the region in the number of university publications in the EU-15 allocated to the industry of the investing firms. We counted university publications at the level of regions and science fields and measure relevant publications for investing firms by linking science fields to the industry that firms are active in (Belderbos et al., 2009).

The likelihood that a host region attracts foreign R&D investments may also rise due to market size and market sophistication (Barrell and Pain, 1996). We include the region's *population* and *GDP per capita* to account for respectively the market size and regional purchasing power and market sophistication. We also include the regional *unemployment rate* as general labour availability can be an important factor in the decision to invest in a region (Friedman et al., 1992). *Airport traffic* measures the total passengers embarked and disembarked on regional airports and is a measure of transportation infrastructure and regional connectivity, which may be particularly important for multinational firms (Bel and Fageda, 2008).

The models also include a number of investor-related characteristics. We include dummy variables taking the value one if the firm had previously located an R&D investment in the region, or a non-R&D related investment, respectively. Manufacturing and sales investments often are a precursor to R&D investments to adapt processes and products to the local market (e.g. Belderbos, 2003), while prior R&D may lead to intra-firm collocation advantages. The *geographical distance* between the source city of the investing firm and the NUTS-1 region is included as a larger distance between the source and destination country can impede R&D investments due to increased informational uncertainty and coordination costs (Ghemawat, 2001, Castellani et al., 2011). *Language similarity* has also been shown to be an important factor for foreign R&D investments because it enables a smooth communication and coordination, lowering transaction costs (Hejazi and Safarian, 2002). We include a dummy variable that equals 1 if the source city and NUTS-1 region share the same official language.

In addition to host country dummies, the analysis includes two variables at the host country level. The *wage costs* of skilled R&D personnel (Belderbos et al., 2009, Kumar, 2001) is measured at the country level, as data at the regional level are not available. We use data on average gross annual earning of qualified engineers drawing on UBS Price & Earning reports. The *b-index* is a measure for the tax pressure on R&D activities (Warda, 2006). The higher this b-index, the less generous the tax treatment of R&D is in a particular country and the less attractive the country's regions might be for R&D investments.

To reduce variance we transformed all variables (except the binary variables) by taking their natural logarithm. All variables are lagged by one year with respect to the year of investment to allow a response time by the investing firms and to reflect the proper time-ordering. Definitions and summary statistics of the variables are provided in table 4 and the correlation table is available upon request.

INSERT TABLE 4

Methods

Within the location choice literature (e.g. Alcácer and Chung, 2007, Head et al., 1995), the conditional logit model (McFadden, 1974) has been widely used to analyze the location determinants of foreign direct investments. A drawback of this model is the restrictive assumption of independence of irrelevant alternatives (IIA). This property states that for any two alternatives the ratio of probabilities is independent of the characteristics of any other alternative in the choice set. Accordingly the relative probability of any two alternatives is independent of the inclusion or removal of other alternatives. This characteristic also implies the absence of correlations between error terms across alternatives. This assumption is however frequently violated in location choice analyses. Recent studies (e.g. Basile et al., 2008, Chung and Alcácer, 2002a) have therefore used the mixed logit model, which does not rely on the IIA assumption (McFadden and Train, 2000). As Hausman tests showed that this assumption was also violated in our sample, we likewise use mixed logit models.

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

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

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

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

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

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

The mixed logit probability is essentially a weighted average of the logit formula evaluated at different values of the betas, where the weights are provided by the density function. We follow the most general approach by allowing a continuous distribution function (Chung and Alcácer, 2002c, Basile et al., 2008, Belderbos et al., 2014b). As there is no closed form solution for the mixed logit probability, it has to be approximated by simulation techniques. The estimation of mixed logic models requires an assumption about the precise distribution function of the coefficients. Our models are estimated under the assumption of a normal distribution – the distribution most commonly adopted as it has the most general properties. Other functional forms have less desirable properties or poor convergence levels (Train, 2003). We have run all our regressions with 100 simulation draws (Revelt & Train, 1998; Train, 2003).

The random parameters in our regressions accommodate a rich array of differential preferences on the part of investors, while they also form the basis for accommodating correlations across alternative locations (a feature causing biased estimates in conditional logit models). Because we have no a priori expectations about whether certain variables should have a random component or not, we allowed the maximum number of variables to have both a fixed and a random component (Chung and Alcácer, 2002c, Basile et al., 2008, Revelt and Train, 1998).[8, 9]

We note that our empirical model includes variables with different characteristic types. The sample includes a number of variables that vary over regions and time (e.g. GDP/cap, population), while there are also time-variant industry-specific variables at the region level (e.g. technological strength, academic research strength). Yet other factors are firm- and region-specific but remain constant over time (such as language similarity and geographic distance), while the variables firm's previous investments and previous R&D vary by investing firm, region and time. Finally, our sample includes also two variables that were only available at the country level: wage cost and the b-index.

EMPIRICAL RESULTS

Results of the mixed logit models are reported in Table 5. Model 1 includes the control variables only, while model 2 adds the technology concentration dummy (proposition 1). In model 3, three dummy variables are added to examine whether the internalization strategy of the technology leading firm of the region significantly deters R&D investments (proposition 2). Finally, Model 4 introduces 7 dummy variables to test whether cross-border internal linkages are more effectively discouraging R&D than domestic internal linkages (proposition 3).

INSERT TABLE 5

Most of the control variables have the expected sign. The technological strength of the NUTS-1 regions has a significantly positive influence on the propensity to locate R&D investments in a region. Patent quality also matters: its coefficient is always positive and turns significant in the more encompassing models 3 and 4. Other significant influences are language similarity, airport infrastructure, the unemployment rate and firm's previous R&D investments. The large coefficient of previous R&D investments shows that multinational firms have a clear tendency to invest in regions where they are already present. This points to the importance of internal agglomeration and collocation forces as documented in prior studies (Defever, 2006, Alcacer and Delgado, 2013). Examining our data in detail, we observe that there are 8 firms that make multiple, consecutive, investments in the same region. Hence, while collocation effects are strong and predict follow-up investments, in our sample this phenomenon is not widespread. From the table, we can observe two rather unexpected findings. One unexpected finding is the significantly negative effect of regional GDP per capita. This negative effect may be caused by a potentially high correlation with an omitted variable in the model: regional wage costs. As wage costs have a negative impact on R&D location decisions, the correlated variable GDP per capita might absorb part of this effect. Due to the unavailability of data, we were however not able to include regional wage variables in our empirical models and instead relied on the inclusion of wage costs at the national level. Another surprising result is the insignificance of academic research strength - although its sign is positive, as expected. We experimented with another proxy to control for the effect of academic research by creating a variable that counts the number of top-500 universities present in the host region, but this variable was similarly insignificant. Part of the explanation may be sought in our restricted sample of regions to those that exhibit patented inventions. As this restriction tends to eliminate regions with poorly developed academic infrastructure, the variation in the academic research variable is substantially reduced. In addition, our data requirements and focus limited the time frame of analysis and number of investments that we could cover in the analysis, in comparison with other location studies (e.g. Belderbos et al., 2014).

In model 2 we observe that the technology concentration dummy is significantly negative (at the 10 percent level), while the other coefficients are not strongly affected. A high technology concentration of technology development activities in a region reduces the probability that foreign R&D investors locate in that region, in support of proposition 1. In model 3 only the coefficient on the dummy representing regions with both high technology concentration and high internalization is significantly negative, while the other two dummies are not significant. This suggests that it is not the concentration as such that distracts investments, but concentration accompanied with a strong internal orientation of R&D by the regional technology leading firm, in support of proposition 2.

Finally, Model 4 introduces 7 dummy variables to compare the effects of cross-border and domestic knowledge internalization. The reference category is low technology concentration in combination with low domestic and low cross-border internalization. The two significantly negative coefficients for regions with high technology concentration combined with high cross-border internalization (with or without high domestic internalization) clearly suggest that foreign R&D investors are deterred from investing in regions where technology leaders follow internalization strategies drawing on cross-border knowledge flows. These patterns suggest that it is cross-border internalisation, rather than domestic internalization, that discourages investment, consistent with proposition 3.

Among the random terms of the coefficients, R&D intensity, population, firm's previous investments, geographic distance, wage cost and the b-index are significant, as well as 3 dummy variables testing our propositions. This indicates that there is unspecified heterogeneity in preferences for different sets of regions and among investors, which will lead to a violation of the IIA in standard conditional logit models. Likelihood ratio tests comparing our models with models having only fixed coefficients also show that these models are significantly different from each other, which underscores the need to utilize mixed logit models. Although it is difficult to assess what the underlying causes are of the observed heterogeneity in the effects of the independent variables we note that the findings are broadly consistent with previous location studies discussing heterogeneity in the valuation location specific characteristics. For instance, Basile et al. (2008) finds variance in the importance of population, R&D intensity, wage costs, firm prior experience and distance; Chung and Alcacer (2002) emphasize the varying importance of R&D intensity. Variance in coefficients related to our patent variables (e.g. patent quality) may be due to different unobserved underlying entry motivations, e.g. a sole emphasis on knowledge sourcing and quality of the local innovation system, versus an emphasis on R&D to facilitate access to the local and national market.

SENSITIVITY ANALYSIS

Our measure of knowledge internalization strategies could be correlated with broader strategic behaviour by technology leaders to reduce knowledge outflows. High self-citation ratios are usually correlated with a low external collaboration intensity, as firms engaged in collaboration networks or alliances share more knowledge compared to non-allying firms (Gomes-Casseres et al., 2006). To explore this, we included an imperfect proxy for external R&D collaboration by the leading firms. As indicator of collaboration, we used the share of co-patents in the leading firm's regional patents. We note that this variable is rather imperfect, as only a fraction of R&D collaboration activities will eventually lead to co-patents, given the complex property rights implications of shared patent rights (Belderbos et al., 2014a). We found that the co-patent ratio was (weakly) negatively related to the self-citation ratio, as expected. Including the variable in the regressions resulted in a positive sign, but the coefficient was not significantly different from zero.

In another explorative analysis, we investigated potential investor heterogeneity by excluding investing firms holding large patent portfolios and planning large R&D investments: in these cases it may be that investing firms are similarly afraid of generating outgoing spillovers to local firms (e.g. Alcácer and Chung, 2013), and local leaders' strategies might become less relevant. The resulting models however did not identify a clear difference for the sample cleaned of such 'leading investors'. Similarly, subsample analysis of investment projects limited to knowledge intensive industries did not indicate stronger effects of knowledge sourcing related variables, with the exception of large coefficients for technological strength.

CONCLUSIONS

If firms take the potential for incoming knowledge spillovers into account when they decide on the location of new R&D facilities (e.g. Aharonson et al., 2007, Chung and Alcácer, 2002a), they may refrain from locating their R&D activities in regions where incumbent firms are making use of mechanisms to prevent outgoing knowledge flows. Leading technology firms in particular may have incentives to prevent knowledge spillovers, including those to new entrants, as they have most to lose from outgoing spillovers and have relatively less to gain from incoming knowledge. One way to mitigate risks of outgoing spillovers is to adjust the internal organization of R&D activities by focusing on knowledge internalization, with new technology development drawing on technological knowledge available within the firm's boundaries (Alcácer and Zhao, 2012). In particular if technology development rests on complementary knowledge residing in several R&D locations across national borders, collocated firms are likely to have fewer opportunities to benefit from leading firms' local R&D efforts (Zhao, 2006). This implies that concentration of technology development activities in a region in leading firms that follow R&D internalization strategies may reduce the probability that foreign R&D investors locate in the region.

We find support for this notion that technology leaders discourage inward R&D investments in an analysis of the location of 196 foreign R&D investment projects drawing on data provided by the Financial Times' Cross-border Investment Monitor (2003-2008). We analyze firms' location choices at the regional (NUTS-1) level and identify the strength of industry technology leaders as dominant players in regional R&D from the concentration of regional patenting activity among local firms. We analyze investment locations and the relationship with technology clusters and technology leaders at the relevant industry level, and consider R&D investment projects across manufacturing industries. Our results show that, while the strength and quality of local relevant technology development attracts R&D projects by foreign firms, investors are discouraged by a concentration of technology development activities among regional industry leaders. We show that this effects depends on the strategy of leading local firms to internalize technology development activities (measured by the intensity of self-citations on firms' patents) By developing technologies that build upon internal knowledge stocks and that require complementary knowledge and resources which are not readily available to potential imitators, knowledge dissipation to, and imitation by, other firms remains limited (Teece, 1986, Feinberg and Gupta, 2004). Consequently, these internalization mechanisms allow the technology leading firm to minimize outgoing knowledge spillovers that could endanger its competitive position (Alcácer and Zhao, 2012). We find that internalization strategies focusing on intra-firm cross-border knowledge flows with R&D units abroad have a much stronger discouraging effect on inward R&D than domestic internal linkages. Cross-border integration of technology development is a greater impediment to knowledge spillovers to investing firms as effective knowledge sourcing may require these firms to combine their investment with complementary R&D activities of their own in other locations.

Our findings contribute to the literature on agglomeration and location decisions (Shaver and Flyer, 2000, Chung and Alcácer, 2002b, Alcácer and Chung, 2007), by focusing on the role of incumbent strategies to avoid outgoing spillovers, which has not received due attention. We contribute to a stream of research suggesting that concentration of ownership of local resources may render locations less attractive (e.g. Cantwell and Mudambi, 2011; Alcacer and Chung, 2013) by highlighting that the presence of dominant firms in local R&D clusters discourages entry primarily if this dominance is accompanied by R&D organizational strategies to prevent knowledge spillovers. In this manner, our results challenge the common premise in the literature on clusters (e.g. Storper, 1995, Porter, 2000, Cooke, 2001) that firms will generally benefit from knowledge spillovers when locating in regions with clustered industrial activity, and call for future research investigating more detailed properties of regional innovation systems as antecedents of or impediments to such knowledge spillovers.

Our results suggest that the presence of 'regional champions' or 'anchor firms', while increasing innovation activities and output in a region (Agrawal and Cockburn, 2003, Feldman, 2003), at the same time may discourage inward R&D investments in the region. If the leading firms organize their internal R&D to prevent knowledge spillovers, this can have detrimental effects for technology development in the region and accordingly has important consequences for regional innovation policies. Limited knowledge spillovers to other firms in the region will limit agglomeration benefits and positive externalities, potentially reducing knowledge accumulation and economic growth (Audretsch and Feldman, 1996, Martin and Ottaviano, 1999, Baldwin and Martin, 2004). At the same time, it reduces inward R&D investments, and policies to attract inward R&D competition may prove to be less effective. This suggests the importance of implementing policies to promote more open innovation strategies by local technology leaders. There are several ways to promote knowledge diffusion. Policy makers can take measures to improve local labour mobility and stimulate spin-offs and other open innovation initiatives, as these are major mechanisms to increase knowledge spillovers (Almeida and Kogut, 1999, Capello, 1999, Capello and Faggian, 2005). A useful instrument may be targeted R&D subsidies that require collaboration with other firms, as R&D collaboration may alter the R&D internalization strategies and generate broader spillovers to collaboration partners (e.g. Gomes-Casseres et al., 2006, Autant-Bernard et al., 2007).

We note a number of limitations of our study, which could provide avenues for further research. First, our analysis could only take into account knowledge protection strategies through internal R&D organization. To the extent that incumbent firms may use a range of protection strategies simultaneously (e.g. patent litigation strategies and non-compete clauses) our findings on the importance of internalization strategies may partially pick up the effect of correlated protection strategies. Future work should aim to analyze the effects of multiple knowledge protection strategies. A stumbling block will be the lack of available data at the regional or firm level, for instance on labour mobility and non-compete clauses. Second, we focused research on 'horizontal' knowledge spillovers due to agglomeration of firms in the same industry. Future studies should take the role of spillovers from upstream (suppliers) or downstream (customers) simultaneously into account. Most studies examining supplier and customer spillovers (Fritsch and Franke, 2004, Klomp and Van Leeuwen, 2001, Tether, 2002) have relied on survey data, and the challenge will be to extend analysis in a representative manner to the level of regions and industries across countries.

Third, our analysis used a relatively broad spatial disaggregation of European countries into regions, at the NUTS-1 level. NUTS-1 regions correspond with areas of between 3 and 7 million inhabitants and might not be necessarily capturing the most relevant R&D clusters. The lack of a regional delineation based on economic areas is a general problem of analysing regional development in Europe, where one has to work with existing regional administrative definitions (Tappeiner et al., 2008, Bottazzi and Peri, 2003, Maurseth and Verspagen, 2002). Although the literature on knowledge spillovers suggests that spillovers decay rapidly at distance (e.g. Autant-Bernard, 2001, Belenzon and Schankerman, 2012, Jaffe et al., 1993), the available estimates of decay functions do not directly suggest that NUTS-1 regions are particularly large in this respect. Estimates of the distance at which knowledge spillovers become less salient range from 250-300 km (Belenzon and Schankerman, 2012, Criscuolo and Verspagen, 2008, Maurseth and Verspagen, 2002) to 200 km (Bottazzi and Peri, 2003), which compares well with the feature that the large majority of NUTS-1 regions have a radius smaller than 150 km.[10] Neverthelesss, a future challenge for research clearly is to work with 'economic areas' in Europe based on actual agglomeration and commuting patterns.

NOTES

1. We limit our analysis to strategies related to R&D organization within the leading firms, as strategies based on legal forms of protections (e.g. employment contracts and non-disclosure agreements) are difficult to identify.
2. Self-citations indicate the extent to which firms build on their own prior technology development efforts in developing new inventions. It is a measure of intra-firm knowledge transfer and represents the extent to which firms retain the value of R&D within internal boundaries (James and Shaver, 2008, Zhao, 2006, Trajtenberg et al., 1997).
3. Some variables (such as R&D Intensity) are not consistently reported by EUROSTAT for a number of countries across years, such that we had to omit a number of region-years observations. This included the years 2003, 2005, and 2007 for Germany and the years 2006, 2007, and 2008 for France. Greece is missing due to lack of information on a range of regional characteristics, but Greece did not receive R&D investments during the period of observation. Since (apart from Greece) all host countries remain in the dataset and the omission of specific years is not systematic, this forced attrition of the sample is unlikely to lead to estimation bias. The models also exclude regions and industry combinations for which no company patents are recorded, as for these regions the key explanatory variables related to technology concentration and internalization cannot be calculated. Regions without any company patents are typically smaller regions in less patent intensive industries. We confirmed that this sample attrition had no appreciable impact on the results by exploring models setting the concentration and internalization variables to zero in case the region has no patented inventions.
4. In a robustness tests we included development projects. This produced similar, though less pronounced empirical results.
5. In case the investing firm is based in an EU-15 country, the regions in their home country are omitted from the choice set. As our FDI data only cover cross-border investments, R&D investments in the home country are not observed by definition.
6. We excluded patents owned by individuals, universities, hospitals, governmental non-profit organizations.
7. Due to the truncation of patents in the most recent years and for consistency, we limited the window of forward citations to 2 years.
8. As the statistical program we use (the mixlogit command in STATA) only allows 20 random variables, we assumed non-random coefficients for two (control) variables. We chose two control variables with insignificant random parameters and for which preference heterogeneity ex ante was less likely as fixed: *Previous R&D* and *Airport traffic*. Alternative settings for non-random coefficients produced consistent results.
9. We note the caveat that significance tests for variances of random components have to be interpreted with caution as they test against a value (zero) that is on the boundary of the parameter

space (Stram and Lee, 1994). This feature does not affect the advantages of the mixed logit model in providing unbiased estimates, relaxing the IIA assumption and allowing for heterogeneous preferences.

10. Other regions such as Catalunya are larger. We experimented with omitting these larger regions from the analysis and obtained comparable results.

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Table 1: Cross-border R&D investments by industry, 2003-2008

Industry	Frequency	Percentage
Food	4	2.0
Textiles	0	0
Paper	0	0
Chemicals	9	4.6
Pharmaceuticals	75	38.3
Rubber	5	2.6
Minerals	0	0
Metals	2	1.0
Machinery	10	5.1
Electronics	78	40.0
Transport	10	5.1
Others	3	1.5
Total	196	100

Table 2: Distribution of Cross border R&D investments over NUTS-1 regions, 2003-2008

NUTS-1 region	Frequency	Percentage	NUTS-1 region	Frequency	Percentage
Catalunya (ES5)	23	11.73	Baden-Württemberg (DE1)	2	1.02
Ireland (IE0)	21	10.71	Bayern (DE2)	2	1.02
East of England (UKH)	14	7.14	Berlin (DE3)	2	1.02
Flanders (FL)	11	5.61	Nordrhein-Westfalen (DEA)	2	1.02
South East England (UKJ)	9	4.59	Sachsen (DED)	2	1.02
Scotland (UKM)	9	4.59	North East Spain (ES2)	2	1.02
Denmark (DK0)	8	4.08	South Spain (ES6)	2	1.02
Comunidad de Madrid (ES3)	8	4.08	Finland (FI1)	2	1.02
Northern Ireland (UKN)	7	3.57	Central France (FR7)	2	1.02
Méditeranée (FR8)	6	3.06	North East England (UKC)	2	1.02
Bassin Parisien (FR2)	5	2.55	London (UKI)	2	1.02
North West Italy (ITC)	5	2.55	Wales (UKL)	2	1.02
Portugal (PT1)	5	2.55	Hamburg (DE6)	1	0.51
East Sweden (SE1)	5	2.55	South West France (FR6)	1	0.51
Île de France (FR1)	4	2.04	Isole (ITG)	1	0.51
Central Italy (ITE)	4	2.04	Luxembourg (LU0)	1	0.51
Walloon Region (BE3)	3	1.53	West Netherlands (NL3)	1	0.51
East France (FR4)	3	1.53	South Netherlands (NL4)	1	0.51
West France (FR5)	3	1.53	South Sweden (SE2)	1	0.51
South West England (UKK)	3	1.53	North Sweden (SE3)	1	0.51
East Austria (AT1)	2	1.02	North West England (UKD)	1	0.51
South Austria (AT2)	2	1.02	West Midlands (UKG)	1	0.51
West Austria (AT3)	2	1.02	**Total**	196	100

Table 3: Regional Technology leaders in selected regions with above median technology concentration and leader's self-citation ratio

NUTS-1 region	Industry	HH-index	Technology leader	Self-citation ratio	Foreign Self-citation ratio
Walloon Region (BE3)	Food	1.00	Monsanto	1.00	1.00
Nordrhein-Westfalen (DEA)	Food	0.82	Bayer	1.00	0.33
Rheinland-Pfalz (DEB)	Chemicals	0.97	Basf	0.47	0.26
West Netherlands (NL3)	Chemicals	0.93	Shell	0.60	0.40
Thüringen (DEG)	Pharmaceuticals	1.00	Bayer	0.53	0.27
North West England (UKD)	Pharmaceuticals	0.99	Astrazeneca	0.73	0.73
Nord-Pas-de-Calais (FR3)	Rubber	1.00	Nexans	1.00	1.00
Walloon Region (BE3)	Rubber	1.00	Total	0.67	0.50
Catalunya (ES5)	Metals	0.50	Sandvik	1.00	1.00
Berlin (DE3)	Metals	0.63	Siemens	0.78	0.67
Portugal (PT1)	Machinery	0.81	Bosch	0.57	0.57
East Midlands (UKF)	Machinery	1.00	Siemens	0.41	0.41
Isole (ITG)	Electronics	1.00	STMicroelectronics	0.53	0.41
South Netherlands (NL4)	Electronics	0.95	Philips	0.52	0.39
South Sweden (SE2)	Transport	1.00	Ford	0.60	0.40
East of England (UKH)	Transport	0.78	Nissan	0.80	0.80

Table 4: Definition and summary statistics of explanatory variables

Name	Definition	Mean	Stdev.
Technological Strength	Logarithm of (1 + share of the NUTS-1 region in EU15 patent applications * 100) (at industry level)	2.31	1.10
Academic Research Strength	Logarithm of (1 + share of the NUTS-1 region in EU15 university publications * 100) (at industry level)	3.20	0.96
R&D Intensity	Logarithm of (total intramural R&D expenditures in business sector of NUTS-1 region / GDP of NUTS-1 region)	0.70	0.35
Patent quality	Logarithm of average number of forward citations per patent in NUTS-1 region (at industry level)	0.64	0.48
Backward citation intensity	Logarithm of average number of citations per patent in NUTS-1 region (at industry level)	0.45	0.38
GDP Per Capita	Logarithm of GDP per capita of NUTS-1 region	3.26	0.27
Population	Logarithm of population (1000) of NUTS-1 region	8.53	0.65
Firm’s Previous Investments	Dummy variable indicating whether the investing company has previous manufacturing investments in the NUTS-1 region	0.03	0.18
Firm’s Previous R&D	Dummy variable indicating whether the investing company has previous R&D investments in the NUTS-1 region	0.00	0.03
Unemployment Rate	Logarithm of unemployment rate of NUTS-1 region	1.96	0.47
Airport traffic	Logarithm of air transport of passengers (total passengers embarked and disembarked)	8.83	1.86
Geographic Distance	Logarithm of geographical distance between investor country and NUTS-1 region	8.24	1.09
Language Similarity	Dummy variable indicating language similarity between investor country and NUTS-1 region	0.21	0.41
Wage Cost	Logarithm of wage costs of engineers of host country	10.72	0.22
B-index	Logarithm of the B-index (R&D tax burden) of the host country	-0.11	0.18
High Technology Concentration	Dummy variable indicating whether the NUTS-1 region has a high technology concentration (at industry level)	0.42	0.49
High Self Citation	Dummy variable indicating whether the self-citation ratio of the leader in NUTS- region is high (at industry level)	0.44	0.50

Table 5: Mixed Logit Analysis of European regional location choices for R&D investment projects, 2003-2008

	Model1	**Model2**	**Model3**	**Model4**
Technological Strength	0.838*	0.855*	1.177**	1.061**
	(0.429)	(0.457)	(0.480)	(0.525)
Academic Research Strength	0.695	0.366	1.138	0.639
	(1.397)	(1.329)	(1.449)	(1.631)
R&D Intensity	0.379	0.359	0.463	0.287
	(0.474)	(0.465)	(0.602)	(0.589)
Patent quality	0.390	0.383	0.591**	0.615**
	(0.242)	(0.234)	(0.271)	(0.288)
Backward Citation Intensity	0.299	0.258	0.414	0.492
	(0.239)	(0.246)	(0.310)	(0.300)
GDP Per Capita	-1.866**	-2.116***	-2.099**	-2.444***
	(0.763)	(0.774)	(0.850)	(0.851)
Population	0.171	0.255	0.431	0.468
	(0.412)	(0.411)	(0.458)	(0.443)
Firm's Previous Investments	0.005	0.852	0.161	-1.066
	(1.055)	(0.771)	(1.216)	(1.974)
Firms's Previous R&D	35.208***	31.809***	42.131***	69.863***
	(7.079)	(3.967)	(7.599)	(21.994)
Unemployment Rate	-1.164**	-1.022**	-1.037*	-1.355**
	(0.498)	(0.484)	(0.566)	(0.553)
Airport traffic	0.717***	0.715***	0.699***	0.760***
	(0.192)	(0.194)	(0.204)	(0.218)
Geographic Distance	-0.158	-0.296	-0.039	-0.311
	(0.420)	(0.371)	(0.442)	(0.490)
Language Similarity	0.705**	0.636**	0.770**	0.635*
	(0.311)	(0.306)	(0.357)	(0.382)
Wage Cost	0.560	0.765	-0.239	0.726
	(1.313)	(1.482)	(1.466)	(1.660)
B-index	-2.776	-2.183	-2.997	-4.967*
	(2.420)	(2.396)	(2.758)	(2.858)
High Technology Concentration		-0.749*		
		(0.383)		
High Technology Concentration /			-4.889**	
High Self-citation			(2.163)	
High Technology Concentration /			-0.009	
Low Self-citation			(0.301)	
Low Technology Concentration /			-0.619	
High Self-citation			(0.712)	
High Tech Concentration / High Dom.				-26.012**
Self-cit/ High Foreign Self-cit				(12.777)
High Tech Concentration / High Dom.				-1.280
Self-cit/ Low Foreign Self-cit				(1.474)
High Tech Concentration / Low Dom.				-2.519***
Self-cit / High Foreign Self-cit				(0.749)
High Tech Concentration / Low Dom.				-0.331
Self-cit / Low Foreign Self-cit				(0.815)
Low Tech Concentration / High Dom.				-17.326
Self-cit / High Foreign Self-cit				(15.123)
Low Tech Concentration / High Dom.				-0.379
Self-cit / Low Foreign Self-cit				(0.931)
Low Tech Concentration / Low Dom.				0.245
Self-cit / High Foreign Self-cit				(0.350)

Continuation Table 5	Model1	Model2	Model3	Model4
Random parts coefficients				
R&D Intensity				-1.945**
Population	1.501***	1.657***	2.178***	2.355***
Firm's Previous Investments	-5.193*	3.395**	6.279**	11.007*
Geographic Distance	1.520**	-1.903***	2.106***	-2.770***
Wage Cost		-2.384*		2.997**
B-index			-2.656**	
Average Forward Citations			-1.304**	-1.430*
High Technology Concentration / High Self-citation			-5.229***	
Low Technology Concentration / High Self-citation			3.346**	
High Tech Concentration/ High Dom. Self-cit / High Foreign Self-cit				-20.081**
Number of observations	7559	7559	7559	7559
Number of projects	196	196	196	196
Number of investing firms	152	152	152	152
Number of regions (maximum)	64	64	64	64
Wald chi²	154.2***	291.9***	178.2***	260.9***

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

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