DEPARTMENT OF ECONOMICS

ISSN 1441-5429

DISCUSSION PAPER 29/07

# FIRM INNOVATION: THE INFLUENCE OF R&D COOPERATION AND THE GEOGRAPHY OF HUMAN CAPITAL INPUTS

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## Abstract

This paper investigates the role played by the sectoral and geographical mobility of labour in the promotion of industrial innovations. Knowledge can be transferred between firms by inter-firm interactions and inter-firm cooperation. In addition, knowledge can also be transferred between firms by labour mobility. In order to examine these issues we employ a unique innovation dataset from Finland which combines firm specific information about the innovation performance of the firms along with their individual characteristics, as well as firm specific information regarding the sectoral and geographical origins of their recent labour acquisitions. Analyzing this data allows us to identify the different roles which the geography of knowledge spillovers and exchanges and the geography of labour markets play in the innovation process.

JEL Categories: O310, J600, R300

Keywords: innovation; labour; mobility; R&D; cooperation

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We are grateful for the suggestions and comments of Mikko Puhakka, Markku Rahiala and Rauli Svento. The authors also wish to thank Statistics Finland for the data provision.
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## Firm Innovation: The Influence of R&D Cooperation and the Geography of Human Capital Inputs

**Abstract**
This paper investigates the role played by the sectoral and geographical mobility of labour in the promotion of industrial innovations. Knowledge can be transferred between firms by inter-firm interactions and inter-firm cooperation. In addition, knowledge can also be transferred between firms by labour mobility. In order to examine these issues we employ a unique innovation dataset from Finland which combines firm specific information about the innovation performance of the firms along with their individual characteristics, as well as firm specific information regarding the sectoral and geographical origins of their recent labour acquisitions. Analyzing this data allows us to identify the different roles which the geography of knowledge spillovers and exchanges and the geography of labour markets play in the innovation process.

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### 1. Introduction

The role played by knowledge spillovers has become a major focus of research interest amongst economists analyzing the nature and processes of innovation and growth. In particular, the interaction between firms and agents in determining the geographical patterns of economic growth and development has become a major focus of research across a range of different academic fields. This research interest has arisen within economics primarily because of the work of Krugman (1991, 1995), within the business and management literature primarily because of the work of Porter (1990), and within geography, primarily because of the work of Scott (1988). Following the original observations of Marshall (1890), the work of Krugman (1991) and Scott (1988) has reawakened interest in the ways in which localised knowledge spillovers and technology spillovers can contribute to the growth of agglomeration. In addition, the work of Porter (1990) has focused our attention on the role played by local knowledge spillovers in the promotion of innovation, and thereby consequently in the competitiveness of both firms and regions. In all three of these various approaches, local knowledge flows are assumed to take place take place between either firms or between firms and organisations, via either local tacit knowledge spillovers between individual people, or via the local movement of embodied human capital. It is now a standard theoretical assumption in the general literature on innovation processes and systems of innovation (Caniels 2000;

Cantwell and Iammarino 2003; Acs 2002; Breschi and Lissoni 2001a,b) that each of these knowledge transfer mechanisms, namely local tacit knowledge spillovers and the local movement of embodied human capital, are assumed to be mediated primarily by face-to-face contact. In addition, there, there is also much empirical evidence which points to such localisation tendencies (Jaffe et al. 1993; Arita and McCann 2000; Acs 2002; Cantwell and Iammarino 2003).

This paper will explicitly examine these questions by identifying and distinguishing between the effects on innovation of tacit knowledge transfers via inter-firm and inter-organizational contacts, from the effects on innovation by labour mobility. In order to do this we employ a unique innovation dataset from Finland on firm innovation behaviour, which combines firm-specific information on the nature of inter-firm and inter-organisational contacts, and also the geographical and sectoral patterns of firm labour recruitment. By relating each of these features to innovation performance we are able to distinguish between the effects of knowledge spillovers from face-to-face contact from those of labour mobility. The paper is organized as follows. In the next section we provide a brief overview of the key theoretical features of the relationship between innovation, face-to-face interaction and labour markets. In section 3, we discuss the data employed and our methodology. In section 4 we examine the issues empirically using twelve different probit models of innovation, and sections 5 and 6 then provide a discussion and conclusions of our results.

## 2. The Determinants of Innovation

Since the seminal work of Schumpeter (1934), the wide-ranging literature on the determinants of innovation has tended to focus on two key lines of enquiry. Firstly, research aims to identify the structural and sectoral characteristics of the firms and entrepreneurs which promote innovation. Here, some of the key issues which have emerged as playing a significant role in promoting firm innovation are the levels of R&D expenditure, the stock of human capital inputs, the sector of activity, the mode of organization, and also the size of the firm. More recently, over the last two decades there has also emerged widespread interest in the role which geography and spatial industrial organization may also play in the innovation process. On this issue, various hypotheses have been developed to account for the widely observed uneven spatial distribution of innovative behaviour (Gordon and McCann 2005 a,b). Some of these hypotheses derive from the product cycle model (Vernon 1960; Markusen 1985). On the other hand, more recent approaches have tended to derive insights from models of clustering and agglomeration, which emphasise the role played by interaction between agents and their local environments. The emphasis of these approaches is on the identification of the specifically local factors which can both stimulate (Chinitz 1961; Duranton and Puga 2001) and also competitively select (Porter 1990) new developments. Various attempts at the identification of these local factors have focussed on issues such as the geography of learning (Glaeser 1999), the geography of creativity (Florida 2002), the geography of labour skills (Audretsch and Stephan 1996) and the density of local employment (Ciccone and Hall 1996), and the geography of entrepreneurship (Acs 2002; Acs and Armington 2004; de Groot et al. 2004). In addition, work on these issues also tends to emphasise the role played by clusters of small firms in promoting local innovation. In part this is because small firms tend to appear to play a disproportionately large role in innovation economic growth (Acs 2002). Also, many models of urban agglomeration, which is often argued to be source of innovation, are predicated on the assumption that most firms are small. In addition, however, following the original insights of Scott (1988), many commentators (Saxenian 1994; Becattini 2004) have also argued that the geography of innovation also depends on the geography of co-operation. This argument rests on the perception that innovation is not only most likely to occur in small and medium-sized enterprises, but that these small firms have neither the scale nor the risk-bearing capacity to provide all of the key inputs on their own account. As such, the geographical proximity of small and medium sized firms is often assumed to be a necessary criterion for the development of mutual trust relations between the firms (Gordon and McCann 2000, 2005b).

In almost all of the literature dealing with innovation and growth it is therefore generally assumed that increased face-to-face contact between individuals and firms is positively related to the levels of innovation. However, much of the literature on innovation also adopts "a rather diffuse and vague notions that knowledge and innovation reside 'in the air' or in the 'buzz' of urban life (Power and Lundmark 2004, 1025), whereas in reality there are four quite distinct mechanisms by which face-to-face contact and innovation can be linked. Face-to-face contact may promote innovation by increasing the possibility of informal knowledge spillovers between firms and individuals (Krugman 1991), by increasing the mutual transparency of competitor behaviour and thereby competitor responses (Porter 1990), by increasing the levels of cooperation between firms as well as competition (Scott 1988), and by increasing the inter-firm mobility of labour (Almeida and Kogut 1997). Unfortunately, a lack of appropriate data has meant that it has previously not been possible to empirically identify these different mechanisms, and therefore it is very difficult to distinguish between and evaluate the effects of tacit knowledge spillovers which accrue because of inter-firm or inter-organisational relations, from embodied human-capital knowledge transfers which take place due to the mobility of labour between firms. As such, the actual role played by face-to-face contact is still largely "a missing aspect of (the) mechanisms that are considered to generate agglomeration" (Storper and Venables 2004, p. 353).

In principle at least it is theoretically possible to treat the first three mechanisms by which face-to-face contact and innovation can be linked, namely informal knowledge spillovers, mutual transparency, and inter-firm cooperation, as being qualitatively quite similar to each other, and at the same time as a group, as being quite different from the fourth mechanism, namely the inter-firm mobility of labour. The reason for this becomes clear if we adopt the analogy of a simply stock-inventory model. The first three types of mechanisms generally involve highly frequent short-term transactions of relatively small quantities of knowledge or information in comparison to the total knowledge of the person(s) undertaking the transaction, whereas the inter-firm mobility and acquisition of labour involves relatively less frequent transactions in which the whole human capital of the individual is transferred for a significant period. In terms of agglomeration theory, either type of transaction could be related to innovation. However, while empirical data on patents and R&D are readily accessible along with aggregate measures of labour skills and education, additional micro-econometric data on labour mobility and innovation is relatively very difficult to find. For this reason, although there is some evidence supporting the role played by the mobility of local human capital in promoting innovation (Angel 1991; Audrestch and Stephan 1996; Almeida and Kogut 1999; Breschi and Lissoni 2003; Franco and Filson 2000; Persson 2002; Power and Lundmark 2004), these papers are very much in the minority. In most recent studies of the geography of innovation, analyses which emphasise the role played by local informal knowledge spillovers (Acs 2002; Kaiser 2002) have tended to predominate over human capital and labour mobility explanations.

## 3. Data and Methodology

In this paper we explicitly aim to identify the role which labour mobility plays in promoting innovation, after having controlled for other firm specific characteristics, including face-to-face contact with other firms and organizations. In order to do this we employ microeconometric data on the innovation behaviour and performance of Finnish high technology firms. As well as information about the innovation behaviour of the firm, these data provide us with detailed information about the structural characteristics of the firms, and also information about the R&D cooperation behaviour between individual Finnish firms.

R&D cooperative relationships usually begin as a result of informal knowledge spillovers, although they subsequently develop into much more complex and formal arrangements. Of all the possible types of inter-firm relations, R&D cooperation relationships require the most intense face-to-face contact in order to be both established and maintained, and for high technology firms at least, have been demonstrated to be the type of inter-firm relations which are most associated with geographical proximity (Arita and McCann 2000). This is because the required level of trust embedded in the mutual commitments made by the firms tends to be the highest of all types of inter-firm and inter-organisational relations. Therefore, testing whether the existence, nature and variety of R&D cooperation relationships is related to innovation, provides an indirect test of whether the existence, nature and variety of intense and continuing face-to-face contact is related to innovation.

Having controlled for the impact on innovation of a firm's structural characteristics, and also for the nature and variety of a firm's cooperative R&D relationships, we are then also able to extend the argument to investigate the effects on a firm's innovation performance of the geographical and sectoral origins of the firm's labour acquisitions. This will allow us to isolate the independent role on innovation performance which is played by knowledge transfers associated with local and non-local human-capital mobility, from the role associated with inter-firm and inter-organisational knowledge spillovers, associated with R&D cooperation relationships.

The establishment-level data used for our research comes from innovation surveys conducted by Statistics Finland in 1996, 2000 and 2002. The innovation surveys undertaken by Statistics Finland are conducted using the subject approach, which is in the line with the European Union Community Innovation Survey (CIS) framework. These surveys collect information about an individual establishment's innovation performance, defined as the launching of any new or substantially-improved products or processes during the previous two years. In addition to the innovation outputs, the innovation surveys also provide information about the firm's innovation cooperation with other enterprises or institutions. For the purposes of this research, these innovation databases have also been further expanded with information from the Finnish R&D Surveys, the Finnish Business Register for 1990-2002, and the Finnish Longitudinal Employer-Employee Database (FLEED) database maintained by Statistics Finland. The combined and extended database now includes establishment-level information regarding each of the types of innovations exhibited by an establishment, the nature and types of R&D cooperation relations of the establishment, the employment size of each establishment, the R&D expenditures of the establishment, the turnover of each establishment, and the geographical and sectoral origins of the labour recently acquired by the firm.

Our dataset is comprised of all the Finnish high-technology firms, defined according to the 1995 SIC and listed in Table 1, which were included in the three innovation surveys of 1996, 2000 and 2002.

**Table 1.** High Technology Industries (SIC 1995)

| **High Technology Industry** | **(SIC 95)** |
|---|---|
| Manufacture of pharmaceuticals, medicinal chemicals and botanical products | (244) |
| Manufacture of office machines and computers | (30) |
| Manufacture radio, television, communications equipment and apparatus | (32) |
| Manufacture of aircraft and spacecraft | (353) |
| Telecommunications | (642) |
| Computers and related activities | (72) |
| Research & Development | (73) |
| Architectural and engineering activities and related technical consultancy | (742) |

The basic establishment-level unit of analysis we adopt is that of the 'local unit', and this local unit contains all of the business units of the firm within the same local municipality. The innovation behaviour we ascribe to the local unit comes from the firm level innovation data. Assigning innovation behaviour to the local unit is straightforward in the case of a single plant or single site firm because the firm is the local unit, or in the case of a multi-site firm with all establishments in the same local municipality. In the case of a multiplant firm which has establishments in different areas, each individual establishment is the unit of analysis, and in the absence of any additional information, the innovation behaviour we ascribe to each establishment is that of the multiplant firm as a whole. In the case of Finnish data this technique has already been previously adopted elsewhere (Alanen et al. 2000).[1] The surveys also provide information about the R&D interaction between individual firms and other firms or institutions, specifically in order to promote innovation, and this information is provided at the level of the firm. Once again, with single plant firms or with multiplant firms in the same locality, assigning interaction and

[1] There are two major justifications for this technique. Firstly, if we assume that information is transferred effectively between different local units within the same firm (Orlando 2000), then it is appropriate to give the same innovation status to all the individual local units of the same firm. Secondly, the vast majority of the surveyed firms had less than three establishments, and almost half had only one establishment. In the few cases where a firm has several establishments in the same local area, the unit of analysis adopted is an aggregate of all the local plants combined.

cooperation behaviour to the local unit is straightforward. However, in the case of multiplant firms with establishments in different localities, it is possible that all the individual establishments do not interact with other firms or organisations to the same extent. However, once again, in the absence of any additional information, we assign the same levels of cooperation and interaction to each establishment within the same firm.[2]

Given the types of data we have at our disposal, the analysis of these data is most appropriately undertaken by employing a series of probit models, in which we estimate the probability of a particular type of innovation taking place, as a function of the size and expenditure characteristics of the firm, the cooperation behaviour of the firm, and the labour acquisition behaviour of the firm. In order to test the relationship between innovation behaviour and the importance of these various features, we estimate three different types of probit models. In each of these three models the binary dependent variable is defined as being equal to 1 if the local establishment has managed to introduce new innovations during the previous two years and equal to 0 if it has not. The three separate probit models cover all three response categories of innovations, i.e. product innovations, process innovations, and new products introduced to the market. Product innovation represents the situation where a firm has introduced a product to the market which is new for the particular firm, but not for the industry. Process innovation represents a situation where a firm has introduced a new production process or a new service delivery process. New products to market represents a situation where a firm introduces a product which is new to the market as whole, and can be considered as being the most advanced form of innovation.

The set of independent variables we employ includes dummy variables for the employment size-band categories of the local establishments, continuous variables for the establishment turnover and the lagged R&D expenditures of the establishment, plus a dummy variable indicating whether the establishment has cooperated with other firms

[2] As with the assignment of the innovation data, this is done because not only the vast majority of Finnish firms have less than three establishments, but also because we assume that information and knowledge received from interactions with other firms and institutions is transferred effectively between the different local units within the same firm (Orlando 2000).

and institutions on R&D issues during the previous two years. Our co-cooperation variable takes a value of 1 if the local establishment cooperates with at least one type of partner, and 0 if it does not have any kind of co-operation relationship with external partners. As we have seen in section 2, the importance of the cooperation dummy variable employed here lies in the fact that inter-firm cooperation is generally regarded as being positively related to the level of face-to-face interaction between firms, because of the need to build up mutual trust and confidence. This variable is therefore employed as proxy for face-to-face contact.

In terms of labour market variables we employ a continuous variable representing the population density of the region, in order to capture any local external agglomeration spillover effects which are external to the individual firm (Ciccone and Hall 1996). In addition, we also employ detailed data about the proportion of the establishment's total employment which has been recently hired. This labour acquisition data is broken down according to both the sectoral origin and also the geographical origin of the recently-hired labour.

We run the series of three different probit models, Model 1, Model 2, and Model 3, in four different sets of circumstances, giving a total of twelve different probit models. Model 1 estimates the likelihood of a firm producing a product innovation, Model 2 estimates the likelihood of a firm producing a process innovation, and Model 3 estimates the likelihood of a firm producing a new product to market innovation. In the first case we test whether innovation is related to either cooperation relations, or the pattern of local and non-local labour mobility. In the second case we test whether the geographical and sectoral origins of the labour acquired are related to innovation, after controlling for cooperation behaviour. In the third case, having controlled for the geographical and sectoral origins of the labour acquired, we test whether the variety of cooperation is significantly related to innovation. In the fourth case we test whether the particular types of cooperation relations are significantly related to innovation, while simultaneously controlling for the geographical and sectoral origins of the labour acquired. As such, our models become progressively more detailed as we move from the three first stage models to the three fourth stage models. The models estimated for the first two stages are estimated on the basis of a pooled dataset from all three survey years of 1996, 2000, and 2002, while the third and fourth state models are estimated on pooled data from the 1996 and 2000 surveys. The reason for this is that the 2002 survey did not contain any questions regarding variety and types of R&D cooperation relations a firm exhibited, whereas both the 1996 and 2000 surveys did so.

## 4. *Results*

Table 2 shows the results of the models which test whether innovation is related to either cooperation relations, or the pattern of local and non-local labour mobility. In terms of the various size characteristics of the establishment, employment size appears to be positively and significantly related to the introduction of new products to market for very small establishment, and negatively related to the probability of producing process innovations by medium sized establishment between 10 and 249 employees. At the same time, turnover is positively and significantly related to new product innovations, and R&D expenditure is positively and significantly related to the introduction new products to market. Interestingly, innovation performance is not unambiguously related to establishment size or R&D expenditure.[3] On the other hand, the one variable which is consistently related to innovation performance is R&D cooperation. Cooperation with other firms or organizations for R&D is always positively and significantly related to all three types of innovation. As we have already mentioned, R&D cooperation relationships require the most intense face-to-face contact in order to be both established and maintained, and for high technology firms at least, have been demonstrated to be the type of inter-firm relations which are most associated with geographical proximity (Arita and

[3] The raw non-adjusted data (McCann and Simonen 2005) shows that between the different size bands, the proportion of establishment innovating is relatively high among both the groups of very small local establishments employing less than 10 people, and also the larger establishments employing more than 50 people, whereas the probability of innovation appears to be lower among the establishments employing between 10 and 49 people. This gives rise to a J-shaped relationship between establishment size and innovation intensity as observed by Tether et al. (1997), who found that found that small enterprises did not introduce a disproportionately large share of innovations relative to their employment share, and only the largest enterprises introduced more innovations than their size would suggest. A similar result also holds in terms of the probability of cooperation for R&D activities.

McCann 2000). Therefore, this result supports the argument that face-to-face contact is always essential for all types of innovation. Having controlled for these various establishment characteristics and also for R&D cooperation, our labour market results find no support for population density as being important. Moreover, in terms of the proportion of labour acquired from within the local region as against outside of the region,[4] although there is tentative evidence for process innovations that labour acquisition from outside of the region is important. These initial results therefore suggest that R&D cooperation is essential whereas the geography of labour market dynamics may not be so critical.

Table 3 reports the results of the models which test whether the geographical and sectoral origins of the labour acquired are related to innovation, after having controlled for R&D cooperation behaviour. As we see, the advantage of smallness appears to become more noticeable for all types of innovation, and the previous results from Table 2 concerning turnover and R&D expenditure also become more marked. R&D cooperation is still always highly significant, and population density is never significant. In term of local labour acquisition, however, labour acquired locally from other firms in the same high technology industry and also from other local non-high technology industries is positively and significantly related to the introduction of both new products to market and also for the introduction of new products.[5] In terms of labour acquired from outside of the region, the acquisition of labour from other high technology industries from other regions is negatively related to the likelihood of introducing either new product innovations or new products to market, while labour acquired from the same industry in other regions it is positively related to the introduction of process innovations.

Table 4 reports the results of the models which test whether the variety of cooperation is significantly related to innovation, having controlled for the geographical and sectoral origins of the labour acquired. In this case, the innovation advantages of smallness are becoming much more striking for both new product innovations and also the introduction

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[4] There are 77 official sub-regions (municipalities, i.e. NUTS 4 regions) in Finland, with an average population of some 65,000.

[5] The result is just outside of the 5% level of significance for new products.

of new products to market, while the results for turnover, R&D expenditure and cooperation all remain the same as before. In terms of the number and variety[6] of R&D cooperation, cooperation with up to two types of partners is significantly related to all three types of innovation, but cooperation with more than two partners is not positively related to innovation. In Table 4 we also see that when we control for the number and variety of a firm's cooperation relationships, the effects of the geographical and sectoral origins of a firm's labour acquisition appear to alter. In particular, in terms of local labour acquisition, labour acquired for the same high technology industry in the same region is now negatively related to product innovations and also unrelated to the introduction of new products to market. At the same time, labour acquired locally from those who were previously unemployed is always negatively related to innovation performance. In terms of labour acquired from outside of the region, labour from the same high technology sector outside of the region is positively related to the introduction of new product innovations, and also labour from research institutes or universities is positively related to the introduction of process innovations. Meanwhile, population density is now negatively related to the probability of introducing new product innovations.

Table 5 reports the results of the models which test whether the particular types of cooperation relations exhibited by a firm are significantly related to innovation, while still controlling for the geographical and sectoral origins of the labour acquired. As we see, the innovation advantages of smallness are very marked for both new product innovations and also the introduction of new products to market. The positive effect of turnover on product innovations remains unchanged while the positive effect of R&D expenditure has disappeared, and in fact is now negatively related to process innovations. Presumably this implies that there is competition for resources between R&D and process innovations. In terms of the types of cooperation, R&D cooperation with other parts of the same enterprise is always positively related to all forms innovation, while R&D cooperation with customers or suppliers is only weakly related to product innovation.

[6] The seven types of cooperation partners are: (1) Other establishments within the same firm (2) Suppliers (3) Customers and clients (4) Competitors (5) Consultants (6) Universities and higher Educations Institutions (7) Government Research Institutes or Non-Profit Private Research Institutes

Meanwhile, R&D cooperation with government or private non-profit research institutes is positively related to the introduction of process innovations. No other forms of R&D cooperation appear to be significantly related to innovation behaviour.

If we now consider the spatial patterns of labour acquisition, we see that having controlled for the types of R&D cooperation relations which a firm exhibits, local labour acquisition is never positively related to any form of innovation, irrespective of the origin of the sectoral labour. This accords with the preliminary findings of McCann and Simonen (2005). Moreover, this is true even after we have controlled for the local population density, which itself is negatively related to the likelihood of introducing product innovations, and unrelated to the probability of producing any other type of innovation. In terms of labour acquired from outside of the region, labour acquired from the same high technology industry in other parts of the country is positively associated with the introduction of product innovations. Meanwhile, the likelihood of introducing process innovations appears to be positively associated with the proportion of labour recently acquired from research institutes or universities in other regions, and negatively related to the proportion of people recently acquired from other high technology sectors in other regions.

## 5. *Discussion and Conclusions*

The results here suggest that R&D cooperation is always essential for the introduction of all types of innovations. However, cooperation between establishments within the same firm enterprise appears to be by far the most important form of cooperation, rather than cooperation with other firms or organizations, which only appears to be significant[7] in specific cases, such as with customer or suppliers for product innovations, and with universities or research institutes for process innovations. This finding would tend to imply that external knowledge linkages and knowledge spillovers may be rather less important for innovation than many authors would assume. Certainly, in terms of promoting innovation, the primacy of a firm's internal knowledge generation capabilities

[7] At the 10% level

over its external knowledge sources is one particular view (Buckley and Casson 1982; Pavitt 1984; Simmie 1998) among several alternative views within the broad literature on the sources of innovation. Our R&D cooperation findings here lend support for this general contention. Given that R&D cooperation relationships require the most intense face-to-face contact in order to be both established and maintained, and that for high technology firms at least, R&D cooperation links have been demonstrated to be the type of inter-firm relations which are most associated with geographical proximity (Arita and McCann 2000), our finding here suggests that the importance of local face-to-face contact in the promotion of innovation may be rather less than proponents of innovation-agglomeration theories (Acs 2002) would assume.

Further support for this argument comes from the labour market findings. In particular, having controlled for the types of R&D cooperation relations which a firm exhibits, the finding that local labour acquisition is never positively related to any form of innovation, irrespective of the origin of the sectoral labour, along with the finding that the local population density is both negatively related to the likelihood of introducing product innovations and unrelated to the probability of producing any other type of innovation, also casts doubt on much of the agglomeration-innovation theories which have been proposed.

Finally, our results concerning the importance of the variety of relations also cast some doubt on certain aspects of the innovation-agglomeration literature. In particular, one common argument is that geographical proximity provides a firm with the possibility for interacting with a greater number of potential contacts (Storper and Venables 2004). The hypothesised advantage here is therefore that an increasing intensity of face-to-face contact is associated with interactions with an increasing variety (Fujita et al. 1999) of firms or individuals per time period. On the other hand, however our findings suggest that face-to-face contact between a firm and a small number of key contacts is relatively much more important than a great variety of contacts. These results appear to be rather more consistent with an argument which is particularly important in the Total Quality Management literature (Schonberger 1996), which suggests that frequent and intense face-to-face contact with just a small selected number of firms and individuals can foster the promotion of so-called ‘win-win’ buyer-supplier relations (Nishiguchi 1994), which themselves allow for long term innovations to take place at all stages in the supply chain. Here, variety is not the important aspect of face-to-face contact, but rather intensity and continuity.

Given that our findings appear to be at odds with much of the currently popular innovation-agglomeration literature, we offer an alternative interpretation of our findings.

Most of the theoretical innovation-agglomeration literature takes a very broad overall view of the relationship between geography and innovation, with a general bias in favour of the advantages of industrial clustering and geographical proximity in the promotion of innovation (Duranton and Puga 2001; Glaeser 1999). Although there are analytical problems involved in applying these arguments to the case of large firms (McCann and Mudambi 2004, 2005) because of the problem of unintended outward knowledge spillovers (Grindley and Teece 1997), the reasons for this bias in favour of the assumed relationship between firm locational clustering and innovation are exactly the same knowledge spillover and labour acquisition arguments underpin the arguments about agglomeration externalities. Unfortunately, however, while empirical research on innovation employs readily-available indices of innovation and R&D, very little of the empirical literature on innovation and agglomeration also has detailed data regarding both knowledge spillovers and also the geography of firm labour mobility. Along with indices of innovation and R&D, some research papers also have information on labour mobility (Audrestch and Stephan 1996; Almeida and Kogut 1999), while others have information on knowledge spillovers along with indices of innovation (Gordon and McCann 2005a). Many of these papers find strong evidence in favour of an association between clustering, knowledge spillovers and innovation (Acs 2002), although some do not (Gordon and McCann 2005a). Yet, without very detailed simultaneous data on both knowledge spillovers and labour mobility, as well as on innovation, identifying the exact mechanism by which any such localization effects are mediated is not possible.

No previous papers, as far as we are aware, have been able to relate data on both knowledge spillovers and labour mobility to innovation simultaneously. As such, no previous papers have been able to identify and distinguish between these two effects. On the other hand, by using data on R&D cooperation as a proxy for face-to-face contact and knowledge spillovers, and combining this with information on the geographical and sectoral origins of a firm’s labour acquisitions, our results here can begin to shed some light on the mechanisms by which innovation takes place. Firstly, our results for R&D cooperation suggest that for all types of innovation, internal knowledge generation is actually more important than external knowledge spillovers. That is not to say that external knowledge spillovers and firm clustering are not important for innovation, but rather that our evidence here points to a relatively lesser importance of external knowledge spillovers in comparison with internal knowledge capability aspects than much of the literature on regional innovation systems (Caniels 2000) would imply. Moreover, this is even case with the very types of inter-firm linkages which are most associated with geographical proximity (Arita and McCann 2000). As such, where geographical localization does occur, it appears to be most advantageous for firms communicating with other parts of the same organization, rather than between separate organizations. This argument is consistent with the arguments of Grindley and Teece (1997) and McCann and Mudambi (2004, 2005). Secondly, the results of the labour market variables actually provide support for human-capital-migration-search arguments (Sjaastad 1962; Hertzog et al. 1993), which suggest that the greater is the geographical area over which labour is searched for and acquired, the greater will be the average quality of the firm’s labour. This migration argument appears to be somewhat at odds with much of the agglomeration labour search (Simpson 1992) and labour productivity (Ciccone and Hall 1996) arguments which focus on the labour market advantages of localization. On the other hand, our findings are consistent with the findings of Gordon and McCann (2005a) and Faggian and McCann (2006) which suggest that innovation performance is related primarily to access to a wider geographical labour market, rather than to the specifics of the local labour market.

To the extent that clustering and innovation are found to be associated, our results here, as well as other broader theoretical arguments regarding the relationship between spatial industrial organization and the sources of innovation (Iammarino and McCann 2007), imply that this outcome is probably most likely related only to the particular information problems faced by small firms. While innovation is most likely to occur in small and medium-sized enterprises, these small firms have neither the scale nor the risk-bearing capacity to provide all of the own key inputs. As such, they need to develop external cooperation relations, and these most easily fostered with other local firms. The result is firm clustering. Yet, as we see from the results here, this is only one limited aspect of the relationship between geography and innovation.

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**Table 2:** The Probit model: Innovation, Cooperation and Labour Mobility (Pooled data for the years 1996, 2000 and 2002)

| **Dependent variable (0,1)** | **Model 1: The introduction of product innovation** | | **Model 2: The introduction of process innovation** | | **Model 3: The introduction of the new products to the market** | |
|---|---|---|---|---|---|---|
| **The name of the explanatory variables** | **The coefficients of Model 1** (p-values in parenthesis) | | **The coefficients of Model 2** (p-values in parenthesis) | | **The coefficients of Model 3** (p-values in parenthesis) | |
| Intercept /Constant | -1.6693 | (0.2022) | 0.5427 | (0.6515) | -2.6382** | (0.0342) |
| Categories of LUs | | | | | | |
| very small LUs (1-9) | 0.7291 | (0.1061) | - 0.6615 | (0.1090) | 0.8417** | (0.0453) |
| small LUs (10-19) | 0.3113 | (0.4258) | - 0.9236*** | (0.0102) | 0.5254 | (0.1461) |
| SMLUs (20-49) | - 0.0127 | (0.9714) | - 1.0085*** | (0.0020) | 0.4053 | (0.2130) |
| SMLUs (50-99) | - 0.2594 | (0.4536) | - 0.7319** | (0.0196) | 0.1891 | (0.5465) |
| SMLUs (100-249) | - 0.2557 | (0.4146) | - 0.5098* | (0.0554) | 0.4403 | (0.1154) |
| Large LUs (250→) | 0.0000 | *Reference category* | 0.0000 | *Reference category* | 0.0000 | *Reference category* |
| Log Turnover | 0.1608*** | (0.0080) | 0.0463 | (0.3998) | 0.0879 | (0.1272) |
| Log R&D expenditures (Lagged) | 0.0288 | (0.5305) | - 0.0413 | (0.3252) | 0.1059** | (0.0164) |
| Cooperation | 1.5000*** | (<.0001) | 0.9459*** | (<.0001) | 0.8143*** | (<.0001) |
| Mobility of labour from the same sub-region (2 year lag) | 0.2072 | (0.1592) | - 0.1186 | (0.3620) | 0.0886 | (0.5084) |
| Mobility of labour from the other sub-regions (2 year lag) | 0.0582 | (0.8083) | 0.3506* | (0.0946) | 0.3274 | (0.1797) |
| Population density | - 0.0002 | (0.5886) | 0.0002 | (0.6115) | 0.0004 | (0.3505) |
| **Number of obs** | 580 | | 514 | | 475 | |
| Log-likelihood | -248.5731 | | -301.0961 | | -279.0992 | |
| **LR statistics** | $\chi^2$ | p - value | $\chi^2$ | p - value | $\chi^2$ | p - value |
| Categories of LUs | 15.68 | 0.0078 | 16.73 | 0.0051 | 6.94 | 0.2252 |
| Turnover | 7.14 | 0.0076 | 0.71 | 0.3986 | 2.34 | 0.1261 |
| R & D expenditures | 0.39 | 0.5303 | 0.97 | 0.3250 | 5.81 | 0.0159 |
| Cooperation | 135.08 | <.0001 | 45.55 | <.0001 | 32.63 | <.0001 |
| Mobility of labour from the same sub-region | 2.04 | 0.1528 | 0.84 | 0.3597 | 0.44 | 0.5069 |
| Mobility of labour from the other sub-regions | 0.06 | 0.8077 | 2.82 | 0.0931 | 1.89 | 0.1695 |
| Population density | 0.29 | 0.5888 | 0.26 | 0.6116 | 0.87 | 0.3498 |
| LR-test (diff., df, p-value) | 89.12 13 | 0.000 | 47.95 13 | 0.000 | 28.90 13 | 0.000 |
| McFadden's likelihood ratio index | 0.264 | | 0.137 | | 0.094 | |
| Efron's pseudo $R^2$ fit measure | 0.312 | | 0.174 | | 0.117 | |

***significant at the 1% level **significant at the 5% level *significant at the 10% level

**Table 3:** The Probit model: Innovations, Cooperation and The Sources of Labour Mobility (Pooled data, years 1996, 2000 and 2002)

| **Dependent variable (0,1)** | **Model 1: The introduction of product innovation** | | **Model 2: The introduction of process innovation** | | **Model 3: The introduction of the new products to the market** | |
|---|---|---|---|---|---|---|
| **The name of the explanatory variables** | **The coefficients of Model 1** | | **The coefficients of Model 2** | | **The coefficients Model 3** | |
| Intercept / Constant | -1.7588 | (0.1942) | 0.9142 | (0.4566) | -2.4308$^{*}$ | (0.0611) |
| Categories of LUs | | | | | | |
| very small LUs (1-9) | 0.8694$^{*}$ | (0.0610) | - 0.7287$^{*}$ | (0.0820) | 0.9158$^{**}$ | (0.0356) |
| small LUs (10-19) | 0.4313 | (0.2812) | - 0.9546$^{***}$ | (0.0080) | 0.5643 | (0.1302) |
| SMLUs (20-49) | 0.1237 | (0.7317) | - 1.0249$^{***}$ | (0.0019) | 0.4986 | (0.1391) |
| SMLUs (50-99) | - 0.1982 | (0.5728) | - 0.7874$^{***}$ | (0.0131) | 0.1763 | (0.5825) |
| SMLUs (100-249) | - 0.2034 | (0.5258) | - 0.5658$^{**}$ | (0.0360) | 0.4496 | (0.1217) |
| Large LUs (250$\rightarrow$) | 0.0000 | *Reference category* | 0.0000 | *Reference category* | 0.0000 | *Reference category* |
| Log Turnover (log) | 0.1657$^{***}$ | (0.0087) | 0.0329 | (0.5590) | 0.0721 | (0.2325) |
| Log R & D expenditures (1 year lag) | 0.0314 | (0.5079) | - 0.0469 | (0.2753) | 0.1137 $^{***}$ | (0.0139) |
| Cooperation | 1.5582$^{***}$ | (<.0001) | 1.0152$^{***}$ | (<.0001) | 0.8806 $^{***}$ | (<.0001) |
| Mobility of labour, **same sub-region** ( 2 year lag) | | | | | | |
| from the same high technology industry | 0.7411$^{*}$ | (0.0694) | 0.0896 | (0.7320) | 0.9461$^{**}$ | (0.0227) |
| from other high technology industry | 0.0543 | (0.9181) | 0.2074 | (0.6207) | - 0.0179 | (0.9710) |
| from research centre or university | 0.0096 | (0.9862) | - 0.3705 | (0.4168) | - 0.6102 | (0.1715) |
| from other industries | 0.8309$^{**}$ | (0.0417) | 0.0118 | (0.9721) | 1.1409$^{**}$ | (0.0250) |
| students | 0.0683 | (0.8639) | - 0.4296 | (0.2124) | - 0.3804 | (0.2356) |
| others (e.g. unemployed) | - 0.5659 | (0.1636) | - 0.0380 | (0.9295) | - 0.8017$^{*}$ | (0.0901) |
| Mobility of labour, **other sub-region** ( 2 year lag) | | | | | | |
| from the same high technology industry | 0.3311 | (0.3801) | 0.8239$^{**}$ | (0.0233) | 0.5494 | (0.2333) |
| from other high technology industry | -1.9710$^{*}$ | (0.0871) | - 1.4020 | (0.3202) | - 2.3353$^{*}$ | (0.0963) |
| from research centre or university | 0.0328 | (0.9597) | 0.3599 | (0.4553) | 4.4450 | (0.2249) |
| from other industries | 0.1204 | (0.8809) | 0.6937 | (0.3415) | 0.4064 | (0.6228) |
| students | - 0.0343 | (0.9628) | - 0.1430 | (0.8160) | 0.1053 | (0.8724) |
| others (e.g. unemployed) | - 0.6792 | (0.5392) | - 0.9919 | (0.3917) | - 0.8385 | (0.4194) |
| Population density | - 0.0005 | (0.2515) | 0.0001 | (0.7729) | 0.0001 | (0.8725) |
| **Number of obs** | 580 | | 514 | | 475 | |
| Log-likelihood | -242.1280 | | -296.7371 | | -266.1842 | |

| **LR statistics** | $\chi^2$ | p - value | $\chi^2$ | p - value | $\chi^2$ | p - value |
|---|---|---|---|---|---|---|
| Categories of LUs | 15.55 | 0.0083 | 15.46 | 0.0086 | 7.18 | 0.2074 |
| Turnover | 7.01 | 0.0081 | 0.34 | 0.5584 | 1.43 | 0.2314 |
| R & D expenditures | 0.44 | 0.5077 | 1.19 | 0.2748 | 6.12 | 0.0134 |
| Cooperation | 135.23 | <.0001 | 49.57 | <.0001 | 34.56 | <.0001 |
| Mobility of labour, **same sub-region** | | | | | | |
| from the same high technology industry | 4.04 | 0.0444 | 0.12 | 0.7327 | 6.84 | 0.0089 |
| from other high technology industry | 0.01 | 0.9176 | 0.24 | 0.6226 | 0.00 | 0.9710 |
| from research centre or university | 0.00 | 0.9862 | 0.67 | 0.4127 | 1.76 | 0.1851 |
| from other industries | 4.43 | 0.0353 | 0.00 | 0.9721 | 5.87 | 0.0154 |
| students | 0.03 | 0.8629 | 1.66 | 0.1975 | 1.41 | 0.2349 |
| others (e.g. unemployees) | 2.04 | 0.1528 | 0.01 | 0.9292 | 2.95 | 0.0861 |
| Mobility of labour, **other sub-region** | | | | | | |
| from the same high technology industry | 0.81 | 0.3694 | 5.61 | 0.0179 | 1.66 | 0.1982 |
| from other high technology industry | 2.59 | 0.1073 | 1.16 | 0.2809 | 3.17 | 0.0749 |
| from research centre or university | 0.00 | 0.9595 | 0.58 | 0.4459 | 3.76 | 0.0526 |
| from other industries | 0.02 | 0.8778 | 1.13 | 0.2870 | 0.29 | 0.5916 |
| students | 0.00 | 0.9628 | 0.05 | 0.8154 | 0.03 | 0.8725 |
| others (e.g. unemployees) | 0.37 | 0.5436 | 0.76 | 0.3818 | 0.65 | 0.4202 |
| Population density | 1.31 | 0.2517 | 0.08 | 0.7730 | 0.03 | 0.8725 |
| LR-test (diff., df, p-value) | 95.56 23 | 0.000 | 52.31 23 | 0.000 | 41.81 23 | 0.000 |
| McFadden's likelihood ratio index | 0.283 | | 0.150 | | 0.136 | |
| Efron's pseudo $R^2$ fit measure | 0.324 | | 0.188 | | 0.159 | |

***significant at the 1% level **significant at the 5% level *significant at the 10% level.

**Table 4:** The Probit model: Innovation, Variety of Cooperation, and the Sources of Labour Mobility (Pooled data, years 1996 and 2000)

| **Dependent variable (0,1)** | **Model 1: The introduction of product innovation** | | **Model 2: The introduction of process innovation** | | **The introduction of new products to the market** | |
|---|---|---|---|---|---|---|
| **The name of the explanatory variables** | **The coefficients of Model 1** | | **The coefficients of Model 2** | | **The coefficients of Model 3** | |
| Intercept / Constant | -11.3791*** | (0.0010) | 2.8173 | (0.2924) | -2.7939 | (0.3046) |
| Categories of LUs | | | | | | |
| very small LUs (1-9) | 3.8112*** | (0.0012) | - 0.3042 | (0.7498) | 2.8865*** | (0.0126) |
| small LUs (10-19) | 3.3762*** | (0.0003) | - 1.5888** | (0.0240) | 1.6268** | (0.0237) |
| SMLUs (20-49) | 2.1586*** | (0.0048) | - 0.8924 | (0.1562) | 1.4520** | (0.0276) |
| SMLUs (50-99) | 0.9137 | (0.1530) | - 1.2003** | (0.0441) | 0.9541 | (0.1103) |
| SMLUs (100-249) | 0.4130 | (0.4499) | - 0.9389** | (0.0320) | 0.9403** | (0.0530) |
| Large LUs (250→) | 0.0000 | *Reference category* | 0.0000 | *Reference category* | 0.0000 | *Reference category* |
| Log Turnover (log) | 0.7295*** | (0.0002) | 0.0728 | (0.6177) | 0.1767 | (0.2206) |
| Log R & D expenditures (1 year lag) | 0.1049 | (0.2890) | - 0.1865** | (0.0290) | 0.0294 | (0.7465) |
| Categories of the wideness of cooperation | | | | | | |
| No partners | - 2.7841*** | (<.0001) | - 1.4426*** | (0.0003) | - 1.7808*** | (<.0001) |
| 1-2 types of partners | - 0.9224* | (0.0842) | - 0.9333** | (0.0175) | - 0.7732*** | (0.0614) |
| 3-4 types of partners | - 0.5223 | (0.2959) | - 1.1563 | (0.6290) | - 0.1441 | (0.7003) |
| 5-7 types of partners | 0.0000 | *Reference category* | 0.0000 | *Reference category* | 0.0000 | *Reference category* |
| Mobility of labour, **same sub-region** (2 year lag) | | | | | | |
| from the same high technology industry | - 5.7411* | (0.0866) | - 2.7913 | (0.2388) | - 0.5735 | (0.8328) |
| from other high technology industry | - 1.8609 | (0.7425) | 2.8085 | (0.5981) | 5.9931 | (0.3987) |
| from research centre or university | 5.9337 | (0.3292) | 0.6111 | (0.8996) | - 1.3189 | (0.8018) |
| from other industries | 0.1567 | (0.8707) | 1.2935 | (0.4455) | 2.3922 | (0.2942) |
| students | - 2.0524 | (0.1940) | 1.0207 | (0.6474) | - 3.2154 | (0.1945) |
| others (e.g. unemployed) | - 2.7455 *** | (0.0016) | - 2.8175* | (0.1043) | - 5.8352*** | (0.0035) |
| Mobility of labour, **other sub-region** (2 year lag) | | | | | | |
| from the same high technology industry | 71.9169* | (0.0589) | 1.1293 | (0.9414) | 41.6184 | (0.1052) |
| from other high technology industry | 11.3487 | (0.5675) | - 10.0651 | (0.1411) | - 2.7650 | (0.8367) |
| from research centre or university | 23.3059 | (0.5074) | 22.8017* | (0.1035) | 15.4599 | (0.3855) |
| from other industries | 3.8675 | (0.4523) | - 2.4587 | (0.6627) | - 0.6332 | (0.9194) |
| students | 1.8495 | (0.4904) | - 2.2598 | (0.4923) | 4.4326 | (0.1454) |
| others (e.g. unemployed) | - 0.2607 | (0.9124) | 0.2461 | (0.9112) | - 0.7531 | (0.7298) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Population density | - 0.0028*** | (0.0086) | - 0.0005 | (0.5504) | - 0.0003 | (0.7561) |
| **Number of obs** | 219 | | 153 | | 151 | |
| Log-likelihood | -55.6587 | | -77.7398 | | -63.1465 | |
| **LR statistics** | $\chi^2$ | p - value | $\chi^2$ | p - value | $\chi^2$ | p - value |
| Categories of LUs | 20.86 | 0.0009 | 11.37 | 0.0445 | 8.34 | 0.1382 |
| Turnover | 16.67 | <.0001 | 0.25 | 0.6166 | 1.54 | 0.2153 |
| R & D expenditures | 1.15 | 0.2831 | 4.96 | 0.0259 | 0.10 | 0.7463 |
| Wideness of cooperation | 71.23 | <.0001 | 17.30 | 0.0006 | 22.79 | <.0001 |
| Mobility of labour, **same sub-region** | | | | | | |
| from the same high technology industry | 2.72 | 0.0992 | 1.37 | 0.2425 | 0.04 | 0.8342 |
| from other high technology industry | 0.10 | 0.7554 | 0.30 | 0.5870 | 0.86 | 0.3542 |
| from research centre or university | 1.06 | 0.3040 | 0.02 | 0.8997 | 0.06 | 0.8027 |
| from other industries | 0.02 | 0.8745 | 0.59 | 0.4415 | 1.22 | 0.2697 |
| students | 1.41 | 0.2345 | 0.21 | 0.6480 | 1.69 | 0.1939 |
| others (e.g. unemployees) | 11.17 | 0.0008 | 4.28 | 0.0385 | 14.99 | 0.0001 |
| Mobility of labour, **other sub-region** | | | | | | |
| from the same high technology industry | 5.61 | 0.0179 | 0.01 | 0.9415 | 3.41 | 0.0649 |
| from other high technology industry | 0.38 | 0.5367 | 2.92 | 0.0877 | 0.03 | 0.8557 |
| from research centre or university | 0.51 | 0.4766 | 3.47 | 0.0625 | 0.99 | 0.3192 |
| from other industries | 0.58 | 0.4460 | 0.19 | 0.6613 | 0.01 | 0.9195 |
| students | 0.47 | 0.4922 | 0.51 | 0.4773 | 2.15 | 0.1427 |
| others (e.g. unemployees) | 0.01 | 0.9126 | 0.01 | 0.9111 | 0.12 | 0.7309 |
| Population density | 7.57 | 0.0059 | 0.36 | 0.5506 | 0.10 | 0.7561 |
| LR-test (diff., df, p-value) | 65.53 25 | 0.000 | 28.28 25 | 0.000 | 26.12 25 | 0.001 |
| McFadden's likelihood ratio index | 0.541 | | 0.267 | | 0.293 | |
| Efron's pseudo $R^2$ fit measure | 0.555 | | 0.307 | | 0.354 | |

***significant at the 1% level **significant at the 5% level *significant at the 10% level

**Table 5:** The Probit model: Innovation, Types of Cooperation, and the Sources of Labour Mobility (Pooled data, years 1996 and 2000)

| **Dependent variable (0,1)** | **Model 1: The introduction of product innovation** | | **Model 2: The introducing of process innovation** | | **Model 3: The introduction of the new products to the market** | |
|---|---|---|---|---|---|---|
| **The name of the explanatory variables** | **The coefficients of Model 1** | | **The coefficients of Model 2** | | **The coefficients of Model 3** | |
| Intercept / Constant | -12.5718*** | (0.0006) | 3.3992 | (0.2362) | -2.9758 | (0.2970) |
| Categories of LUs | | | | | | |
| very small LUs (1-9) | 4.5259*** | (0.0003) | - 0.2813 | (0.7835) | 2.8761*** | (0.0129) |
| small LUs (10-19) | 4.1804*** | (<.0001) | - 1.3363* | (0.0707) | 2.1010*** | (0.0081) |
| SMLUs (20-49) | 2.8335*** | (0.0011) | - 0.7491 | (0.2584) | 1.8701*** | (0.0121) |
| SMLUs (50-99) | 1.3931** | (0.0482) | - 0.9900* | (0.0995) | 1.3548** | (0.0369) |
| SMLUs (100-249) | 0.6547 | (0.2907) | - 1.1753*** | (0.0139) | 1.0135** | (0.0534) |
| Large LUs (250→) | 0.0000 | *Reference category* | 0.0000 | *Reference category* | 0.0000 | *Reference category* |
| Log Turnover (log) | 0.8223*** | (0.0002) | 0.1037 | (0.5189) | 0.2170 | (0.1656) |
| Log R & D expenditures (1 year lag) | 0.1615 | (0.1389) | - 0.2220** | (0.0225) | 0.0070 | (0.9446) |
| Cooperation | | | | | | |
| within enterprise | 1.8126*** | (0.0006) | 0.7874** | (0.0271) | 1.2222*** | (0.0030) |
| with suppliers | 0.8284* | (0.0733) | 0.4778 | (0.1493) | - 0.2434 | (0.5084) |
| with clients or customers | 0.8163* | (0.0919) | - 0.1522 | (0.7083) | 0.5325 | (0.1965) |
| with competitors | - 0.6431 | (0.2358) | 0.3245 | (0.3640) | 0.3504 | (0.3723) |
| with consultants | 0.2160 | (0.6741) | - 0.2038 | (0.5102) | - 0.4223 | (0.2500) |
| with universities and higher education institutes | 0.0961 | (0.8547) | - 0.1664 | (0.6888) | 0.3976 | (0.3507) |
| with government or private non-profit research institutes | 0.8396 | (0.1402) | 1.1620*** | (0.0007) | 0.2556 | (0.5062) |
| Mobility of labour, **same sub-region** ( 2 year lag) | | | | | | |
| from the same high technology industry | - 6.9019* | (0.0694) | - 3.9485 | (0.1377) | - 1.8106 | (0.5318) |
| from other high technology industry | 0.3006 | (0.9686) | 3.7089 | (0.5727) | 10.9225 | (0.1813) |
| from research centre or university | 6.6034 | (0.3624) | 0.7588 | (0.8833) | 0.0969 | (0.9857) |
| from other industries | 0.2885 | (0.7776) | 0.7242 | (0.7027) | 1.4291 | (0.5419) |
| students | - 2.2993 | (0.2537) | 2.0622 | (0.3953) | - 2.0943 | (0.4047) |
| others (e.g. unemployed) | - 3.2600*** | (0.0012) | - 4.0907* | (0.0895) | - 6.5109*** | (0.0018) |
| Mobility of labour, **other sub-region** ( 2 year lag) | | | | | | |
| from the same high technology industry | 76.9516** | (0.0553) | 7.1750 | (0.6587) | 35.7045 | (0.1785) |
| from other high technology industry | 9.6407 | (0.6470) | - 13.5992* | (0.0911) | - 7.6838 | (0.4691) |
| from research centre or university | 22.4983 | (0.4536) | 33.2921** | (0.0286) | 18.9136 | (0.2221) |

| | | | | | | |
|---|---|---|---|---|---|---|
| from other industries | - 0.2191 | (0.9685) | - 3.9143 | (0.5234) | 0.8464 | (0.8934) |
| students | 4.0364 | (0.2102) | - 3.0002 | (0.4050) | 4.4235 | (0.1503) |
| others (e.g. unemployed) | 0.3848 | (0.8794) | 1.6473 | (0.5092) | - 0.7148 | (0.7448) |
| Population density | - 0.0032*** | (0.0062) | - 0.0001 | (0.9124) | - 0.0002 | (0.8790) |
| **Number of obs** | 219 | | 153 | | 151 | |
| Log-likelihood | -52.4981 | | -69.7248 | | -60.6747 | |
| **LR statistics** | $\chi^2$ | p - value | $\chi^2$ | p - value | $\chi^2$ | p - value |
| Categories of LUs | 26.52 | <.0001 | 10.24 | 0.0688 | 9.12 | 0.1043 |
| Turnover | 16.88 | <.0001 | 0.42 | 0.5167 | 1.98 | 0.1599 |
| R & D expenditures | 2.24 | 0.1344 | 5.60 | 0.0179 | 0.00 | 0.9446 |
| Cooperation | | | | | | |
| within enterprise | 15.66 | <.0001 | 4.99 | 0.0255 | 9.76 | 0.0018 |
| with suppliers | 3.43 | 0.0640 | 2.09 | 0.1485 | 0.44 | 0.5052 |
| with clients or customers | 2.93 | 0.0868 | 0.14 | 0.7076 | 1.69 | 0.1934 |
| with competitors | 1.44 | 0.2298 | 0.84 | 0.3606 | 0.81 | 0.3681 |
| with consultants | 0.18 | 0.6723 | 0.44 | 0.5092 | 1.35 | 0.2448 |
| with universities and higher education institutes | 0.03 | 0.8545 | 0.16 | 0.6878 | 0.87 | 0.3513 |
| with government or private non-profit research institutes | 2.28 | 0.1308 | 12.39 | 0.0004 | 0.44 | 0.5076 |
| Mobility of labour, **same sub-region** | | | | | | |
| from the same high technology industry | 3.03 | 0.0815 | 2.16 | 0.1416 | 0.37 | 0.5406 |
| from other high technology industry | 0.00 | 0.9684 | 0.36 | 0.5475 | 2.12 | 0.1458 |
| from research centre or university | 0.96 | 0.3260 | 0.02 | 0.8836 | 0.00 | 0.9857 |
| from other industries | 0.07 | 0.7904 | 0.15 | 0.7010 | 0.39 | 0.5309 |
| students | 0.93 | 0.3347 | 0.72 | 0.3951 | 0.70 | 0.4041 |
| others (e.g. unemployees) | 12.51 | 0.0004 | 3.94 | 0.0472 | 15.06 | 0.0001 |
| Mobility of labour, **other sub-region** | | | | | | |
| from the same high technology industry | 5.88 | 0.0153 | 0.19 | 0.6638 | 2.34 | 0.1264 |
| from other high technology industry | 0.21 | 0.6437 | 4.45 | 0.0348 | 0.27 | 0.6009 |
| from research centre or university | 0.80 | 0.3714 | 6.47 | 0.0110 | 1.80 | 0.1801 |
| from other industries | 0.00 | 0.9685 | 0.42 | 0.5194 | 0.02 | 0.8932 |
| students | 1.42 | 0.2330 | 0.73 | 0.3934 | 2.09 | 0.1483 |
| others (e.g. unemployees) | 0.02 | 0.8789 | 0.44 | 0.5061 | 0.11 | 0.7456 |
| Population density | 8.42 | 0.0037 | 0.01 | 0.9124 | 0.02 | 0.8791 |
| LR-test (diff., df, p-value) | 68.69 35 | 0.000 | 36.30 35 | 0.000 | 28.60 35 | 0.010 |
| McFadden’s likelihood ratio index | 0.567 | | 0.342 | | 0.320 | |
| Efron’s pseudo $R^2$ fit measure | 0.563 | | 0.398 | | 0.366 | |

*** significant at the 1% level ** significant at the 5% level * significant at the 10% level