LOCATION PATTERNS AND DETERMINANTS OF MNT KNOWLEDGE INTENSIVE ACTIVITIES IN OECD COUNTRIES: AN EMPIRICAL STUDY BASED ON AN INTERNATIONAL COMMERCIAL DATABASE

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Table of contents

SUMMARY

The purpose of this piece of work is to address a specific problem, the extent to which a commercial firm level database can be used to examine spatial patterns and location determinants of firms. Specifically, we examine the location of high technology manufacturing and service foreign affiliates, within a set of OECD member countries. This report is by Professor Nigel Driffield[1] and Stefano Menghinello[2]

This therefore seeks to build on previous reports and research papers presented at OECD previous meetings on the Globalisation of the industry, including Sachwald (2007), Mataloni (2007), Hatem and Py (2008) and Py and Hatem (2008). Our intention therefore is to extend the existing work, by offering a different perspective, possible through the use of a large scale commercial database, and to adopt a different modelling strategy from that applied hitherto. Much of the literature discussed below employs a form of the conditional logit model or nested logit model. We however adopt a multilevel count-data model to the problem of modelling location, and subsequently highlight some of the inferences that may be drawn from this.

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INTRODUCTION

1. The expansion and productivity growth of innovation related activities is considered by the majority of policy makers in OECD countries as the most appropriate and effective way to enhance an enduring and robust economic growth in advanced countries, after a long period of economic downturn and financial turmoil. Multinational enterprises play a crucial role in this respect as a channel for the transmission of technological knowledge and managerial capabilities, also stimulating the growth of knowledge intensive industries and the development of a skilled workforce.

2. This study aims to expand the empirical evidence currently available on the spatial patterns and determinants of MNE location in advanced countries, with a specific focus on knowledge-intensive MNE activities. Given the relevance of the general information framework on MNEs activities provided by official statistics, these data present significant confidentiality and data quality constraints for the analysis of MNE location at the sub-national level. This is in conflict the current state of the art of the theoretical literature on MNE, which emphases the role of local and sub-regional factors, universities, science parks and high tech business clusters for instance, as key drivers of the MNE location choice, especially with respect to knowledge-related activities.

3. In order to overcome the limits of the current empirical literature on MNE location, this study exploits a unique firm level commercial database with an extensive international coverage, the *ORBIS* database produced by Bureau Van Dijk and recently licensed to the OECD. This database encompasses, among other business data, relevant and very detail information on MNE location based on the foreign affiliate postal code. The use of firm level information permits to build virtually any types of territorial classification and breakdown. Nevertheless, it presents some significant drawbacks in terms of data quality and consistency. These limits, which include problems of coverage, potential structural breakdown or selection effects, and misleading information on plants location based on the company legal location, have to be carefully assessed in order to consistently exploit MNE location analysis. By any large, all sources of bias in the commercial database affect the consistency and quality of basic statistics calculated from them, while only the sources of bias correlated to the model error are likely to produce bias in econometric results. In this respect, the spatial distribution of firms within a country drawn from the commercial database can be consistent with the real distribution of firms, under the relatively mild conditions that the sources of bias of the dataset are significant only at the national level. This means in practice that biases in the national level data, such as under coverage, structural breakdown etc, affect each sub-national location with a similar intensity.

4. While the exploratory analyses of the location patterns of MNE knowledge-intensive activity at the sub national level, based on spatial statistics indicators such as *LISA*, exclusively requires data on the geographical distribution of foreign affiliates, the analysis of location determinants induces to combine information on foreign affiliates location and the determinants of location. These data are usually available at different levels of territorial breakdowns, so a multi level modelling approach is required to take advantage of all relevant information. The adoption of a multi-level approach is particularly suitable in the case of the analysis of the determinants of knowledge-intensive MNE location, where local level factors, such as research centres, high tech business clusters act as catalysts of knowledge sourcing FDI. Within a multi-level modelling approach, factors affecting MNE location at different levels of territorial breakdown can also be tested as interaction effects. As a result, national advantages, such as a first class material and

immaterial infrastructure endowment, can be associated to the potential presence of regional innovation systems or high tech business clusters.

5. This report is organised as follows. Chapter one draws on two literatures, the location literature in general, taking work from economics, international business and regional science. This highlights the important factors in explaining firm location, and location of high tech sectors in particular, and serves to inform the model. Chapter two introduces the data, and discusses some of the linking between the main *ORBIS* database, and various local and national level databases. Chapter three introduces the model, and discusses briefly some econometric considerations that derive from the modelling strategy. Chapter four discusses the results from our estimation, followed by the conclusions.

CHAPTER 1. LOCATION THEORY AND THE THEORY OF THE FIRM

1.1 Theoretical treatments of firm location

6. Much of the modern theory of the location of industry can be traced to Moses (1958) work that deals with the theory of the firm in a spatial setting. As has been noted in many works since, Moses' work is notable for its attempts to link analysis of location with the theory of the firm. The essential contribution of this work was to bring the location decision of the firm within the remit of neoclassical economics. This is the basis for many theoretical treatments of firm location that have been employed since. Hirsch (1976) for example extends these types of arguments to "international direct investment", showing how theories developed from international trade and industrial organization can be applied to the multinational firm, and in turn to explaining the location decisions. This however largely focuses on the export / FDI decision, developing a set of general principles from the theory of the firm, that can be applied to FDI. While this does not consider the importance of location beyond cost differences between two countries, this argument has been significantly developed by the now substantial literature that bases analysis of FDI on either industrial organisation, or the new economic geography literature. Much of this literature applied to the multinational firm is developed from "the so called new trade theory" as Markusen (1995) describes it. The important development of the formal theory in this area has been to offer a more formal treatment of the interactions between Dunnings (1979) ownership advantages and location advantages. The early literature (Helpman, 1984 or Markusen, 1984) crucially allowed ceratin activities to be differentiated spatially, such that R&D did not have to co-locate with production, or head offices could be remote from m ore basic manufacturing. This lead to models that allowed this spatial differentiation to be an endogenous part of the firms development, and at the same time generate inferences concerning the links between the location of certain activities and regional development in the host region. It is not the purpose of this report to provide a comprehensive review of this literature, but the links to the spatial economics literature of Krugman (1991) are clear.

7. The crucial issue, as Krugman most famously highlights is that models of location which focus on the regional dimension have to resolve two competing forces. On the one had, there exist centripetal forces that encourage agglomeration, and centrifugal forces, that limit their size. Applied work on firm location has struggled to resolve these issues. This is highlighted in Krugman and Venables (1996), who show that vertical linkages encourage agglomeration. As Krugman and Venables (1996) crucially point out, this finding highlights the links between industrial organisation theory and the new economic geography, that have informed much of the literature in the last ten years. Ottaviano and Puga (1997) provide a survey of this literature, highlighting the links between agglomeration, trade costs and location, which is discussed in more detail below.

1.2 Agglomeration and the location decision.

8. There have been numerous attempts to apply the fundamental analysis of Krugman and Venables (1996) or Markusen and Venables (1999). The existence of agglomeration effects are likely to be important in the context of industrial location decisions. For example, Wheeler and Mody (1992), draw the distinction between ergodic and non-ergodic systems, with the former systems returning to their initial state once existing conditions are replicated. In the context of industrial location this means that once policy interventions in the realm of location marketing cease, then industry will return to location patterns prior to intervention. Agglomeration economies resulting from growing numbers of related activities in a

given space are linked to the concept of a non-ergodic system. Consequently location advantages could be self perpetuating where further growth of an industry sector makes the location even more attractive (Head, Ries and Swenson, 1995, see also Krugman, 1991). Under such circumstances random location decisions in the past can result in the development of specialised support infrastructure and a concentration in a given industry (Wheeler and Mody, 1992).

9. Where technology spillovers and pecuniary externalities play a role in determining industry competitiveness, then agglomeration forces might increasingly influence the location decisions of multinational firms. Shaver (1998) shows that foreign firms, in the presence of agglomeration economies, could be motivated to locate in areas where industry is already concentrated, such that in the US case, agglomeration economies could lead to similar location patterns between US and foreign firms. However, there could also be agglomeration economies among foreign firms which do not locate amongst extant domestic capital. Some alleviation of the 'liability of foreigness' may occur as a result of knowledge spillovers between multinationals (see Shaver, Mitchell and Yeung, 1997). Wheeler and Mody (1992) examined the overseas decisions of US manufacturing in the 1980s. Using a capital expenditure function which incorporated proxies for agglomeration benefits, as well as variables describing risk and classical location factors linked to national endowments, they found that US investors had given considerable decision weight to agglomeration benefits.

10. The importance of agglomeration benefits in recent multinational firm location literature might suggest that spatial concentration of high technology facilities strengthens the relationship between R&D spending and productivity growth. A strong foreign presence in an industrial sector featuring high levels of spatial concentration could increase the likelihood of knowledge spillovers to the indigenous sector, which could improve the overall industry innovation. Improvements in industry comparative advantage may, however, also be a factor determining future inward investment levels. For example, Dunning (1993) demonstrates that foreign multinationals have tended to concentrate in sectors where industry comparative advantage is higher than the average (see also Milner and Pentecost, 1996). However, studies have not specifically explored the dynamic relationship between inward investment, agglomeration and improvements in industry comparative advantage, and the consequent role of industry comparative advantage as a foreign direct investment determinant. As suggested above, industry levels of foreign investment are likely to be determined in part by industry comparative advantage. At the same time, where industry comparative advantage is partially determined by the activities of encumbent foreign investors, then there are likely to be important ramifications for the efficient sectoral targeting of inward investment promotion resources.

11. Perhaps the best known treatments of the links between the new economic geography, agglomeration and the location of activity is the literature developed by Diego Puga and his various equally prolific coauthors. Typically, the focus of this work is the link between industrial agglomeration and economics development (Puga and Venables 1996). In this, they show how the growth of sectors initially stimulates agglomeration, but following Krugman's central issue about competing forces, show how firms begin to move away from this agglomeration, stimulating growth in other countries. Of crucial importance to the study of hi-tech firms, is that this centrifugal force works in their model though the labour market. In sectors with specific demands for highly skilled workers, one can easily see how this can quickly cause firms to move away for particularly high concentrations. This also links to the work of Woodward et al (2006) discussed below, that other amenities are required to attract such workers, and suggests why strong correlations are found between universities and high tech start-ups. In a similar vein, Puga and Venables (1995) link trading arrangements to industrial location. Here, they argue that trade blocs cause changes in the production structures of countries, highlighting the case of Mexico, but mirroring more recent work on high tech FDI being attracted to other transition economies (Meyer et al 2009). Puga and Venables (1995) argue that economic integration lessens motivations of governments to be self sufficient in certain activities, and tends to focus activities on certain core regions that are likely to

become more specialised. Puga (1998) and Puga and Venables (1998) subsequently examine the relationships between these competing forces economic development. Again the focus of the mechanism by which this occurs is the labour market. Migration intensifies agglomeration, as do trade costs. This highlights the role of wages, and regional wage disparities in determining optimal locations of firms, highlighting the fact that under such circumstances poorer regions are likely to continue to lag behind, and to find it ever harder to attract high productivity employment. and and Duranton and Puga (2005)

12. Building on the above discussion, the empirical literature seeking to explain variations in Inward FDI across countries has, at a macro level, focussed on the following factors:

1.3 The location of a MNE in advanced countries

13. The literature is consistent in terms of identifying the important likely determinants of FDI flows from source countries. Much of this literature is based on the dominant paradigm of international business (Dunning 1988). This essentially explains the decision of a firm to enter into a foreign market in terms of the ability of the firm to operate successfully in a foreign environment, the ability of the firm to manage its resources across national boundaries, and subsequently the attractiveness of a given location. In the context of the links between inward investment, location and agglomeration of activity, this paradigm is discussed in detail in Driffield and Munday (2000). The theory of multinational enterprises (MNEs) and the process of FDI is now well established. The process of FDI was formalised within Dunning's eclectic paradigm (see for example, Dunning, 1988, 1993). Within this framework the level and structure of a firms overseas activities depend on three conditions. First, the extent to which the firm is in possession of sustainable (tangible or intangible) ownership specific advantages with respect to foreign and domestic firms already operating in the market it wishes to serve. Second, the extent to which it is in the interest of the firm to exploit such advantages itself rather than to license production. Third, the extent to which such ownership advantages are best exploited by actually producing in a foreign market.

14. It is the possession of ownership advantages which characterise the core competencies of the multinational firm and distinguish it from its competitors, whereas the remaining elements of Dunning's paradigm are external to the organisation and may equally be applicable to other industry players. However, through time the multinational firm may develop new ownership advantages by virtue of its multinationality, for example, advantages derived from common governance. This could be important because, whilst the costs of operating abroad could fall through organisational learning, the multinational firms' original 'stock' of advantages may spillover or be appropriated by competing indigenous firms (Caves, 1996).

1.3.1 Source Country Market Size

15. Affluent countries with a large number of competitive multinational firms should be able to make larger investments in the international market. Larger economies imply greater availability of capital resources and intangible assets such as technical know-how and marketing expertise that can be used to establish foreign production to meet consumer demand in a target country. Thus, we might expect a positive relationship between host country size and FDI. Nevertheless, despite considerable support for this hypothesis the direction of this effect has not always been found to be positive in previous studies.

16. We would argue that the cause of this disparity in the previous empirical evidence may be related to the estimation problem associated with straightforward data pooling, which neglects country specific effects. In the absence of controls for such country specific effects, and given that variation in a given economy's size will be relatively small compared to the variation between economies, the market size variable may simply serve as a proxy for these uncontrolled effects, and will therefore give a biased estimate of the actual impact of market size on FDI flows. Indeed, our below results suggest that this has

been a source of much of the confusion in the literature with regard to the impact of market size on FDI flows, see for example, Stone and Jeon (1999), Grosse and Trevino (1996), Tallman (1988), Kyrkilis and Pantelidis (2003) or Thomas and Grosse (2001). In our study, the focus is the region, suggesting that regional GDP, and GDP per head are the appropriate metrics here.

1.3.2 Labour force availability Labour Costs

17. Studies of location have often focussed on the labour market conditions in the host and home country as a determinant for firms to relocate. Often studies have focussed on wage differentials between the source and host counties combined with the international immobility of labour is often considered to be another major determinant of FDI. The conventional response is that a rise in host country wages relative to those in the source country is an impediment to FDI inflow, particularly for MNEs that engage in labour-intensive production. Nevertheless, higher wages do not necessarily deter FDI into all industries because higher wages may well reflect higher productivity, notably in high tech industries in which the quality of labour is particularly important. Thus, there is often ambiguous empirical evidence with regard to the labour cost effect on FDI even after allowing for differences in labour productivity and labour skill. European MNEs within Europe are attracted by agglomeration, R&D and high quality workers, while non-European MNEs tend to be attracted to low cost locations in the periphery of Europe. In a similar vein, Basile (2009) highlight than many firms in Europe are less willing to enter regions contiguous to other countries. Reasons for this are not discussed in detail in the paper, though it is widely accepted that forces for agglomeration tend to be lower in border regions. In the context of our study, this highlights the importance of regional characteristics in explaining location. These however are typically time invariant.

18. By contrast, in an analysis of the locational determinants of FDI, Culem (1988) suggests that higher unit labour costs are an impediment to inward bilateral FDI flows among industrialised countries. The results for intra-European FDI, on the other hand, are found to be more subtle: MNEs do seem to be attracted by the lower labour cost of destination countries, but once a location decision is made they are attracted by higher labour costs. Hatzius (2000) examines the effect of unit labour cost differentials on British and German bilateral FDI flows to and from OECD partner countries and shows that higher unit labour costs stimulate FDI outflows. This study concludes that British multinationals seem to be attracted to locations with lowest cost production worldwide, whereas German counterparts seem to do so only within Europe. In a study of Japanese outward FDI for the whole economy and for the manufacturing sector in the US and EC panel members, Barrell and Pain (1999a) demonstrate that higher labour costs in target countries have a noticeable negative impact on FDI. Taylor (2000) also supports this view by providing evidence that the wage rates of 39 host countries are negatively associated with the change in the assets of US owned affiliates. Likewise, further evidence is presented in the case of industrialised economies such as US manufacturing FDI in Europe (Barrell and Pain, 1998; Barrell and Pain, 1999b), and German outward FDI in both manufacturing and service sector in EU countries and the US (Pain and Lansbury, 1997). However, it has also been showed that in a regional setting, earnings, or earnings differentials become endogenous when seeking to examine the links between FDI and wages, see for example Driffield and Girma (2001). Rather than using labour costs or differentials, much of the literature then uses labour force based measures, such as unemployment (as an indicator of labour availability) and human capital based on education.

1.3.3 Source Country Risk

19. Empirical studies that examine the impact of source country risk on FDI are extremely limited and lack solid empirical evidence. The extent to which political factors affect the FDI decisions of MNEs depends largely on the managerial perceptions toward risk and the nature of political conditions in the source and host countries. A positive overall investment climate in the host country has a direct effect on its ability to attract FDI. In a study of major industrialised source countries between 1974 and 1980,

Tallman (1988) demonstrates that domestic conflicts in the investing country, which produce a poorer business climate and a higher risk stimulate FDI inflow to relatively stable countries like United States. However, in the context of the OECD countries concerned here, political instability of the form observed in developing countries is unlikely, though crime at the regional level may impact on the location decision.

1.4 Firm level analysis of the location of high tech activities

20. There is a well established literature in international business / technology management that has recognised that many of the worlds largest firms carry out R&D outside of their home country. This typically is linked to ideas surrounding agglomeration of technological effort, or on the use of FDI in technology sourcing, such as the use of offshore facilities as "listening posts" (Almeida, 1996; Pearce, 1999; Cantwell and Janne, 1999). Pearce (1999) for example illustrates the roles played by R&D labs within the modern firm, and particularly highlights the strategic decisions behind the location of such labs. Pearce (1999) highlights the increased emphasis that such firms place on product development. This, Pearce sees as a response to a growing number of countries with core competitive competences, and the desire of firms to tap into these. This however, is not, as is suggested in the technology sourcing literature, merely about appropriating spillovers, but is something much deeper, concerning the specialisation within the firm across national boundaries. A similar point is made by Patel and Vega (1999), building on Patel and Pavitt (1991). This literature shows that the technological activities undertaken by a firm outside its national boundaries are become ever more embedded in national and regional innovation systems, and influenced by the conditions in the host countries. Patel and Vega (1999) highlight the use of strategic alliances in R&D, notably in pharmaceuticals, computer and telecom. Equally, most firms that do engage in R&D abroad do so in sectors where they are strong at home. However, it is also fair to say, as Patel and Vega (1999) note, the forces for this are not fully understood. Le bas and Siers (2002) provide a good illustration of how the literature examining both the host and home country effects determine location. Building on Kuemmerle(1999a,b) develop the taxonomy of technology seeking FDI in R&D, home base-exploiting FDI in R&D, home-base augmenting FDI in R&D and market seeking FDI in R&D. Driffield et al (2010) extend this analysis with respect to technology flows between parent and subsidiary, and between subsidiary and host country firms. Driffield et al (2010) report clear evidence of very substantial knowledge flows between MNE parent companies and their foreign affiliates. Although knowledge flows from parent to affiliates are common, there is also evidence of extensive flows in the reverse direction, often as part of a two-way transfer. Further affiliates' R&D and capital asset intensity (both tangible and intangible) are important in generating 'reverse' knowledge flows from affiliates to parents, but play no role in distinguishing between different patterns of spillover behaviour to the domestic economy. Finally, while intra-firm knowledge transfer patterns are determined largely by affiliates' investment in R&D, capital intensity and export intensity, the principal determinant of the nature and likelihood of spillovers is country of ownership. This is consistent with the role of the hierarchy in general, and MNEs in particular, as a superior vehicle of knowledge transfer and diffusion with respect to arms' length market forces under uncertainty and other market failures conditions. In addition, the fact that we find substantial evidence of the transfer of managerial competencies, while much or the FDI literature focuses exclusively on technology transfer and spillovers, is consistent with the standard theoretical of the superior ownership advantage held by MNEs. The analysis of Menghinello et al (2010). More generally, provides evidence of the the multi-directional and multi-faceted nature of knowledge flows between parent companies and foreign affiliates. There is a great deal of complexity and heterogeneity in MNE knowledge transfer behaviour. Such an extended theory would also help in understanding the existence of cumulative processes spurred by virtuous circles of knowledge creation and transfers between the parent company, the foreign affiliate and domestic companies.

21. In a wide ranging piece for OECD secretariat, Belderbos and Sleuwaegen (2007) examines the location of Japanese R&D, at the country level. Belderbos and Sleuwaegen (2007) highlights the extent to which technological development is now internationalised, and as such R&D in a given location is as likely

to feed into global production and technology networks, as it is into the location of the investment. Belderbos and Sleuwaegen (2007) also highlight the relationship between location and efficiency, even in R&D. This encourages multinationals to offshore R&D activities, and place greater responsibility on such subsidiaries to contribute to technological development at the firm level. This is increasing the scope for new clusters to be formed, though as is discussed elsewhere in this paper, weak IPR protection outside of the richest economies is limiting the spread of this beyond the West.

22. Much of this literature, and the ideas that it encompasses is discussed in detail in an OECD working paper (OECD secretariat 2007). This highlights the crucial links between innovation and multinationality, and indeed location more specifically. An important issue for this report is that they specifically highlight the high tech sectors where these issues are paramount, and illustrate the geographic dispersion of these sectors across the major countries. Analysis of the FATS database highlights that in Europe over half of the total turnover is under foreign control (this being due to high levels of intra-EU cross border activity, but that even for the US nearly one third of turnover is under foreign control). These figures are very similar for R&D activity, suggesting that R&D activity in these sectors is just as dispersed as production. In general foreign R&D in the US exceeds R&D production in these sectors, which others have taken to be a sign of technology sourcing by MNEs in the US (Griffith et al (2006). Overall, the OECD (2007) report establishes a tentative ordering in terms of location of R&D and high tech activity, with Japan and the US most attractive locations, and Germany being the most attractive location for R&D in Europe. The UK then seems to attract most knowledge intensive services, building on its strong domestic base. However, as the report also points out, the data available to the authors is insufficient to go further.

23. It is important however when seeking to model loxcation decisions in these sectors, to link location to the motivations of the firms to locate outside their home country. Building on this literature, an idea that has gained a good deal of support is the concept that global firms establish a set of worldwide ‘listening posts’ designed to source and access best-practice technology wherever in the world it may be located (Gassman and Von Zedtwitz , 1999). Building on this, Von Zedtwitz and Gassman, (2002) examine what they refer to as “intercontinental R&D”. They point out that often, R&D dispersion occurs as a result of non-R&D related mergers. Again however, Von Zedtwitz and Gassman, (2002) highlight the competing forces that determine the location of of high technology activity. Again, the focus on the “pull” factors in terms of the attractiveness of the foreign location, but also highlight the “push” factors, in terms of IT facilitating international coordination of activity.

24. The above discussion links to a wider literature that seeks to explain the location of particular types of economic activity, and the location of R&D is no exception. In general, these studies take two particular forms. The first relates to the ability of certain regions or locations within a country to attract high technology activities, while the second focuses on the level of the firm, and seeks to explain how a firm determines the locations of its various activities.

25. The fist of these addresses the issue from both an empirical and theoretical perspective, though we focus here on the empirical literature. The issue is also addressed in a range of empirical literatures, including international business, regional science, and international and industrial economics. It is also discussed in a related labour economics literature that focuses on the labour demand effects of firms locating, and re-locating activities both within and between countries. However, much of this literature has one key feature in common, it seeks to focus on the characteristics of the location in terms of its ability to foster, attract and retain innovative capacity. One particular focus of research is the links between the indigenous and foreign innovative capacity for R&D, see for example Agrawal and Cockburn (2003). This literature essentially highlights the importance of locally based innovative activity , and the links between local innovation systems and the location of internationally mobile investments. This literature focuses on the importance of spillovers between different forms of innovation and R&D, but treats this as endogenous

to the process of location choice, in a way that much of the literature on FDI more generally ignores. Woodward et al (2006) for example highlight that the potential relationship between university and private sector R&D impacts on the location decisions of firms. However, in general Woodward et al (2006) argue that the existence of local (university) R&D locally may well generate spillovers into the local private sector, and can be illustrated through patent behaviour, but that it has little impact on plant births. As Woodward et al (2006) point out however, university presence is merely part of the urban framework of innovative activity and innovation system that generates a regions compartative or competitive advantage. In a different seeting, theoretical work by for example Markusen and Venables (1996) highlights how Inward FDI can play a part in stimulating this, linked to the wider spillovers literature. This however is just part of a wider literature on the importance of location in the distribution of high tech activities. Carrincazeaux et al (2001) for example discuss proximity in explaining location of R&D more generally. This highlights the spillover effects of R&D, with localisation of R&D activities. In particular, Carrincazeaux et al (2001) highlight the tendency of R&D activities to cluster together, but that inter-industry effects are limited to certain sectors. Finally, in common with the earlier literature, Carrincazeaux et al (2001) demonstrate the extent to which the agglomeration of R&D is influenced by the agglomeration of other production activities.

26. A wider literature concerned with the location of R&D activities internationally is discussed by Verspagen and Schoenmakers (2004), who summarise a lot of the earlier spatial literature. Firstly, this highlights the argument that knowledge of this type cannot be accessed from a distance, and thus asset seeking FDI encourages firms to undertake R&D in foreign countries, but in well established clusters of innovative activity. Therefore, Verspagen and Schoenmakers (2004) argue, the choice of a (foreign) location of a firms R&D will be determined by two factors. The first is the nature of the region's knowledge base, the importance of which is discussed widely in the literature, and indeed measured by a variety of proxies, including patent citations, R&D spend, agglomeration of activity etc. The second one however is less commented upon, which concerns the ability of the new entrant to tap into this knowledge base. This is more problematic in terms of measurement, though absorptive capacity, in terms of R&D spend, human capital, or even productivity have been used. This highlights an important issue, which has become more popular in recent years, which is that of knowledge seeking, as opposed to knowledge exploitation, as a motive for FDI in general, and FDI in high technology sectors in particular. This distinction, and its importance in the context of technology spillovers is discussed in detail in Driffield and Love (2007), but to summarise: The classic 'ownership' advantage involves some form of technological superiority; thus where a company has some competitive advantage over its rivals, and where for reasons of property rights protection licensing is unsafe, a company will set up production facilities in a foreign country through FDI, as long as there are specific advantages in the host country which make FDI preferable to exporting. This traditional analysis of why a firm seeks to undertake FDI is articulated by Buckley and Casson (1976) and Dunning (1979, 1988, 1993). The necessary condition within this framework for a firm to undertake FDI is that it owns an asset that provides some essential advantage for the inward investor over host country firms. More recent literature, based on Cantwell (1989, 1991) or Pearce (1999) has characterised such advantages being generated through R&D, and linked to the exploitation of economies of scale. Indeed, recent applied work in this area attempting to characterise ownership advantages in a given location suggests that new technology and quality of the capital stock are key variables (see, for example, Oulton 2001, Griffith 1999, Griffith et al (2004) and Criscuolo and Martin 2004). Kuemmerle (1999) characterises this form of international expansion as 'home-base exploiting' FDI.

1.5 The importance of local infrastructure.

1.5.1 The importance of local R&D

27. There is a growing literature that seeks to link agglomeration economies, and firm location more generally, to wider measures of agglomeration. Most popular of these currently seeks to link business R&D location to university research. This builds on the work of Abramowsky et al (2007) that seeks, for the UK, to link business R&D location to the UK higher education funding councils ranking of science departments. They show that foreign owned R&D facilities are strongly correlated with top performing university science departments. These results are strongest in chemicals and pharmaceuticals, and are also linked to the location of science parks.

28. In a similar vein, De Silva and McComb (2009) perform a similar analysis, but for a much more focussed region, examining relationships between firm start ups and survival, and university activity in Texas. They show that both size and proximity of university research facilities explain the likelihood of start-ups at the local level (by county). Interestingly, their findings also illustrate the importance of non-research activitivities of universities, embodied in the locations metropolitan characteristics of the region. As De Silva and McComb (2009) point out therefore, while their findings are consistent with the spillovers of technology between universities and business, they are also consistent with graduates of universities forming a crucial skills base in the attraction of new firms, and also a potential source of entrepreneurial talent. This is consistent with the earlier findings of Woodward et al (2006), who highlight the importance of cultural and natural amenities in attracting firms, being central to for example skilled workforce retention.

1.5.2 The importance of infrastructure spending in attracting FDI

29. Perhaps the best known papers linking infrastructure to FDI, and in turn to regional development are Coughlin et al (1991), Coughlin and Segev (2000) and Fredriksson et al (2003). All of these find a positive link between infrastructure and the ability of a region to attract FDI. The most useful for current purposes is perhaps Coughlin et al (1991), which uses three measures of transport infrastructure, highways, railways and airports (all per square mile) to explain FDI location across US states. All these measures are found to impact positively on FDI, although Coughlin et al (1991) only report the "raw" coefficients rather than the marginal effects or increased probabilities that may result from increased infrastructure3. Similarly, Friedman et al (1992) report that access to a port significantly increases the probability of a US state being able to attract FDI.

30. In a UK context, Hill and Munday (1992) show the importance of road spending. This influences not only the number of FDI projects that enter a UK region, but also the level of employment in those projects.

1.6 Technology Sourcing and location

31. Thus far the focus of the analysis has been on the *technology exploiting* motivation, the desire of firms to exploit their existing technological capacity in a foreign couintry. However, recent theoretical work has given renewed impetus to something long recognised in the literature, that a possible motive for FDI is not to exploit proprietary technology, but to access it: thus *technology sourcing* may be the motive for FDI. Fosfuri and Motta (1999) question the need for firm-specific advantages to give rise to

[3] When undertaking any of the limited dependent variable models such as probit or logit it is usual to report "marginal effects", that is how the dependent variable would respond to an x% increase in one of the explanatory factors.

multinational activity, and provide a formal model of FDI in which the motivation is not to exploit existing technological advantages in a foreign country, but to access such technology and transfer it from the host economy to the investing multinational corporation via spillover effects. This possibility has had some policy influence in the United States and Europe, with concerns that the technological base of these economies may be at risk through the technology sourcing activities of Japanese and US corporations respectively (Kogut and Chang 1991; Neven and Siotis 1996)[4]. The literature on the internationalization of R&D suggests that there is a growing willingness to locate such facilities close to leading centres of research and innovation specifically with a view to absorbing learning spillovers from geographical proximity to such sites (Pearce, 1999; Niosi, 1999). For example, an analysis of foreign R&D direct investment in the United States by Serapio and Dalton (1999) concludes that the nature of such investment is changing, with more emphasis on gaining direct access to American technology and expertise, especially in biotechnology and electronics. Shan and Song (1997) provide supportive evidence in relation to US biotechnology, while Pearce (1999) comes to broadly similar conclusions from a survey of multinational corporations' production and laboratory facilities in the UK.

32. Note, therefore, that technology sourcing need not necessarily imply technological weakness in any absolute sense, simply the recognition that knowledge can be acquired by targeting it in locations which are at least as technologically strong as the investor. This is what Kuemmerle (1999) characterises as 'home-base augmenting' FDI; a similar idea is evident in the 'strategic asset-seeking' behaviour identified by Dunning and Narula (1995) and in the 'diversity sourcing' motive postulated by Cantwell and Janne (1999) and Chung and Yeaple (2004). The present analysis is consistent with these interpretations; we regard any FDI by a foreign investor as technology sourcing if it involves investment in a host sector which is more R&D intensive than the source sector, regardless of the absolute levels of R&D intensity in each.

33. The focus on technology in explaining flows of FDI, however, ignores the second pillar of Dunning's (1979) analysis of FDI, *location advantage.* We therefore extend the analysis of the technology exploitation/sourcing motivation by allowing for the key element of locational influence. The analysis here concerns the benefit conferred on the organisation by its decision to operate in a particular host location. This is generally related to country specific phenomena, or, within the international economics literature, the factor endowments of a particular country or region. As is pointed out in a wide ranging report by Midelfart-Knarvik et al (2002), the links between the location of (foreign owned) R&D is increasingly responsive to countries / regions endowments of innovatory capacity, in the form of researchers, capital investment and R&D stocks. Midelfart-Knarvik et al (2002) highlight the increasing tendency for innovation to be attracted to such locations. Equally, sectors with strong buyer / supplier linkages are also become concentrated in core regions, to the detriment of development in the periphery.

34. This highlights the importance of the unit of analysis in these studies. Much of the technology sourcing literature for example focuses on the firm, but then seeks to infer technology sourcing rather indirectly, either by employing measures of agglomeration, or inferring technology sourcing from apparent productivity growth. As Driffield et al (2010) argue, this is rather limited in outlook, and rather should focus on the interactions between inward investors and their host locality, and also the nature of the knowledge and technology flows more explicitly. In this context, we seek to capture the attractiveness of a region in terms of its stock of knowledge, using both public sector and private sector R&D expenditure, as well as the patent stock at the local level.

[4] However, in a detailed analysis of US direct investment flows, Love (2003) finds little evidence of technology sourcing as a motivation for FDI.

1.7 Location and the importance of institutions

35. Both technology sourcing and the links between technology transfer and location per se, have typically ignored one crucial issue, which is the extent to which host and source country institutions, in the form of freedom from corruption, intellectual property protection, freedom from government interference, and the protection of minority investors. There is a large literature, summarised by Javorcic and Wei (2009) that highlights the role that corruption can play in deterring FDI. However, while there is a large body of evidence that suggests that corruption does indeed deter FDI, this typically takes the form of cross country regressions at a macro level. Driffield et al (2009) illustrate however that this relationship is by now means as monotonic, and using the same main data source as we use here, illustrate that institutions play an important role in explaining not merely the entry decision, but also the form of entry and percentage of shareholding taken by the parent. It should be stressed however that Driffield et al (2009) focus on FDI to a set of eastern European countries, where institutional quality is more variable than for most OECD member states, and particularly the ones we consider here. In a similar vein, Branstetter et al (2009) point out that while intellectual property rights (IPR) are enshrined within the WTO, there never the less exist in practice very large differences in practice within WTO members. Branstetter et al (2009) find that US MNEs respond favourably to improved IPR in host countries, by being willing to transfer more technology to their foreign subsidiaries. Similar results are reported by Belderbos et al (2006) for Japanese FDI. Importantly, Belderbos et al (2006) also allow for the demand for the final product in the most country. In the spirit of the theoretical contribution of Krugman et al discussed above, this is important in combining the firm level and regional level analysis, and hints at a more complex modelling structure than has previously been employed. Temouri et al (2010) also discuss this phenomenon in the context of offshoring in high tech sectors. They show that investor protection is a crucial determinant of a firms' decision to offshore high tech activities to low cost locations. However, it should again be stressed that IPR among the leading OECD member countries has very little variance, all observe US and EU patents.

1.8 The limits of the current empirical literature

36. The literature outlined above has highlighted many of the issues that have been considered. One potential limitation of the existing work is the unit of empirical analysis. Typically, as has been discussed, the unit of analysis is "the firm" but with firm level activity often proxied by sectoral or regional level activity. Equally, much of the literature focuses for example only on one level of analysis, for example spatial data using national data to proxy certain issues where less aggregate data are not available. However, as we will illustrate, this potentially misses a layer of analysis, and imposes a potentially erroneous model of the decision making process. For example, much of the literature on clusters is based at a relatively local level, and one could then assume that firms, when contemplating entry, may choose between several alternative clusters located across Europe for example. However, the literature imposes a rather different ordering of the decision making process, with the firm choosing the country, then the region, and finally (if data permits) the location. Nested or conditional logit models have sought to address the issue of the attractiveness of one country impacting on the decision on the decision to locate in another, but these still assume that effectively the location decision is "restricted" to a subset of locations within the data. Mataloni (2007) extends this argument by examining the extent to which US MNEs entering Europe engage in a sequential choice process, that they select a country, and then a region, and subsequently a location based on local and regional attributes.

37. The review of the literature carried out in the previous sections has highlighted that multiple factors may affect the location of knowledge-intensive activity by foreign MNEs. These factors reflect both broad incentives, such as costs saving opportunities, geographical proximity to local demand or material infrastructures, as well as knowledge-oriented motivations, such as absorptive capacity by local suppliers and knowledge sourcing from firm specific or local hubs of specialised knowledge. In addition, it has shown that different drivers of MNE location act at dissimilar levels of territorial breakdowns. In this

respect, the location choice problem, can be considered as a hierarchical problem, a decision tree moving from the larger to the smaller scale dimension, or a simultaneous problem, where all factors and dimensions are jointly considered. As Table 1 shows, broad and especially knowledge specific motivations in MNE location choice are influenced by different drivers according to dissimilar levels of territorial breakdown.

38. Finally, much of the existing literature focuses on only a limited number of variables designed to capture the stock of knowledge or innovation at the local level. We focus on both input measures (R&D), output measures (patents) and agglomeration as indicators of the innovatory capacity of the locality.

Table 2.1 Factors influencing a MNE location choice by level of territorial breakdown

Level of territorial breakdown	Broad factors	Knowledge-related factors
National	Labour costs, material infrastructure endowment, country risk, market structures and domestic demand	National education system, innovation policies
Regional	Regional taxes and incentives, Regional differences in wages and other costs, regional material endowments	Key components of a regional innovation system
Local	Characteristics of the local labour markets and competitiveness of local suppliers, metropolitan area facilities.	Presence of high tech business clusters and/or universities or research labs

39. A theoretically grounded analysis focusing on the location of foreign MNE knowledge-intensive activity should consider all the above mentioned factors, including possible interactions, at the appropriate level of territorial breakdown. For instance, high tech business clusters located in innovative regions are, ceteris paribus, more attractive than isolated high tech business clusters? Data constraints and model specification will be discussed in the following chapters.

CHAPTER 2. THE DATA

40. Our data on the location of foreign affiliates is taken from *ORBIS*, provided by Bureau van Dijk, which is an electronic publishing and consultancy firm. A growing number of researchers have used this rich firm-level data set in recent years to analyse various economic issues, including Helpman *et al.* (2004), Budd *et al.* (2005) Konings and Murphy (2006), Bhaumik et al (2010). It provides detailed financial and other operational information on private and public companies operating ina large sample of countries worldwide. The dataset used in this paper comes from the full version of *ORBIS*, covering some 20 million firms.

41. The advantages and drawbacks of the ORBIS database for the development of new statistics and economic analysis, including territorial level indicators, have been assessed in a number of OECD feasibility studies. It is important to remind here that there are two distinct sources of bias in the use of ORBIS data for territorial analysis.

42. The first source of bias refers to under coverage and other structural differences (dissimilarities in firm distribution by industry and size class) that characterise the business population extracted from the ORBIS database with respect to the target population mirrored by Official statistics. In this context, empirical results from territorial analysis based on ORBIS are inconsistent as long as under coverage or other structural breakdowns in the data alter the spatial distribution of firms within a country. Given that ORBIS relies at the country level on national sources, this type of effect is assumed to be limited. However, national sources used by ORBIS quite often do not perform data quality checks, and data collection is based on an extensive network of local data providers, this is the case of Chambers of Commerce. In addition, the hypothesis of alteration in the spatial distribution of firms extracted from ORBIS can be further relaxed in the context of data modelling, where the negative impact is limited to the presence of a significant correlation between the spatial alteration in firms distribution and the random error of the conditional model.

43. The second source of bias concerns the use of firm level data as a proxy of local unit (establishment) data. In this case, the magnitude of the bias is connected to the presence of multi-plants firms, it is sensitive to the geographical scale of the analysis. In effect, the presence of multi-plants firms is irrelevant in the case all local units are localised within the same area of analysis.

44. Another important issue on the data quality and consistency assessment of ORBIS database concerns the limits for international comparison. As long as there are no under coverage and other structural breakdowns in the data across countries, or those biases are relatively similar in terms of direction and magnitude across countries, international comparison is economically meaningful and statistically sound. If this is not the case, data modelling and the development of indicators based on ORBIS should consider this issue.

45. The focus of this analysis is high tech industries and knowledge intensive service industries, based on the official OECD-Eurostat definitions of high tech manufacturing industries, and high tech knowledge intensive services , highlighted in table 2.1.

Table 2.1: Classification of high tech industries high-tech knowledge intensive services

High tech industries	High-tech knowledge intensive services
Pharmaceuticals Aircraft & spacecraft Medical, precision & optimal instruments Radio, television & communication equipment Office, accounting & computing machinery	Post and telecommunications Computer and related activities Research and Development

46. The *ORBIS* data are then linked to various local, regional and national level data included in the OECD official statistical portal, to capture agglomeration of activities, and regional characteristics, designed to capture then many issues expected to impact of firm location highlighted in chapter 1. These are outlined, along with their various sources in table 2.2. These are divided into the local, regional and national variables. The link between ORBIS data and OECD regional and local data was carried out by using the OECD Territorial Grids of OECD member countries (2008) to identify official territorial units at both the regional and the local level.

Table 2.2 List of model variables at Local level (NUTS3, BEA US or other local areas) variables

Name	Description	Type of variable	Data source
HTKISFA	Number of foreign affiliates active in high-tech manufacturing industries or in high tech knowledge-intensive services	Dependent variable	ORBIS database
HTKISDF	(Log of the) Number of domestic firms active in high-tech manufacturing industries or in high tech knowledge-intensive services	Innovation related variables	ORBIS data base
UFRC	Dummy variable which identifies world wide known Universities and research labs	Innovation related variables	Press and global ranking of Universities
LPOP	(Log of the) Local population	General variables	OECD Regional database
LSUR	(Log of the) territorial surface in square metres	General variables	OECD Regional database
LUA	dummy variable which identifies predominantly urban areas	General variables	OECD Regional database
LIA	dummy variable which identifies intermediate areas	General variables	OECD Regional database
LRA	dummy variable which identifies predominantly rural areas	General variables	OECD Regional database
LCR	Crime rate (incomplete for some countries)	General variables	OECD Regional database
LGDP	GDP (incomplete for some countries)	General variables	OECD Regional database
LPAT	Number of patents (experimental data)	General variables	OECD Innovation indicators database

Table 2.3 List of model variables at Regional level (NUTS2, states in US or other regional areas) variables

Name	Description	Type of variable	Data source
RGDP	(Log of) GDP in US dollars PPP	General variables	OECD Regional database
RGDPPC	(Log of) GDP per capita in US dollars PPP	General variables	OECD Regional database
RPOP	(Log of the) Population	General variables	OECD Regional database
RUR	Total unemployment rate	General variables	OECD Regional database
RYUNR	Youth Unemployment rate	General variables	OECD Regional database
RCR	Crime rate	General variables	OECD Regional database
RI2	Secondary education (as % of labour force)	Innovation related variables	OECD Regional database
RI3	Tertiary education (as % of labour force)	Innovation related variables	OECD Regional database
RI4	(Log of) Employment in High and medium high-technology manufacturing	Innovation related variables	OECD Regional database
RI5	(Log of) Employment in Knowledge intensive services	Innovation related variables	OECD Regional database
RI6	High and medium high-technology manufacturing (as % of total manufacturing)	Innovation related variables	OECD Regional database
RI7	Knowledge intensive services (as % of total services)	Innovation related variables	OECD Regional database
RI8	High and medium high-technology manufacturing (as % of total employment)	Innovation related variables	OECD Regional database
RI9	Knowledge intensive services (as % of total employment)	Innovation related variables	OECD Regional database
RI10	PCT patent applications per million population	Innovation related variables	OECD Regional database
RI11	R&D expenditures performed by the business sector (as % of GDP)	Innovation related variables	OECD Regional database
RI12	R&D expenditures performed by the government sector (as % of GDP)	Innovation related variables	OECD Regional database
RI13	R&D expenditures performed by the higher education sector (as % of GDP)	Innovation related variables	OECD Regional database
RI14	R&D expenditure total (as % of GDP)	Innovation related variables	OECD Regional database
RI15	(Log of) R&D expenditure total (PPP)	Innovation related variables	OECD Regional database

Table 2.4 List of model variables at National level variables

Name	Description	Type of variable	Data source
NI1	R&D expenditures performed by the business sector (as % of GDP)	Innovation related variables	OECD database
NI2	R&D expenditures performed by the government sector (as % of GDP)	Innovation related variables	OECD database
NI3	R&D expenditures performed by the higher education sector (as % of GDP)	Innovation related variables	OECD database
NI4	R&D expenditure total (as % of GDP)	Innovation related variables	OECD database
NI5	(Log of) R&D expenditure total (PPP)	Innovation related variables	OECD database
NI7	Secondary education (as % of labour force)	Innovation related variables	OECD database
NI8	Tertiary education (as % of labour force)	Innovation related variables	OECD database
NI9	PCT patent applications	Innovation related variables	OECD database
NI10	PCT patent applications per million population	Innovation related variables	OECD database
GDP1	GDP per head of population relative to the USA (USA=100)	General variables	OECD database
GDP2	GDP per hour worked relative to the USA (USA=100)	General variables	OECD database
GDP3	(Log of) Hours worked per head of population	General variables	OECD database

47. Table 2.5 below presents some characteristics of the limited set of OECD countries considered in this exploratory analysis, and the levels of aggregation used. This demonstrates what is already well understood, which is that Ireland has a much higher incidence of inward investment than the other countries, and while the US does attract a significant amount of inward investment, it also has a large stock of indigenous high tech firms. The profiles of France, Italy and Spain are similar, with approximately 2% of Firms active in high-tech manufacturing or knowledge-intensive services being foreign owned.

48. Finally, table 2.6 demonstrates the mapping of the Times Higher top 200 universities onto our data.

Table 2.5 The breakdown of the sample of ORBIS firms across countries and regions

					Firms active in high-tech manufacturing or knowledge-intensive services		
Country	Type of region	N° of regions	Type of locality	N° of localities	Total	Foreign affiliates	Domestic firms
France	NUTS2	22	NUTS3	96	39,142	986	38,156
Ireland	NUTS2	2	NUTS3	8	2,744	259	2,485
Italy	NUTS2	21	NUTS3	103	36,848	442	36,406
Spain	NUTS2	19	NUTS3	49 (*)	15,950	464	15,486
USA	US States	51	BEA areas	179	337,170	4,772	332,398
Total		115		435	431,854	6,923	424,931

Source: *ORBIS* database

Table 2.6 List of high-tech top universities

PAE	LOC	Nome
ES	ES511	University of Barcelona
ES	ES300	Universidad Politécnica de Madrid
ES	ES523	Universidad Politécnica de Valencia
FR	FR104	Ecole Polytechnique
FR	FR101	Paris VI, Pierre et Marie Curie
FR	FR101	Ecole Normale Supérieure, Paris
FR	FR813	Montpellier I University
IE	IE021	Trinity College, Dublin
IE	IE021	University College Dublin
IT	ITC45	Politecnico di Milano Technical Univ
IT	ITD55	Bologna University
IT	ITE17	Normale di Pisa
IT	ITC11	Politecnico di Torino
US	US072	Massachusetts Institute Technol
US	US030	University of California, Berkeley
US	US146	Stanford University
US	US097	California Institute of Technology
US	US129	Carnegie Mellon University
US	US011	Georgia Institute of Technology
US	US072	Harvard University
US	US028	Illinois University
US	US013	University of Texas at Austin
US	US162	Cornell University
US	US078	Purdue University
US	US097	University of California, Los Angeles
US	US118	Princeton University
US	US022	Massachusetts University
US	US047	University of Michigan
US	US145	University of California, San Diego
US	US118	Yale University
US	US101	Wisconsin University
US	US075	Texas A&M University
US	US138	Virginia Polytechnic Institute
US	US022	Boston University
US	US161	Penn State University
US	US174	Johns Hopkins University
US	US004	Rensselaer Polytech Institute
US	US118	Columbia University
US	US127	Pennsylvania University

Source: Times Higher Education-QS World University Rankings

CHAPTER 3. THE MODEL AND ESTIMATION

3.1 Spatial statistics tools for the analysis of MNE location at the sub-national level

49. A valuable asset of the ORBIS database is the possibility to visualise on a map the location patterns of MNE high-tech manufacturing and services activities at a very detailed territorial scale, usually not covered by official statistics. In particolar, it is feasible to map firms location from ORBIS at any territorial breakdown based on the enterprise level location information (postal code, municipality, etc).

50. Traditional territorial indicators to analyse the spatial features of a firm population include, among the others, the location quotient (LQ):

$$Q_{ih} = \frac{A_{ih} / A_{i0}}{A_{0h} / A_{00}} \qquad (1)$$

51. Where A is any meaningful economic variable to analyse territorial data (number of firms, employment, turnover), and i and h index the geographical area and the industry, respectively. Although traditional indicators are important for a preliminary analysis of the data, they are not very informative on the spatial patterns of economic activity.

52. Statistical measures of spatial correlation seem to provide very interesting insights on spatial association of economic data. An univariate measure of spatial association captures the correlation of a variable with itself through space. In effect, it measures the correlation between an observation's value on a variable and the value of close-by observations on the same variable. Several measures are available (Moran's I, Geary's cetc.). The Moran's I is the most commonly used measure of spatial correlation:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (y_i - y)(y_j - y)}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n} (y_i - y)^2} \qquad (2)$$

53. Where n is the number of units, y is the mean of the variable, y_i the variable value at location i and w_{ij} is a weight indexing location of i relative to j. Moran's I can be interpreted as the correlation between variable y, and its "spatial lag", formed by averaging all the values of y for the neighboring units. The output of Moran's I is similar to the output of Person correlation coefficient. It varies between -1.0 and +1.0, where 0 indicates on spatial autocorrelation, and negative/positive values indicate negative/positive spatial autocorrelation. A positive and significant value for Moran's I indicate positive spatial correlation, showing for instance that counties have a high or low number of establishments similar to their neighboring counties. Conversely, a negative and significant value for Moran's I indicates negative spatial correlation, showing that counties have high or low number of establishments.

54. In contrast to the Person correlation coefficient or other non spatial measures of association, usually based on one single dimension such as time, measures of spatial association require the definition of the nature and direction of spatial connection between units. This information is incorporated within a spatial weight matrix W, indexing the relative location of all points i and j. Moran's I results are very sensitive to the different types of W, based on dissimilar measures of contiguity or distance between units.

55. In the case of uneven spatial clustering, global spatial indicators, such as the Moran's I, are found to be less useful. Local indicators of spatial association (LISA), developed by Anselin (1995), seem to provide more interesting output in this respect. LISA is a direct extension of the Moran's I scatter plot, based on a variable and its spatial lag. Each quadrant of this scatter plot corresponds to one of the four different types of spatial association (SA): High-High, Low/Low; High/Low; Low/High.

56. Moran's I and LISA differ in terms of data employed and analytical scope. Moran's I is a global measure of spatial autocorrelation. It uses the complete data set to derive a single value for the entire study region and the overall pattern in the data is summarized in a single statistic. In contrast, LISA calculate a local version of local version of Moran's for each areal unit in the data. In particular, LISA shows statistically significant groupings of neighbours with high and with low values around each region in the study area. From an analytical perspective, LISA are a decomposition of the Moran global indicator. In particular, . the sum of LISAs for all observations is proportional to global Moran's I, implying that LISA statistic can be interpreted as indicators of local spatial clusters and as diagnostics for local instability. From an economic perspective, LISA help to identify 'hot spots' or clusters of regions with similar values.

57. LISA cluster map provides a graphic representation of locations with a significant Local Moran statistic classified by type of spatial correlation: (a) high-high association (HH), for instance a county with many high-tech firms has neighboring counties with many high-tech firms; (b) low-low association (LL), a county with few high-tech firms has neighboring counties with few high-tech firms; (c) low-high association (LH), a county with few high-tech firms has neighboring counties with many high-tech firms; and (d) high-low association (HL) , a county with many high-tech firms has neighboring counties with few high-tech firms. The HH and LL locations suggests clustering of similar values (positive spatial correlation), whereas the HL and LH locations indicate spatial outliers (negative spatial correlation) (Anselin, 1995).

58. Multivariate LISA represent a natural extension of univariate LISA. This is relevant to analyse spatial association between different variables. For instance, the location of foreign-owned high-tech companies with respect to the location of domestic high-tech companies, or the location high-tech firms with respect to the location of high-tech universities. Local bivariate spatial correlation measure the degree of linear association (positive or negative) between the values for one variable at a given location i and the average of another variable at neighboring locations.

59. Given the high informative potential of univariate and especially of multivariate LISA in spotting, respectively, potential clusters of firms and significant spatial association between economic variables, the scope of these indicators must be limited to exploratory data analysis. In the absence of a well defined spatial modelling framework, which include control variables, LISA results are affected by virtually any type of spatial drivers, including spurious spatial correlation effects. In effect, the evidence of a spatial association between high-tech foreign affiliates and domestic high-tech firms may be led not only by co-location and interaction effects in high-tech activities but also by spurious spatial correlation with respect to urban areas or to the co-location of industrial facilities or of a rich and efficient infrastructure endowment.

3.2 Econometric modelling of MNE location choice

60. Location modelling has its roots in the work of recent authors, such as McFadden (1974) and Carlton (1979, 1983). In particular, McFadden (1974) derived discrete choice models directly from the microeconomic theory of firm behaviour, while Carlton (1979, 1983) first applied the random utility maximisation-based conditional logit model (CLM) to firm location choice. The basic theoretical framework in economic location modelling assumes a simple individual behavioural rule: a firm will locate in a particular region if and only if that choice will provide the highest return to its investment:

$$\prod_{ij}^{*} = \max\{\pi_{ij};\, j = 1.....n\} \tag{3}$$

61. Where *i* denotes the firm and *j* indicates the locality providing the highest profit among a set of *n* regions. the profit function can be re-written in a linear form as follows:

$$\pi_{ij} = \beta^{'}\mathbf{x}_j + \varepsilon_{ij} \tag{4}$$

62. where **x** is a vector of location specific variables, and the random term ε_{ij} is introduced to account for the idiosyncrasies specific to each investor and for the unobserved variables relevant for location choice. The random term is assumed to be identically and independently distributed across firms and regions, and to follow an Extreme Value Type I distribution.

63. Under a specific and restrictive assumption on individual choice behaviour, in effect the Independence of Irrelevant Alternatives (IIA) axiom first introduced by Luce (1959), it can be demonstrated following McFadden (1974) that the random utility maximisation (RUM) approach can be reformulated in terms of the conditional logit model (CLM):

$$p_j = \frac{\exp(\beta^{'} y_j)}{\sum_{j=1}^{n} \exp(\beta^{'} y_j)} \tag{5}$$

64. Guimarães *et al.* (2003) demonstrate, on the basis of the equivalence of CLM and Poisson log-likelihood functions, that same results can be obtained under the assumption that the number of investments in region *j* hereafter denoted by n_j , follows a Poisson distribution where:

$$E(n_j) = \exp(\alpha + \beta^{'} y_j) \tag{6}$$

65. As stressed by McFadden (1974), the primary limitation of this model is that the assumption on the IIA is inconsistent with empirical settings when alternative choices are close substitutes. Head *et al.* (1995) and, more recently, Guimarães *et al.* (2004) highlight that the violation of IIA assumption is likely to plague industrial location modelling. In particular, Head *et al.* (1995) show that the available set of regional or local based variables is usually very limited, allowing non observable characteristics to play a significant role in location choice and thus making IIA assumption unrealistic. In addition, they underline that observable variables, like overall industry agglomeration, are frequently correlated with unobservable variables, like the endowment of natural resources. Guimarães *et al.* (2004) state that with very disaggregated spatial data, the potential for violating IIA increases, with contiguous regions being close substitutes.

66. Alternative approaches for dealing with the IIA problem are proposed in the literature (see Guimarães *et al.* (2004) for a review). These, however, appear to have been only partially successful, while

introducing the potential for further bias. Guimarães *et al.* (2004) provide a more consistent framework to deal with IIA violation problem. First, they introduce in the CLM model an additional specific effect to each location alternative to account for unobserved spatial variables. Then, they reformulate the CLM model in terms of a Poisson model, by taking advantage of the above mentioned equivalence between the log-likelihood functions (Guimarães *et al.*, 2003). The Poisson model is consistent with the theoretical framework underling the CLM, and places no significant restrictions on the model in terms of cross-regional effects. These various approaches are also discussed in some detail in various OECD reports, see for example Hatem and Py (2008). The standard approach to this problem, see for example Py and Hatem (2008) is to employ an approach that allows for the violation of the IIA assumption, such as the nested logit model. This allows for the fact that a firm may choose a location within a given subset of locations, and seeks to explain location conditional on the initial decision to enter the set of locations. As we discuss below however, this has its limitations.

67. This section introduces a three level variance component model for the analysis of MNE location in OECD countries. This is motivated by both theoretical considerations and data constraints highlighted in the previous chapters. This model reconsiders traditional location modelling in the context of a new class of econometric models, named Generalised Linear Latent And Mixed Models (GLLAMM), which seems to provide an appropriate data modelling framework for location data available at different levels of territorial breakdown. The traditional econometric specification of location models permit neither to exploit relevant information from data available at different levels of territorial breakdown, nor to decompose and explore the sources of variability in location distribution. Traditional location models can be easily extended in the context of Generalised Linear Latent And Mixed Models (GLLAMM). This class of models combines features from a range of models with unobserved components – multilevel models, certain latent variable models, panel data models, or models with common factors – with the characteristics of the broad class of generalised linear models (GLM), where this latter class of model is directly connected to location choice modelling. More precisely, this class of models includes the following items as the basic model components:

a) a link function $\boldsymbol{\eta} = g(\boldsymbol{\mu})$, with inverse function $\boldsymbol{\mu} = g^{-1}(\boldsymbol{\eta})$ that maps the mean μ of the response variable to the linear predictor $\boldsymbol{\eta} = \mathbf{x}'\boldsymbol{\beta}$

b) the distribution of the response variable belongs to the exponential family

c) unobserved variables enter the linear predictor part additively: $\boldsymbol{\eta}_{\mathbf{ij}} = \mathbf{x}'_{ij}\beta + \mathbf{z}'_{ij}\mathbf{u}_{\mathbf{i}}$ where i and j index groups of observations and individual observation within the group respectively, and **z** represents the design matrix of different levels.

68. As a result, it is feasible within this class of model to produce consistent ML estimates for a model simultaneously typified by nominal outcomes (binary response or count data) and a multilevel data structure for unobserved variables. From a formal point of view, the link function of a Poisson model for count data can be re-formulated as

$$E(\mu_{ijk}) = \exp(\mathbf{x}'_{ijk}\beta + \mathbf{z}'_{ijk}\mathbf{u}) \tag{7}$$

69. where i, j and k index local, regional and national level variables, and **z** represents the design matrix of different levels. This model can be considered as a linear combination of a fixed and a random part. The fixed part of the model $\mathbf{x}'_{ijk}\beta$ is a linear function of independent variables available at different level of territorial breakdowns, and contains all the fixed coefficients. The random part of the model $\mathbf{z}'_{ijk}\mathbf{u}$

decomposes the unexplained variability of the dependent variable into across nations, across regions but within nations, and across localities but within regions variability components. Random errors are specific to each level of the model: national, regional and local. Besides the usual regularity conditions, they are assumed to be uncorrelated across levels.

70. Let y_{ijk} be the count of high tech foreign affiliates located in the ith municipality of the jth region included in the kth country which is assumed to follow a Poisson distribution with mean μ_{ijk} and random error ε_{ijk}. The random or unconditional model part of a three level model for count data with random intercepts only can be written as follows:

$$E(\mu_{ijk}) = \exp(\beta_1 + \zeta_{jk} + \zeta_k) \tag{8}$$

71. The variance components (random deviation from the overall mean count of the population) of the model reflect the following sources of unexplained variability

$\varepsilon_{ijk} \rightarrow$ Poisson distribution across municipalities but within region variability

$\zeta_{jk} \rightarrow N(0, \tau_{jk}^2)$ across regions but within country variability

$\zeta_k \rightarrow N(0, \tau_k^2)$ across countries variability

72. Once the contribution of each source of variability in the spatial distribution of foreign affiliates has been assessed, explanatory variables can be introduced at different levels of territorial breakdown to (partially) explain these sources of variability, as in the following example.

$$E(\mu_{ijk}) = \exp(\beta_1 + \beta_2 x_{ijk} + \beta_3 x_{jk} + \beta_4 x_k + \zeta_{jk} + \zeta_k) \tag{9}$$

73. Where the coefficients $\beta_2, \beta_3, \beta_4$ measure the effect on the expected mean number of foreign affiliates of municipality level, regional level and country level covariates, respectively. In addition, the model can be expanded to consider not only intercepts but even slope coefficients as random effects, this permits to explore inter-level interactions between explanatory variables. For instance are some local level effects amplified or discouraged by regional or state level characteristics? A list of possible variables to be included in this model is included as table 3 in the data chapter.

CHAPTER 4. THE RESULTS

74. The results are introduced by some empirical evidence on the spatial patterns of high-tech foreign affiliates. These results focus on the USA.

75. The machting of ORBIS data with the map on US postal areas (available from the US Census website), based on the company zip code, provides an interesting empirical setting to use LISA for the analysis of the spatial patterns of high-tech manufacturing and service foreign affiliates in the USA. The basic territorial unit of the maps is the sectional center facility of the US Postal system. The number of sectional center facilities in the US is around 2.400. The following three maps visualise the outcomes of LISA routine embedded in the Geoda software. Significance tests are set 0.01 level and 999 permutations are performed in the randomisation process.

76. The spatial distribution of high-tech manufacturing and service foreign affiliates in the USA by postal areas exhibits a slightly significant value (0.33) of global spatial association, based on Morans 'I. Figure 4.1 highlights that the presence of high-tech MNE in the USA is characterised at the local level by a significant spatial concentration in a limited numbers of spatial clusters. In particular, red areas identify the hubs of consolidated business clusters while blue areas detect potentially emerging ones.

77. Figures 4.2 and 4.3 use LISA bivariate analysis to explore the spatial association between the location of high-tech foreign affiliates to the location of domestic high-tech firms and high-tech universities, respectively. Figure 4.2 apparently provides some significant empirical evidence on the co-location and possible interaction between foreign and domestic high-tech firms (Global Moran=0.30). However the evidence of a direct connection between domestic high-tech firms attracting foreign high-tech firms cannot be inferred from this map, given the possible presence of some spurious spatial correlation effects.

78. Figure 4.3 highlights the presence of limited spatial interaction between foreign affiliates and high-tech Universities (Global Moran=0.14). The number of cases which exhibit a strong local interaction between high-tech foreign affiliates and high-tech universities are very limited (red colours), while it is significant the number of potentially emerging co-location of high-tech foreign affiliates and high-tech universities, where these latter are identified using an unofficial classification provided by the Times Higher Education-QS World University Rankings.

Legenda for all three maps

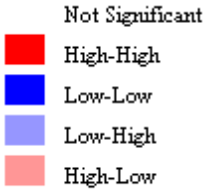


Figure 4.1 Spatial agglomeration of high tech foreign affiliates in the USA (univariate local spatial autocorrelation LISA)

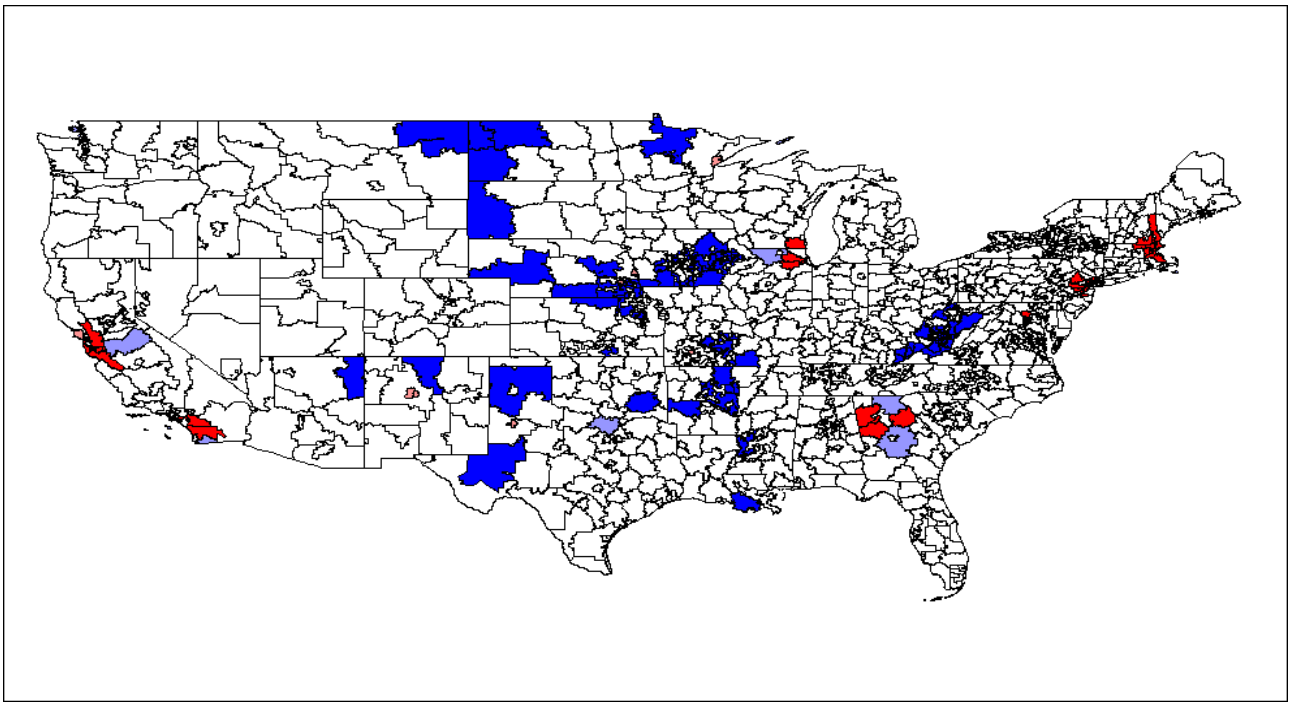


Figure 4.2 Spatial agglomeration of high tech foreign affiliates in the USA conditional to the location of domestic high tech firms (bivariate local spatial autocorrelation LISA)

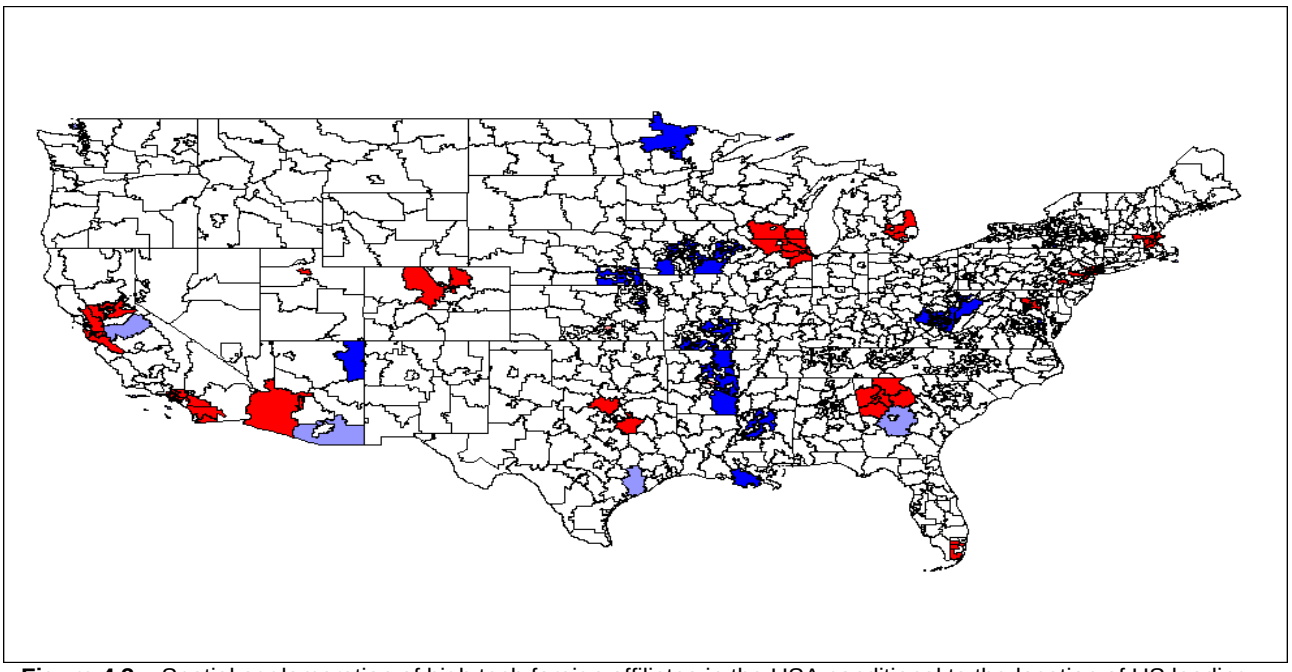
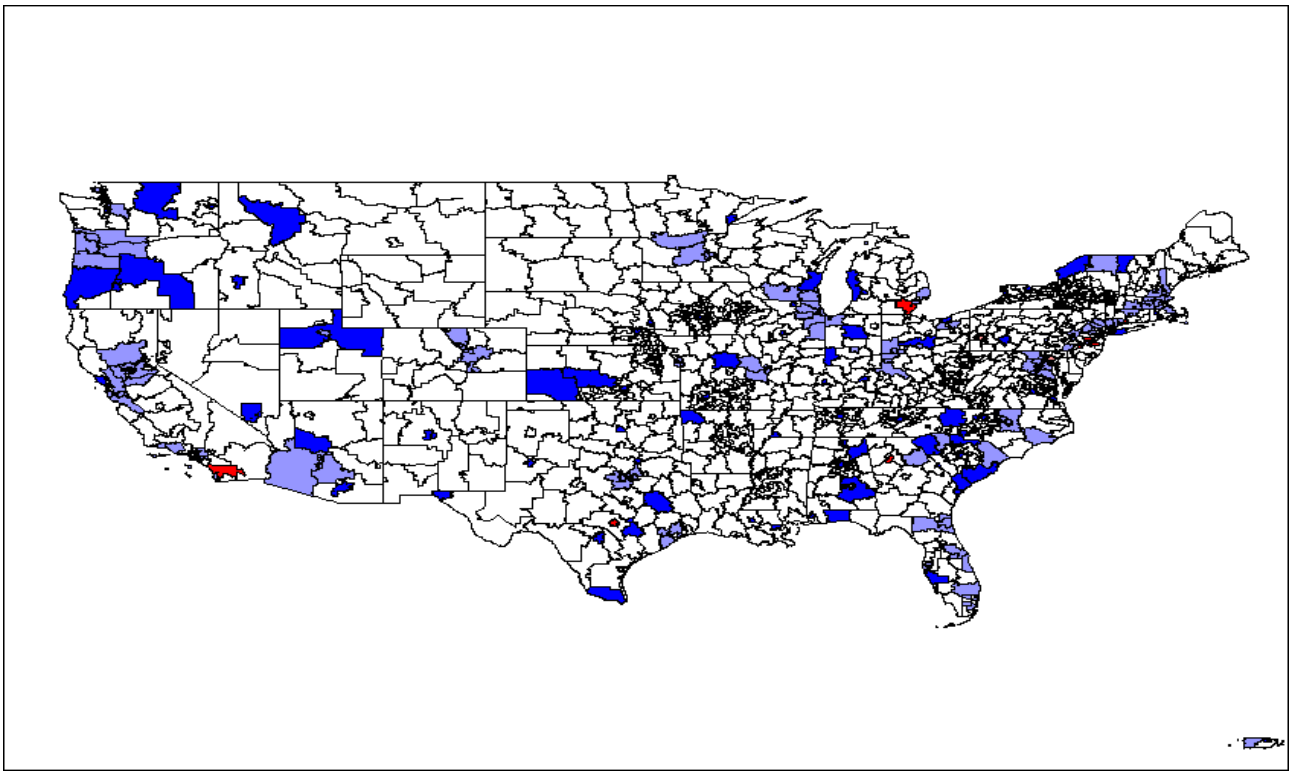


Figure 4.3 – Spatial agglomeration of high tech foreign affiliates in the USA conditional to the location of US leading High tech Universities (bivariate local spatial autocorrelation LISA)



79. The empirical analysis then focuses on the investigation of the location decision of high tech firms across a sample of 5 OECD countries: France, Italy, Spain, Ireland and the United States. This is based on the three levels Poisson count data model outlined above. In keeping with the general premise of the modelling structure outlined above, the variables in the model are first specified and estimated separately at local, regional, and national levels of aggregation using all the variables reported in the national, regional and local tables included in the data Chapter. Then, all the statistically significant parameters at each level of territorial analysis are pooled together and estimated as a multi-level model. The results highlight in table 5 for the three levels model show the importance of considering the different levels of effects, with the variance components at the national and regional level declining significantly as successive levels of fixed effects are added. This gives more reliability to the coefficient estimates, as one can be sure that the location-specific unobservable "fixed effects" are captured by the modelling procedure.

80. The results from the estimation are illustrated in table 4.1. The results show clearly the importance of focussing on the local level when seeking to explain firm location. The local measures of agglomeration and urbanisation are positively associated with the location of high tech firms. The coefficient on population is negative, suggested that not surprisingly when one controls for urbanisation and agglomeration at the local level, the most densely populates localities do not attract investment. We also consider the impact of universities in the location decision of firms, by including as an additional variable the location of high tech leading universities. This shows no additional effect in the location decision attributable to the presence of a leading university.

81. Turning now to the regional factors, regional agglomeration also explains location decisions of firms, with concentrations of firms active in high sectors explaining entry. Regional unemployment has a negative effect, suggesting that areas with higher unemployment attract less high tech investments. This is in turn suggestive that not surprisingly, high tech investments are not attracted to locations with large quantities of (relatively low skilled) labour.

82. Finally, the national effects are also important, highlighting that countries with high levels of business sector R&D attract high tech firms, as do countries with high levels of public sector R&D. This suggests that high levels of public sector R&D dominates the university effect, with high levels of government funded R&D being synonymous with high numbers of well trained R&D scientists and technicians. The percentage of the workforce with only secondary education is also negatively associated with high tech entry. This highlights the role for education policy, getting more people into higher education attracts more high tech firms.

Table 4.1 Results for a 3 levels Poisson model

Fixed effects					
Effect	Estimate	Standard Error	Valore t	Pr > |t|	
Local level effects					
HTKISDF	1.48	0.06	25.60	0.00	***
LPOP	-0.42	0.06	-6.56	0.00	***
LUA	0.29	0.06	4.82	0.00	***
LIA	0.37	0.06	6.23	0.00	***
UNIV	-0.04	0.05	-0.71	0.48	
Regional level effects					
RGDP	-0.52	0.68	-0.75	0.45	
RGDPPC	0.46	0.70	0.66	0.51	
RPOP	0.19	0.52	0.36	0.72	
RI4	0.23	0.12	1.94	0.05	*
RI5	-0.20	0.51	-0.40	0.69	
RI15	0.50	0.28	1.80	0.07	*
RCR	-0.01	0.04	-0.30	0.76	
RUNR	-0.10	0.06	-1.67	0.10	*
RYUNR	0.02	0.02	0.89	0.38	
RI2	-0.01	0.01	-0.49	0.62	
RI3	-0.02	0.02	-1.01	0.31	
RI10	0.00	0.00	-0.80	0.43	
RI11	-1.12	0.71	-1.58	0.12	
RI12	-0.97	0.79	-1.23	0.22	
RI13	-1.49	0.82	-1.82	0.07	*
RI14	0.96	0.68	1.41	0.16	
National level effects					
NI1	2.21	0.39	5.73	0.00	***
NI2	4.53	1.97	2.30	0.02	**
NI5	-1.21	0.16	-7.44	0.00	***
NI7	-0.06	0.02	-2.57	0.01	***
Variance components					
	Country	Region			
Unconditional model	1.009	1.877			
Model with national level effects only	0.430	1.890			
Model with regional level effects only	0.260	0.390			
Model with local level effects only	1.060	0.110			
Model with all 3 level effects	0.004	0.067			
Model fit					
-2 Res Log Pseudo-Likelihood			1270.66		
Generalized Chi-Square			676.33		
Gener. Chi-Square / DF			1.65		
Data information					
Regional levels	109				
Country levels	5	ES FR IE IT US			
Number of Observations	435				

CONCLUSIONS

83. The essential brief of this project was to examine the extent to which a large scale commercial database could be employed in the modelling of the location decisions of firms within a set of OECD countries. By linking the ORBIS data with various OECD data sets, we have been able to address the brief, and also make three contributions to the literature. Firstly, the model works well, and highlights the important determinants of location decisions. More importantly however, our hierarchical model has demonstrated the importance of allowing for effects at different levels of regional aggregation. This is not simply a matter of including some local, some regional and some national level variables within the same regression, but allowing for the time invariant effects of these hierarchies. By doing this, it is possible to demonstrate the improved fit of the model once one allows for this hierarchy of effects. This approach also offers an improvement over the nested or conditional logic approaches to this problem, by not being limited to a subset of regions in explaining the location decision. We also highlight the importance of agglomeration effects in explaining location decisions, and highlight how different agglomeration effects at different spatial levels of aggregation are associated with the location of high tech firms.

84. The work presented here does however suggest numerous extensions. Firstly, it would be possible to model the inter-regional effects in a more explicit manner, testing whether for example innovation or agglomeration in one region impacted on the ability of neighbouring regions to attract high tech entry. Secondly, one could also model investment rather than entry, focussing on a continuous variable rather than a discrete count variable. This would capture expansion by existing firms, as well as new entry. Equally, one could focus on exit, determining the extent to which different regions experience different exit rates. Finally, there is scope here for examining in more detail the nature of the relationships between different types of high tech activities, whether there exist inter-industry relationships as well as inter-regional ones in explaining location decisions. Overall, this study has highlighted the importance of agglomeration and innovation in explaining location decisions, but these relationships should be examined in more detail.

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