What Determines the Location Choice of Multinational R&D Firms?

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Abstract

We analyse 446 location decisions of foreign affiliates in the R&D sector incorporated in the European Union over 1999-2006. Our results suggest that on average, the location probability increases with market potential, agglomeration economies, R&D intensity and proximity to centres of research excellence. It appears that the European Union's regional policy and country corporate tax rates as well as regional characteristics such as income per capita, the unemployment rate and human capital had no significant effects in fostering the attractiveness of regions to R&D foreign investment over and above other determinants. We find evidence of geographical structures relevant for the location choice of R&D multinational firms across the European Union. Further, our evidence suggests that European investors have responded differently to location characteristics in comparison to North American investors.

JEL classification: F23; O32; R38

Key words: Foreign direct investment; Internationalisation of R&D; Location choice; Conditional logit models; Nested logit models; European Union.

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1 Introduction

There has been a growing internationalisation of enterprise R&D activities in recent years. Multinational enterprises (MNEs) are the main drivers of this growing internationalisation of enterprise R&D and in many countries foreign affiliates carry out more R&D than domestic firms (OECD, 2007). While traditional cross-border R&D enterprise activities have tended to locate in developed economies, an increasing amount of R&D outward investment in recent years has gone to emerging economies.

While internationalisation of R&D is not new, its speed and extent have increased in recent years. In addition to the traditional role of R&D foreign investment in diffusing technology (demand-driven) related to adapting products and services to local market conditions and supporting MNEs local manufacturing operations, R&D foreign investment is being increasingly motivated by tapping into worldwide centres of knowledge (supply-driven) as part of firms strategies to source innovation globally (OECD, 2008).

Over the period 1995-2005, the share of foreign affiliates in total business R&D expenditure has increased substantially in almost all European Union's countries. In 2005, this share was over 70 per cent in Ireland, over 50 per cent in Belgium and the Czech Republic, over 40 per cent in Austria and Sweden. The share of R&D expenditure by foreign affiliates was lower, less than 25 per cent in Slovakia and Finland. The European Union (EU) is the largest recipient of R&D investment by US multinationals. In 2005, the European Union accounted for 62.5 per cent of the R&D

expenditure of affiliates of US parent companies abroad (European Commission, 2008).

This increasing internationalisation of R&D activity in the European Union raises a number of questions which are interesting and relevant for both research and policy making: Where are the multinational R&D enterprises located? Who are the main foreign investors in the R&D activity? What factors drive the location choice of multinational R&D activity?

To answer these questions, this paper analyses the determinants of the location choice of multinational R&D firms across European Union regions. We use a large firm-level data set which enables us to consider a wide range of location choices of multinational firms in the R&D sector. Specifically, we analyse the location choice of 446 new foreign affiliates incorporated in the European Union over the 1999-2006 period. The large number of location choices (246 regions) enables us to obtain robust estimates of determinants of the attractiveness of regions to R&D foreign investment.

There has been a renewed interest in recent years in the empirical analysis of the location choice of multinational enterprises which is linked to recent theoretical advances in international trade and investment to account for increasing returns to scale, imperfect competition and product differentiation[1] (Belderbos and Caree, 2002; Barry et al., 2003; Crozet et al., 2004; Disdier and Mayer, 2004; Barrios et al., 2006; Pusterla and Resmini, 2007; Basile et al., 2008). This literature has examined the location decision of multinational firms assuming that R&D activity is located where production takes place and it has not addressed specifically the case of the location

[1] For overviews of this literature see Fujita et al. (1999) and Markusen (2002)

choice of R&D foreign affiliates[2]. Given that multinational enterprises are concentrated in R&D intensive industries, many factors driving the location choice of foreign affiliates are also relevant and important in the case of foreign affiliates in R&D. However, as documented in a number of recent studies in the field on international business, factors specific to the R&D sector, in particular in relation to the knowledge sourcing aspect of the foreign direct investment in R&D are increasingly important (Florida, 1997; von Zedtwitz and Gassmann, 2002; Belderbos et al. 2008).

To the best of our knowledge there has been no attempt to bring together these two strands of literature. To fill this gap, we add to the empirical literature on the location choice of multinational enterprises in three ways. First, we use a rich micro data set and estimate location choice models which consider both demand-driven (market access) and supply-driven (knowledge sourcing) motivations for foreign direct investment in R&D. Second, in contrast to previous studies which have looked at the location choice of multinational firms using standard discrete choice models, we use an improved econometric methodology to account for correlation among location alternatives and firms. Third, we allow the probability to invest in a specific region to be different depending on the country of origin of foreign investors.

Our results suggest that on average, the probability to locate in an EU region (NUTS 2) increases with market potential, agglomeration economies, R&D intensity and proximity to centres of research excellence. It appears that the EU regional policy, country corporate tax rates as well as regional characteristics such as income per capita, unemployment rate, and human capital had no significant effects in fostering

[2] Notable exceptions are Markusen (2002) and Ekholm and Hakkala (2007). These theoretical contributions allow the geographical separation of knowledge-based activities (R&D) and production facilities in a two-country general equilibrium setup. However, in this paper we consider a multicountry setup.

the attractiveness of regions to R&D foreign investment over and above other determinants. There is also evidence of a geographical structure in the location choice of R&D multinational firms across the European Union. Further, we find that European investors have responded differently to location characteristics in comparison to North-American investors.

The remainder of this paper is organised as follows. Section 2 describes the empirical methodology and testable hypotheses. Section 3 presents our data and summary statistics. The results of our econometric analysis are presented in section 4. Finally Section 5 summarises our results and concludes.

3 Empirical Methodology

3.1 Modelling Location Choice

We assume that a firm's location decision is part of a three-step decision-making process which starts with the firm's decision to serve a foreign market and follows with the choice to undertake foreign direct investment and the location choice. In this paper, we focus on the last step of this process[3].

We analyse the location choice of R&D foreign affiliates by using two discrete choice models. First, we estimate a conditional logit model following McFadden (1974). This model has been widely used for spatial choice analysis as it allows the modelling of a decision with more than two discrete outcomes (Haynes and Fotheingham 1990). These random utility maximization model assigns a utility level U_{ij} to each alternative $j = 1,.....,N$ for each decision maker $i = 1,.....I$ for vectors of observed attributes (McFadden 1974). For each firm (i) the utility from locating in a given region j depends on a deterministic component X_{ij} which is a function of the

[3] For a discussion of this convention see Devereux and Griffith (1998), Head and Mayer (2004) and Basile et al. (2008).

observed characteristics and some unobservable factors which are captured by a stochastic term ε_{ij} :

$$(1) \qquad U_{ij} = X'_{ij}\beta + \varepsilon_{ij}$$

The probability that a firm i chooses to start up a plant in a region j as opposed to any other region k is then equal to the probability of U_{ij} being the largest of all $U_{i1},.....,U_{iJ}$ (Heiss 2002).

To estimate equation (1) an assumption must be made about the joint probability distribution of the unknown stochastic utilities ε_{ij}. As shown by McFadden (1974) under the assumptions of independently and identically distributed (IID) error terms with type 1 extreme value (Gumbel) distribution the probability of choosing a location h is:

$$(2) \qquad P(y = h \mid 1,..., J) = \frac{e^{\beta X_{ih}}}{\sum_{j=1}^{J} e^{\beta X_{ij}}}$$

The IID assumption on the error terms implies a statistical property in the conditional logit model, the independence of irrelevant alternatives (IIA). This property states that the odds ratio of any alternative being chosen over another alternative is independent of the size and composition of the choice set of alternatives. With IID, the errors cannot contain any alternative specific information and so adding a new alternative cannot alter existing relationships between pairs of alternatives. The assumption thus constrains the ratios to be constant over all possible choice sets. This imposes a rigid substitution pattern across all alternatives as for the odds ratio to remain constant as alternatives are added and removed from the choice set the individual choice probability of the remaining alternatives will have to change by the same amount

(Hunt 2004). If the model's IIA property is violated this will lead to inconsistent parameter estimates. As discussed in Haynes and Fotheingham (1990), the equal substitution pattern implied by the IIA property is unlikely to hold in a spatial choice framework due to choice characteristics of size, aggregation, dimensionality, continuity and variation. These characteristics may yield alternatives spatially correlated in unobservable factors and so estimates will be inconsistent.

To account for this, a generalised extreme value model within the framework of random utility maximization is used (McFadden 1984). These models allow a more complex pattern of substitution while maintaining a simple closed form structure for the choice probabilities (Sener et al 2008). Thus, the nested logit model takes into account correlation among alternatives. The nested structure is created by grouping the alternative locations choices into nests chosen according to the degree of similarity and so correlation between the alternatives (Basile et al 2003). Therefore in the location choice model the nests consist of regions with similar characteristics, hence correlation is allowed within but not across nests. The structure allows the independence of irrelevant alternatives (IIA) property to hold within nests but not across nests.

Following Heiss (2002), let the error term to follow a generalised extreme value distribution. Denote $\tau_k = \sqrt{1-\rho_k}$, where ρ_k is the correlation of alternatives in nest k, thus τ_k, the inclusive value (IV) parameter, measures the independence of alternatives in nest k. If $\tau_k = 1$, the alternatives are perfectly independent of each other and so there the nested structure is not required. At this value of the IV parameter the nested model collapses into the conditional logit model. If $\tau_k = 0$, perfect dependence exists and as the alternatives are perfect substitutes, the nest then becomes the alternative. One can further write the log sum of utilities generated from alternatives in nest k as follows:

(3) $$IV_k = \ln \sum_{j \in n_k} \exp(U_{ih} / \tau_k),$$

IV_{k} is the inclusive value of nest k (denoted by n_k). Therefore, τ_k is the IV parameter of n_k. The probability function of alternative h in nest k being chosen is the product of the probability of choosing nest k ($\Pr(k)$) and the conditional probability of choosing h given k is chosen ($\Pr(h \mid k)$). The function can be expressed as follows:

(4) $$\Pr(y = h \mid 1,...,J) = \Pr(h \mid k)\Pr(k) = \frac{\exp(U_h / \tau_h)}{\exp(IV_h)} \frac{\exp(\tau_h IV_h)}{\sum_K \exp(\tau_k IV_k)},$$

where τ_h and IV_h are the IV parameter and the inclusive value for the nest where alternative h is in.

The choice of possible nested structures is multiple and there is no systematic way to identify a best structure amongst all possible nests (Greene and Hensher 2002). However, for the nested model to be consistent with the Random Utility Maximisation (RUM) framework - the IV parameter τ_k s has to be bounded between 0 and 1 (Heiss 2002).

3.2 Testable Hypotheses and Model Specifications

The dependent variable is the location choice of each foreign affiliate over 246 possible locations. It is equal to 1 if firm i located in region j over the period 1999 to 2006 and zero for all regions different from j.

$$y_{ij} = \begin{cases} 1 & if \, \pi_{ij} > \pi_{ik}, \forall j \neq k \\ 0 & otherwise \end{cases}$$

π_{ij} is the expected profit for firm i in region j. Since π_{ij} is not observed we estimate it as a function of variables that are likely to influence it.

Each firm's location decision is explained as being a function of regional characteristics as well as policy variables at national and EU level. The explanatory variables that are used in the models are summarised in Table A1 in the Appendix. Pair wise correlations between explanatory variables are shown in table A2.

The empirical analysis of the location choice of multinational enterprise activity distinguishes between horizontal and vertical motivations of foreign direct investment (Mayer et al. 2007). Horizontal motivations are driven by market access and market potential of an area and affect the revenue component of the profit function. Vertical motivations are concerned with the firms' cost, locating the firm and its affiliates in regions that will minimize the cost element of the profit function. In the literature on the internationalisation of R&D (Dicken, 2004; Daniels and Lever 1996; OECD, 2008) firms are also motivated by the possibility of connecting with local innovation systems and accessing high quality labour markets.

For horizontal motivations, the location and demand of the final consumer market is important. Using a model with increasing returns, Krugman (1980) shows that firms will locate in larger markets and use these as a base to export to smaller markets in the region. This occurs as by concentrating production in one place the firm can simultaneously realise economies of scale (EOS) and also minimize transportation costs. This is important in the case of R&D firms as by far the most common form of overseas R&D facility is the support laboratory. The purpose of these facilities is to adapt technologies and products to local markets and also provide technical backup for local manufacturing and sales (Dicken 2004). However as shown by Motta (1992) and Neary (2002) this relationship between market size and foreign direct investment is not monotonic as market size also affects the number and so competition between firms.

Following Harris (1954), we measure *market potential* of each host region by GDP in that region and a distance weighted sum of GDP in adjacent regions[4]. Our theoretical prior is a positive effect of market potential on the probability to locate in a region.

Agglomeration in the R&D sector is likely to be of particular importance as R&D activities are characterised by the need to assemble a diverse and skilled network of workers, sophisticated infrastructure and also uncertainty surrounding outcomes. This leads to a need to concentrate activities (Dicken 2004). This effect can be negative as agglomeration diseconomies, due to resources such as labour being bid up in the region (Head et al. 1999). Proximity to other regions is also considered as agglomeration effects are assumed to spill across borders and so a neighbouring region agglomeration count is also used (Head et al. 1999). Firm specific agglomeration occurs as it reduces the uncertainty of operating in a region and so reduces the risk of new investments[5]. To account for this spatial dependence, we measure agglomeration by the number of foreign R&D firms in the same region plus a distance[6] weighted measure taking into account foreign R&D firms located in all

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[4] The argument made by Harris (1954) is that, in a multicounty set up, the actual demand which firms in a given location is determined in addition to the size of local market by the sum of the market sizes of the neighbouring regions weighted by a measure of accessibility to all regions. For a discussion of measuring market potential in modelling the location choice of multinational firms see Crozet et al (2004) and Altomonte (2007).

[5] Barry et al (2003) provide empirical evidence showing that the presence of multinational firms in Ireland has acted as a "demonstration effect" for the attraction of new foreign direct investment

[6] Distance is measured by estimated road - freight travel time in hours between capital cities of regions. We thank Matthieu Crozet for providing us with these estimates. The data used and estimation methodology are described in Brülhart et al (2004)

other regions. Firms are counted at the beginning of the period to mitigate endogeneity problems.

As for vertical motivations, a number of factors are considered important in determining the costs of production such as labour costs, labour market flexibility, and taxation.

We proxy labour costs with *GDP per capita* in each region. The expected effect can be positive or negative. While regions with a high GDP per capita can indicate the presence of highly skilled workers, regions with low GDP per capita would be associated with low cost locations. It is thus necessary to account for *human capital*. We use the percentage of the economically active population with tertiary education as a proxy for human capital in a region indicating a more productive labour force. Our theoretical prior is a positive effect of human capital on the location probability.

The effect of the *unemployment rate* on the location probability is ambiguous. On one hand, as shown in efficiency wage models, unemployment reduces workers bargaining power and increases worker effort as it increases the cost of being fired. On the other hand, high unemployment can indicate a pool of available labour but may also be related to labour market rigidities in a region.

Tax directly reduces the profits of firms. Devereux and Griffith (1998) show that corporate profit taxes significantly influence US multinational firms' decision on which European country to locate in. Griffith (2002) shows that R&D tax credits have a significant effect on the level of R&D investment[7]. Tax can also indicate a stock of public goods and so the sign may be positive. Benassy - Quéré et al (2000) show that firms may be willing to pay higher taxes in exchange for more public goods. To

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[7] While controlling for the tax treatment of R&D is desirable, data on R&D tax credits is not available for a sufficient number of countries and time periods.

control for the effect of taxation on the location probability of R&D multinational firms we use the top corporate tax.

Basile et al. (2008) find that EU regional policy has been successful in attracting foreign investment to peripheral regions through funding training, infrastructure and R&D activities. We test the effect of EU regional policy on the location of R&D foreign affiliates by including in our model a dummy variable which equals 1 for regions eligible to receive EU Structural Funds under Objective 1[8]. A positive sign of this variable would indicate that the EU regional policy has been successful in fostering the attractiveness of regions to foreign investment in the R&D sector.

Recent literature on the internationalisation of R&D (Daniels and Lever 1996; Florida 1997; Zedtwitz and Gassmann 2002; Dicken 2004; OECD 2008) points to access to a strong knowledge-base as a factor driving foreign investment in the R&D sector. To test this effect on the location choice of R&D multinational firms, we use government and business R&D expenditure as a percentage of regional GDP to proxy the knowledge-base of regions. Our theoretical prior is a positive effect of R&D intensity on the location probability.

Abramovsky et al (2007) finds that foreign-owned R&D labs are located in the proximity of centres of university research excellence in the UK. Universities provide firms with access to high quality researchers for basic scientific research. Location close to universities indicates that R&D firms are engaging in a higher level of research than a basic production support function and are engaging in global market orientated R&D (Dicken 2004). To capture the effect of proximity to centres of research excellence, we include a dummy variable which is equal to 1 if a region has a university ranked in the *Top 500 ranked universities*. We test the hypothesis that the

[8] NUTS 2 regions in the European Union with a per capita GDP lower than 75% of the EU average

presence of a top ranked university has a positive effect on the location choice of R&D foreign affiliates.

The quality of infrastructure in a region affects the costs of and productivity of operations in a location. R&D is characterised by the need to operate networks of workers and may require access to *advanced IT infrastructure.* We test this effect by using the total number of internet users at country level as a proxy for information technology infrastructure.

Explanatory variables are lagged with respect to the dependent variable to account for the fact that investment decisions are lagged in time and to avoid possible endogeneity problems. In the estimated models we cluster standard errors at country level to account for possible correlation of error terms across regions within each country due to unobserved country characteristics following Moulton (1990) and Pepper (2002).

4 Data and Summary Statistics

The firm level data used in this analysis is taken from the *Amadeus* database, which contains information on over 11 million firms located in 45 European countries. Foreign owned R&D firms are selected for analysis on the assumption that their MNE parents had a multiple country and region decision when locating their affiliate and so using the observed location pattern along with the varying regional and national characteristics it is possible both to identify the variables that affect their decision and estimate their importance. A firm is defined as foreign - owned if the firm has one foreign shareholder with at least 10 per cent of voting share in it. This definition is in line with the IMF and OECD's definition of "foreign direct investment enterprise"

(IMF 1993). Data on R&D firms are extracted from the database according to NACE Rev. 1.1 codes[9]. R&D firms are those classified as the K73 sector.

This paper uses data on 446 location decisions of new R&D foreign affiliates in 17 European countries over the period 1999 to 2006. This period allows us to include both the EU15 countries and the new EU countries in MNEs' location-choice set[10]. The location choice is analysed at regional level as MNEs do not only consider country level characteristics in their decision. This analysis is possible as a substantial databank now exists for this level of spatial aggregation. The geographical area of the choice set is the EU 27 group of countries. Regions are defined according to the NUTS 2 classification system[11].

Tables A3 – A5 present descriptive statistics of the R&D foreign affiliate's location.

Column one and two of Table A3 show the location of the new firms by country over the period. Regions in the United Kingdom and Germany attracted the bulk of R&D foreign investment, approximately 72 per cent of the total. Six per cent of the new firms chose regions in the new EU countries. Column three and four show the rank of the regions by the location of firms. Inner London attracted the largest share of R&D foreign affiliates. In column five the rank of new R&D foreign affiliates per total GDP is given for each of the countries as we expect the number of R&D firms to be positively related to total GDP. Romania attracted the largest number of R&D foreign affiliates relative to its economic size.

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[9] NACE is the European Communities statistical classification system for economic activities.

[10] The EU15 countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK. New EU Countries are Bulgaria, Cyprus, Czech, Estonia, Hungary, Latvian, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia. We do not include Cyprus and Malta in this study due to lack of data.

[11] NUTS stands for "the Nomenclature of Territorial Units for Statistics", which is a geographic coding system developed by the EU to reference administrative regions within its countries. There are three levels of NUTS codes which break countries down to finer regions one after another. Namely, they are NUTS 1, NUTS 2 and NUTS 3.

Table A4 provides a summary of the origins of the firms in the sample by broad geographical classification. From column two and three it can be seen that 50.9 per cent of the firms in the sample originate from one of the EU 15 countries, Switzerland or Norway. A further breakdown of this geographical area is given in column 3 with Switzerland accounting for most of the firms originating from this area. As for individual countries the top origin country is the United States followed by Switzerland accounting for 30.7 per cent and 9.6 per cent of the firms respectively.

As the United Kingdom and Germany are the most popular destinations, a breakdown by geographical origin of the firms locating in these countries is given in Table A5. Most of the R&D foreign affiliates located in the United Kingdom originated from North America (United States and Canada) while in the case of Germany the largest number of foreign affiliates came from the Western European countries.

Table 1 presents summary statistics of the explanatory variables used in our empirical analysis. In addition to summary statistics for the full sample, these statistics are also provided for the samples of EU15 countries and new EU countries (EU10).

Table 1 about here

There is a large range in the agglomeration of R&D firms across the regions and so a very uneven geography of location. A sizable disparity across regions also exists in terms of tertiary education and R&D intensity across regions. The EU15 regions have higher mean market potential, GDP per capita, human capital, R&D intensity, internet users, top ranked universities and lower mean unemployment than the EU10 countries. It can be seen that even within the EU15 group there still exists large disparities in many of the variables. In terms of regions, the highest agglomeration, education and GDP per capita in the EU15 group are all recorded in the Inner London region and the highest R&D intensity is in the Braunschweig region of Germany. In the EU10 the regions of the Czech Republic of and adjacent to Prague record the highest market potential, R&D intensity, GDP per capita and the lowest unemployment.

5 Econometric Results

5.1 Conditional Logit Models

Table 2 shows the estimates of the conditional logit model for all R&D foreign affiliates over all regions. The first column shows the baseline model with three explanatory variables: market potential, GDP per capita, agglomeration of foreign firms in the R&D sector, and the unemployment rate. In subsequent columns the other variables are added. The figures reported are the average probability elasticities (APE)[12] of each variable aside from the two dummy variables. For the variables in percentage form the APE is evaluated at the mean value of the variable. The standard errors reported are the clustered standard errors of the estimated coefficients.

Table 2 about here

Market potential has a positive and significant coefficient across all specifications. From the full model in column 8 it can be seen that a 10 per cent increase in market potential increases the probability of a region being chosen by 5.3 per cent. This suggests that R&D foreign affiliates are attracted to regions with large markets and with access to large adjacent markets. This effect on R&D foreign affiliates may reflect the importance of horizontal motivations in location choice for the firms selling into foreign markets. Overseas research centres often operate to adapt products

[12] The APE for the conditional logit model is given by the formula: $\beta(1-\frac{1}{J})$ where J is the number of regions in the choice set and β is the estimated paramater.

to local technical specifications or characteristics of markets as well as provide technical support to local operations and so may match the pattern of final production and sales operations (Dicken 2004).

The coefficient on GDP per capita is negative and insignificant. In the base model this variable captures the opposing effects of high labour cost and high productivity on firms. When we control for human capital the magnitude of this coefficient increases. That this variable is insignificant even when other labour market characteristics are controlled for indicates that labour costs do not affect significantly the location decision of R&D foreign affiliates. As previously mentioned the sign on the agglomeration variable may be positive or negative. The estimated coefficient for the agglomeration of foreign firms is positive and significant indicating that the benefits of clustering activity are important in the R&D sector and outweigh any local competition effects. This variable is also an indicator of positive unobserved characteristics in a region as when R&D firms locate in a region it can be taken as a signal by other firms of favourable characteristics. The effect of the regional unemployment rate is negative but insignificant indicating that the availability of labour or the presence of labour market rigidities do not affect the attractiveness of regions to R&D foreign affiliates.

The tax variable is introduced in column two and is negative but insignificant across all specifications. This result suggests that the corporate tax rate in a country has no affect on the location of R&D foreign affiliates in regions of that country over and above other control variables. This insignificant tax effect is also found in Basile et al. (2008). The Objective 1 dummy variable is insignificant across all specifications in Table 2 indicating that this policy has not had a significant effect on regional investment conditions so as to attract R&D foreign affiliates. Regional education level is insignificant.

In column 5 and 6 two measures of regional R&D intensity are used to proxy the technological development of regions. Both measures are positive and significant. This indicates that foreign firms locate in regions with a high research capacity and that business R&D expenditure has a greater impact on firm's location choice than government R&D expenditure. This may be as to access the local innovation system and incorporate it into the firm's broader innovation network.

As a proxy for infrastructure the number of internet users is included in column seven. It is positive but insignificant so the level of information technology infrastructure is not an important factor in attracting R&D foreign investment over and above the other control variables. As a measure of the knowledge-base of regions a dummy variable for the presence in the region of a top 500 ranked university is included in column eight. This variable's significance shows that R&D foreign affiliates are attracted to centres of research excellence. This result along with the significant result for government and business R&D intensity suggest the importance of the knowledge base in attracting foreign investment in the R&D sector.

The baseline model was estimated across all regions and firms. However it is possible that heterogeneity among firms in the treatment of regional characteristics exists and so firms may weight regional characteristics differently. This difference in firm behaviour will not be seen when they are grouped together. To examine this possibility the sample of foreign affiliates is divided by country of origin and the models are estimated for North American and European multinational firms separately. The results for these conditional logit models are shown in Table 3.

Table 3 about here

For the North American firms, the APE on agglomeration is increased and is significant. For European firms this variable is not significant which indicates that the clustering effect on location is only present for North American firms. There is a differentiation by origin in the role of R&D intensity on location choice. It appears that North American firms are attracted to regions with high business R&D intensity while European firms are attracted to regions with high government R&D intensity.

The dummy for top ranked university is significant in the case of North American R&D multinational firms and not for European R&D multinational firms. This result indicates that while access to research excellence and tapping into local knowledge is an important determinant in the location decision of North American R&D multinational firms it is not in the case of European R&D multinational firms.

As a robustness check the conditional logit model is estimated with the maxima and minima for the explanatory variables omitted. The estimated coefficients show no substantial changes[13].

5.2 Nested Logit Models

As discussed in Section 3, it is necessary to test if a nesting structure is relevant in the location choice. Following Hausman and McFadden (1984), the IIA property can be tested by eliminating a subset of alternatives from the choice alternatives and comparing the estimated parameters from the restricted and unrestricted choice sets. If the parameter estimates are consistent, the IIA property holds. The Hausman test was preformed first using the countries to partition the regional subsets. One country was excluded from the estimation each time. In 40 per cent of tests, the null hypothesis that the IIA property holds was rejected at 10 per cent significance level. However a

[13] The results are available from the authors upon request.

number of models failed to estimate. A generalised test was also applied, using seemingly unrelated estimations. 70.4 per cent of these tests rejected the null at a 10 per cent significance level. This test was also performed dividing the regions into 4 geographically based subsets[14]. In the Hausman and generalised tests 75 per cent and 100 per cent of the tests rejected the null at a 10 per cent significance level respectively[15].

These tests indicate that a nesting structure is required. A number of structures were tested. The final choice of the structure was restricted in many cases by models inability to achieve convergence. A country based structure was found to be inconsistent with random utility maximization. A model with a 4 group nesting structure was found to be the most successful nesting structure. The results from the four group structure are presented in Table 4.

Table 4 about here

The inclusive value parameters are all between zero and one indicating that the geographical structure is relevant and that choices are geographically nested. Market potential is now insignificant for both European and North American firms. This result indicates that when choosing a location within the geographical nests, horizontal FDI motivations appear to be not important for these firms. Agglomeration is now significant for European firms but the clustering effect is still stronger for North American firms. Business R&D intensity drives the location choice of both European and North American firms. The effect is again stronger for the North American firms. While proximity to university centres of research excellence is an

[14] Regions were grouped as follows: regions of United Kingdom & Ireland; Centre: regions of France, Germany, Belgium, the Netherlands, Denmark, Sweden, Norway, Finland, Austria, Switzerland and Luxembourg; East: regions of Bulgaria, Hungary, Romania, Slovakia, Czech Republic, Poland, Latvia, Lithuania, Estonia and Slovenia; South: regions of Spain, Italy, Greece and Portugal.
[15] These results are available from the authors upon request

important determinant of the location choice within nest in the case of North American R&D multinationals it is not in the case of European multinationals. This result is important as the primary and most intensive phase of research and development by firms tends to be located close to universities with a high capacity for research (Dicken, 2004; Daniels and Lever 1996).

6 Summary and Conclusions

In this paper we estimated the determinants of the location choice of new foreign affiliates in the R&D sector across regions in the European Union over the period 1999-2006. With respect to methodology improvements, in addition to conditional logit models we estimated nested logit models to account for the fact that in relation to many alternative location choices, conditional logit models might lead to biased estimates. We also cluster the standard errors to control for correlation of unobserved characteristics among firms located in the same country.

Our results suggest that on average, the probability of the location of a representative R&D foreign affiliate in an EU region increases with market potential, agglomeration economies, business and government R&D intensity and proximity to centres of research excellence. It appears that, over the analysed period, regional characteristics such as per capita income, unemployment rate and human capital had no effect on the attractiveness of regions to R&D foreign investment over and above other determinants. Our evidence also suggests that, EU regional policy and country level corporate tax rates had no significant effect in fostering the attractiveness of regions to R&D foreign investment over and above other determinants. This result might be explained by the fact that the sensitivity of the probability to location to taxation in a country/region is higher in the case of a small number of location options (Barrios et al., 2008). Also, multinationals locate foreign affiliates in more than one country and they optimize the tax on a global base. The country level information technology infrastructure was also found to be an insignificant location determinant over and above other control variables. We find evidence of a geographical structure in firm's location choice across the European Union.

The determinants of the location choice of R&D foreign affiliates vary depending on the country of origin of the foreign investor. Thus, agglomeration externalities and business R&D intensity had a higher positive effect on the propensity to locate in an EU region in the case of multinationals from North America in comparison to European based multinationals. The presence of a ranked university had a significant effect on the location choice for North American R&D multinationals but no significant effect in the case of European R&D multinationals.

Our research results suggest a number of policy implications. First, policy aiming to increase the R&D intensity of regions are likely to foster the attractiveness of regions to R&D foreign investment. Second, positive externalities from clustering of R&D foreign affiliates outweigh competition effects. Third, given the heterogeneous behaviour of foreign investors, differentiated policy depending on target partner countries can increase the success of such policies.

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Appendix A: Data and Descriptive Statistics

Table A1: Variables and data sources

Variables	Description	Source
Market potential	Log of the real GDP in region j plus real GDP of adjacent regions weighted by their respective distances to region j, averages over 1995-2002.	Eurostat
GDP per Capita	Log of real GDP per capita in region j, average over 1995-2002.	Eurostat
R&D Agglomeration	The total number of foreign R&D firms located in each region plus a distance weighted measure of the firms in all other regions up to 2002.	AMADEUS
Unemployment Rate	Rate of unemployment, average over 1995-2002	Eurostat Cambridge Econometrics
Top University	Dummy variable for the presence of a world top 500 ranked university in each region. Equal to 1 if a ranked university is present.	The QS World University Rankings
Business R&D Intensity	R&D expenditure in the business enterprise sector as a percentage of GDP in each region, average over 1995-2002.	Eurostat
Government R&D intensity	R&D expenditure in the government sector as a percentage of GDP in each region, average over 1995-2002.	Eurostat
Objective 1	Regions qualifying for objective 1 status, dummy variable. Equal to one if a region is eligible for funds.	Eurostat
Human Capital	Percentage of the regional economically active population which have attained tertiary education level (International Standard Classification of Education), average over 1998-2002.	Eurostat
Corporate Tax Rate	Top corporate tax rate, average 1995-2002.	World Tax Database, Michigan Business School.
Internet Users	Log of number of internet users in each country, average over 1995-2002.	World Development Indicators

Table A2: Correlations of explanatory variables

	Market Potential	GDP Per Capita	Agglomeration	Unemployment Rate	Corporate Tax Rate	Objective 1
Market Potential	1					
GDP Per Capita	0.837	1				
Agglomeration	0.263	0.145	1			
Unemployment Rate	-0.009	-0.170	-0.200	1		
Corporate Tax Rate	0.223	0.087	-0.144	0.194	1	
Objective 1	-0.414	-0.650	-0.194	0.410	0.033	1
Human Capital	0.231	0.411	0.325	-0.129	-0.251	-0.395
Business R&D Intensity	0.446	0.388	0.208	-0.314	-0.196	-0.425
Government R&D Intensity	0.166	0.115	0.109	-0.016	-0.024	-0.141
Internet Users	0.600	0.628	0.224	-0.059	0.038	-0.606
Top University	0.534	0.380	0.259	-0.229	-0.052	-0.314
	Human Capital	Business R&D Intensity	Government R&D Intensity	Internet Users	Top University	
Human Capital	1					
R&D Business Intensity	0.387	1				
R&D Government Intensity	0.245	0.247	1			
Internet Users	0.190	0.328	0.164	1		
Top University	0.268	0.320	0.223	0.323	1	

Table A3: The location of new R&D foreign affiliates, 1999-2006

Country	Country share in total R&D foreign firms (%)	NUTS 2 Region With the highest number of R&D foreign firms	Ranking of countries after the number of firms per GDP
United Kingdom	35.9	Inner London	Romania
Germany	35.9	Oberbayern	Estonia
Austria	4.9	Berkshire et al.	Ireland
France	4.3	East Anglia	United Kingdom
Romania	4.0	Bucuresti - Ilfov	Austria
Ireland	2.7	Darmstadt	Bulgaria
Sweden	2.5	Dusseldorf	Germany
Italy	2.0	Koln	Denmark
Denmark	1.8	Freiburg	Sweden
Holland	1.8	Hamburg	Poland
Spain	1.6	Ile de France	The Netherlands
Poland	1.3	Outer London	Czech Republic
Finland	0.4	Karlsruhe	Finland
Estonia	0.2	Southern and Eastern	France
Bulgaria	0.2	Wien	Spain
Belgium	0.2	Berlin	Italy
Czech Republic	0.2	Hovedstadsreg	Belgium

Columns one and two give the rank of countries by the percentage of firms located. Columns three and four give the rank of individual regions for location choice and column five shows the rank per GDP of the chosen countries.

Table A4: Origin of new R&D foreign affiliates

Origin of Firms by Area	% of total number of firms	% of total number of firms from EU 15 + Switzerland & Norway (top seven countries of origin)	
EU 15 + Switzerland & Norway	50.9	Switzerland	19.0
North America	33.1	Germany	16.3
Asia & Australia	8.1	France	11.0
Rest of Europe	3.4	United Kingdom	8.4
South & Central America	1.6	Netherlands	7.5
Middle East	1.6	Ireland	7.5
Africa	1.3	Belgium	4.8

Table A5: Origin of new R&D foreign affiliates located in United Kingdom and Germany

R&D foreign affiliates in UK	% of the number of firms	R&D foreign affiliates in Germany	% of Firms
North America	46.3	EU 15 + Switzerland & Norway	55.6
EU 15 + Switzerland & Norway	36.3	North America	25.0
Asia & Australia	11.9	Asia & Australia	10.6
Rest of Europe	1.9	Rest of Europe	5.6
South & Central America	1.9	Middle East	1.9
Middle East	1.3	Africa	0.6
Africa	0.6	South & Central America	0.6

Table 1: Summary statistics

Full Sample					
Variable	Observations	Mean	Std. Dev.	Min	Max
Market Potential	271	9.5	1.7	4.5	12.8
GDP per Capita	254	9.3	1.3	4.5	10.9
Agglomeration	261	13.3	33.5	0.008	371
Human Capital	252	21.7	8.5	5.9	46.6
Government R&D Intensity	234	0.8	0.9	0	4.2
Business R&D Intensity	235	0.2	0.3	0	1.9
Unemployment Rate	256	9.2	5.2	2.3	28
Internet Users	265	15.1	1.2	11.2	16.5
Corporate Tax Rate	279	32.6	4.6	15.0	39
Objective 1	279	0.4	0.5	0	1
Top University	265	0.5	0.5	0	1
EU 15 Countries					
Market Potential	207	10.1	1.1	6.6	12.8
GDP per Capita	202	9.8	0.4	8.9	10.9
Agglomeration	199	15.2	36.6	0.008	371.1
Unemployment Rate	203	23.0	7.9	5.9	46.2
Government R&D Intensity	191	0.9	0.9	0	4.2
Business R&D Intensity	189	0.2	0.3	0	1.9
Unemployment Rate	203	9.1	5.1	2.3	28.2
Internet Users	211	15.4	1.0	11.2	16.5
Corporate Tax Rate	211	33.6	2.6	28	39
Objective 1	211	0.2	0.4	0	1
Top University	211	0.6	0.5	0	1
EU 10 Countries					
Market Potential	64	7.5	1.7	4.5	1.0
GDP per Capita	52	7.2	1.4	4.5	9.0
Agglomeration	46	6.0	17.2	0.016	114
Human Capital	55	17.1	8.9	7.7	36.2
Government R&D intensity	43	0.3	0.4	0.0	2.7
Business R&D intensity	46	0.2	0.2	0	0.91
Unemployment Rate	53	12.7	5.3	3.4	25.2
Internet Users	54	13.6	0.9	11.8	14.8
Corporate Tax Rate	68	29.5	7.3	18	36.8
Objective 1	68	0.8	0.4	0	1
Top University	54	0.2	0.4	0	1

Table 2: Determinants of the location choice of R&D foreign affiliates: Conditional logit models: All regions, all firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market Potential	0.861***	0.885***	0.868***	0.851***	0.698***	0.673***	0.662***	0.536**
	(0.181)	(0.189)	(0.193)	(0.186)	(0.199)	(0.195)	(0.201)	(0.231)
GDP Per Capita	-0.545	-0.501	-0.652	-0.739	-0.742	-0.678	-0.779	-0.728
	(0.756)	(0.889)	(0.917)	(0.867)	(0.587)	(0.637)	(0.631)	(0.608)
Agglomeration	0.107*	0.094	0.107	0.080	0.107**	0.121**	0.107**	0.107**
	(0.005)	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Unemployment	-0.807	-0.734	-0.596	-0.669	-0.348	-0.431	-0.504	-0.348
	(0.080)	(0.089)	(0.081)	(0.081)	(0.072)	(0.059)	(0.050)	(0.043)
Corporate Tax Rate		-0.061	-0.069	-0.055	-0.003	-0.017	-0.018	-0.017
		(0.077)	(0.071)	(0.070)	(0.062)	(0.064)	(0.070)	(0.067)
Objective 1			-0.540	-0.500	-0.418	-0.357	-0.067	-0.183
			(0.502)	(0.399)	(0.323)	(0.310)	(0.569)	(0.564)
Human Capital				0.584	0.514	0.350	0.490	0.397
				(0.020)	(0.022)	(0.023)	(0.025)	(0.023)
Business R&D Intensity					0.302***	0.243***	0.216***	0.221***
					(0.107)	(0.095)	(0.099)	(0.100)
Government R&D Intensity						0.165**	0.157***	0.123**
						(0.359)	(0.296)	(0.311)
Internet Users							0.276	0.258
							(0.646)	(0.624)
Top University								0.815**
								(0.348)
Observations	100488	100488	100488	100383	92955	91469	91469	91469
Pseudo R-squared	0.151	0.153	0.155	0.157	0.161	0.165	0.167	0.172

Notes: Clustered standard errors in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures given are average probability elasticities. Market potential, GDP per capita and internet users are in logs. University and objective 1 are dummy variables. Unemployment, tax, education and R&D intensity are in percentage form and are evaluated at their mean value. Agglomeration is evaluated at its mean value.

Table 3: Determinants of the location choice of R&D foreign affiliates: Conditional logit models: North American versus European firms

	All Firms	North American Firms	European Firms
Market Potential	0.536**	0.513*	0.602**
	(0.231)	(0.295)	(0.282)
GDP per Capita	-0.728	-0.619	-0.708
	(0.608)	(0.401)	(0.704)
Agglomeration	0.107**	0.134*	0.080
	(0.004)	(0.004)	(0.005)
Unemployment Rate	-0.365	-0.739	-0.681**
	(0.043)	(0.031)	(0.028)
Corporate Tax Rate	-0.526	-1.484	0.866
	(0.067)	(0.060)	(0.066)
Objective 1	-0.183	-0.402	0.060
	(0.564)	(0.826)	(0.647)
Human Capital	0.216	0.127	0.433
	(0.023)	(0.034)	(0.025)
Business R&D Intensity	0.212***	0.192***	0.156
	(0.100)	(0.076)	(0.123)
Government R&D Intensity	0.127**	0.098	0.155**
	(0.311)	(0.525)	(0.270)
Internet Users	0.258	0.170	0.253
	(0.624)	(0.660)	(0.612)
Top University	0.815**	0.977***	0.465
	(0.348)	(0.322)	(0.402)
Observations	91469	29808	50760
Pseudo R-squared	0.172	0.232	0.136

Notes: Clustered standard errors in parentheses, *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures given are average probability elasticities. Market potential, GDP per capita and internet users are in logs. University and objective 1 are dummy variables. Unemployment, tax, education and R&D intensity are in percentage form and are evaluated at their mean value. Agglomeration is evaluated at its mean value.

Table 4: Determinants of the location choice of R&D foreign affiliates: Nested logit models

	All Firms	North American Firms	European Firms
Market Potential	0.889**	0.829	0.932
	(0.200)	(0.228)	(0.268)
GDP per Capita	-1.137	-0.882	-1.176
	(0.329)	(0.295)	(0.418)
Agglomeration	0.178**	0.238**	0.117**
	(0.002)	(0.003)	(0.002)
Unemployment Rate	-0.533	-0.540	-1.091
	(0.017)	(0.026)	(0.035)
Corporate Tax Rate	0.549	-0.275	1.487
	(0.021)	(0.014)	(0.023)
Objective 1	0.232	-0.041	0.556
	(0.219)	(0.252)	(0.307)
Human Capital	0.198	0.113	0.473
	(0.012)	(0.012)	(0.014)
Business R&D Intensity	0.267**	0.440***	0.207*
	(0.061)	(0.048)	(0.070)
Government R&D Intensity	0.106	0.094	0.139
	(0.236)	(0.266)	(0.279)
Internet Users	0.237	0.124	0.294
	(0.370)	(0.358)	(0.333)
University	0.750	1.280**	0.292
	(0.299)	(0.217)	(0.303)
IV Parameters			
South	0.171*	0.107*	0.190
UK&Ireland	0.633***	0.700**	0.518**
Central&North	0.689**	0.584**	0.689**
East	0.241*	0.240*	0.222
Observations	91469	29808	48816
Cases	422	138	226

Notes: Clustered standard errors in parentheses. *** Significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures shown are average probability elasticities. Market potential, GDP per capita and internet users are in logs. University and objective 1 are dummy variables. Unemployment, tax, education and R&D intensity are in percentage form and are evaluated at their mean value. Agglomeration is evaluated at its mean value.