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*The Effects of Geographical Proximity on Innovation: Evidence from  
Ireland*

**by**

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## *Abstract*

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This paper analyses the effects of geographical proximity on innovation output in small to medium sized enterprises (SMEs) in the South-East and South-West Regions of Ireland. The effects of geography on innovation are analysed in three ways. Firstly, the effects of urbanisation and localisation agglomeration economies on innovation output in SMEs are analysed. Secondly, this paper analyses the effects of geography on a key innovation input; research and development (R&D). Finally, this paper analyses the effects of proximity to external agents on the frequency of interaction with these agents. The data set used by this paper is a combination of the DRIVE for Growth survey as well as data from the Irish Central Statistics Office.

This paper finds what may be a weak urbanisation effect on innovation output in SMEs. However, proximity to a skilled pool of labour, one proxy for localisation economies, is found to have no significant effect on innovation output. Regarding R&D this paper finds that this innovation input is not geographically constrained but that it consistently positively influences innovation levels in SMEs. Interaction with external agents is found to play an important role in the innovation process, however it is found to be unaffected by geographical constraints, with proximity to interaction agents having no significant effect on the frequency of interaction.

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**Keywords:** Innovation; Research and Development; Interaction.

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## *Section 1: Introduction*

This paper analyses the effects of geography on the innovation output of small to medium sized enterprises (SMEs) in two of Ireland's NUTS3 regions; the South-East and South-West. There is emerging regional evidence to suggest that geography matters for innovation. Work by Krugman (1991), Porter (1990) and Scott (1988) suggest that knowledge flows take place more easily over shorter distances primarily due to the advantages of face to face interaction (Gordon and McCann, 2005). Thus, firms' innovation performance may benefit from proximate location to external interaction agents such as their customers, suppliers and competitors or other factors such as higher education institutes (HEIs) or innovation support agencies.

However, the benefits derived from external knowledge flows may not exhaust the potential benefits which may accrue to a firm from its location. The firms may also benefit from what are referred to as external agglomeration economies (Parr, 2002). Two forms of agglomeration economies are considered by this paper; localisation and urbanisation economies. Localisation agglomeration economies arise from the co-location of like firms and their support agents. This allows firms access to specific input providers and a pool of skilled labour (Marshall, 1890; Porter, 1990). Urbanisation agglomeration economies arise from proximity to a large urban area. Benefits which may arise for the firm are access to a large pool of general labour and improved infrastructure which may facilitate business innovation (Jacobs, 1969; Gordon and McCann, 2005).

In attempting to analyse the effects of proximity on innovation in Irish SMEs four research questions are addressed. These are (i) whether proximity to urbanisation and localisation agglomeration economies affects the likelihood of an SME innovating, (ii) whether research and development (R&D) affects the likelihood of an SME innovating and subsequently whether R&D performance is affected by proximity to urbanisation or localisation agglomeration economies, (iii) whether external interaction affects the probability of an SME innovating and whether the frequency of interaction is dependent on geographical proximity and (iv) whether R&D is a substitute or a complement for an SME interacting with external interaction agents.

The structure of this research article is as follows. Section 2 contains a literature review detailing the relevant theory which underpins the research questions addressed in this paper. This section also places the research questions posed by this paper in the context of the key literature in the field of innovation and presents the methodology which is utilised to analyse the research questions. Section 3 identifies and describes the data which is used by this paper. Section 4 presents the empirical results derived in this paper. Section 5 concludes the paper and summarises the main findings and policy implications.

## *Section 2: Literature Review on Innovation*

Schumpeter (1934) identifies two distinct types of innovation: product and process innovation. Product innovation is defined as the introduction of a new good, one which the consumers are not familiar with, or a new quality of a good. Schumpeter (1934) states that process innovation can take four forms: (i) the introduction of a new method of production, (ii) the opening of a new market, (iii) the acquisition of a new source of supply of raw materials or (iv) the carrying out of the new organisation of any industry (Schumpeter, 1934).

When attempting to develop a conceptual model of innovation, Kline and Rosenberg (1986) proposed the Chain Link Model of innovation. This model elaborates on the linear model of innovation<sup>1</sup>, which they felt was inadequate in describing the innovation process. The Chain Link Model highlights the importance of external interaction for innovation through its use of feedback loops and external knowledge sources outside the central chain of innovation. The importance of external interaction is further highlighted by Roper (2001), McCann and Simonen (2005) and Jordon and O’Leary (2007).

The key contribution considered by this paper is whether geographical proximity increases the likelihood of an SME innovating or affects the SME’s R&D performance. Geographical proximity is defined as “...the spatial or physical distance between economic actors, both in its absolute and relative meaning”. The theory behind geographical proximity is that short distances bring people together, favour information contacts and facilitate the exchange of knowledge. It is argued that the greater the distance between agents, the less effective these positive externalities become (Boschma, 2005).

Gordon and McCann (2005) cite research by Krugman (1991), Porter (1990) and Scott (1988) which suggests that knowledge flows take place more easily over shorter distances. This, they state, can be accredited to the ease and reliability of face to face contact. This view is also highlighted by Freel (2002). He notes that the standard theory of communications states that communication efficiency decays as distance increases. As noted, by Storper and Venables (2004), this would imply that geographical proximity to these agents would promote more frequent interaction which in turn would promote an increased level of innovation.

Audretsch and Feldman (2003) argue that the key concept underlying theories which state that proximity facilitates communication is the difference between information and tacit knowledge. Spender (1995) states that all knowledge is comprised of codified and tacit elements. An example of information is the price of gold on the New York Stock Exchange or the value of a currency. Audretsch and Feldman (2003) state that this has a familiar meaning and interpretation irrespective of the location of individuals. Tacit knowledge is defined as being intangible knowledge that is intuitively difficult to codify. It refers to knowledge that is only gained through experience. While information can be codified tacit knowledge, by definition, is either non-codifiable or has not yet been codified.

Von Hippel (1994, cited in Audretsch and Feldman 2003) states that tacit knowledge can only be transmitted through frequent and repeated interaction. Audretsch and Feldman (2003) note that an implication of the distinction between information and tacit knowledge is that the marginal cost of transmitting information across geographic space has been rendered invariant by modern telecommunications while the marginal cost of transmitting tacit knowledge is lowest with frequent social interaction, observation and communication. This supports the concept that geographical proximity to interaction agents would facilitate communication which in turn would promote interaction. This presents the first hypothesis analysed by this paper; whether proximity to external agents facilitates more frequent interaction.

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<sup>1</sup> The linear model of innovation is not utilised by this paper but can be shown as follows:

Basic Research → Applied Research → Development → (Production and) Diffusion

A more complete discussion on the linear model of innovation can be obtained from Godin (2005).

Progressing from the geography of interaction, this paper also analyses the effects of proximity to localisation and urbanisation agglomeration economies. These are examined as they may affect the level of innovation or R&D performance in SMEs. Localisation economies are derived from the common location of independent firms in the same industry. They can be referred to as external economies of scale. The benefits accruing from these localisation agglomeration economies are industry specific (Parr, 2002). Lorentzen (2005) notes that the terms innovation *milieus* or clusters are often applied to these areas. Theory suggests that these clusters increase the likelihood of companies innovating as a result of three main elements (Parr, 2002). The first is access to a pool of labour with specific occupational skills and the accompanying avoidance of labour shortages. The second source involves the availability of a range of auxiliary trades and specialised services. Finally, the third source of localisation economies is related to knowledge spillovers or the advantage to firms of having access (and also contributing) to information on products, processes, innovations, and market intelligence (Marshall, 1890; Parr, 2002).

Urbanisation agglomeration economies result from the common location of firms belonging to different and unrelated industries. These agglomeration economies can also be referred to as external economies of scope. A distinguishing feature of urbanization economies is that they are not specific to firms within a particular industry (Marshall, 1890). There are three main factors concerned with urbanisation agglomeration economies. Firstly, there is a large pool of general labour. The second involves the availability of a wide range of non-industry specific auxiliary trades and services. Finally, the third source of urbanisation economies is related to knowledge spillovers or the advantage to firms of having access to a wide berth of different cultures and ideas (Parr, 2002). The effects of these urbanisation and localisation agglomeration economies on innovation output and R&D present the second and third hypotheses being analysed by this paper.

Innovation output (IO), which can be either product or process innovation, is a result of developing commercially useful knowledge. These sources of knowledge can be both internal and external to a firm. Internal knowledge production (IKP) can arise from R&D as well as the absorptive capacity of the workforce (Jordan, 2007). Cohen and Levinthal (1990) suggest that the absorptive capacity of the workforce is critical for the innovation process as it allows individuals to exploit external knowledge. On the other hand external sources of knowledge can be external interaction (EI) with agents; such as customers, suppliers, competitors, HEIs and innovation support agencies. The standard approach to measuring the effects of IKP and EI on innovation output is to use an innovation production function.

These innovation production functions are similar to standard production functions. The output in the case of the innovation production function is innovation and the inputs are factors which contribute to the level of innovation within the firm. These inputs include R&D and interaction with external agents as well as a range of business specific factors and external factors (such as urbanisation and localisation agglomeration economies). The function describes the way in which these inputs are converted into innovation outputs (Roper, 2001).

$$IO = f(IKP, EI, CV) \quad (1)$$

Equation (1) is an example of the standard format of an innovation production function. IO is expressed as a function of IKP, EI and CV. CV represents a vector of firm specific control

variables (CV) which affect individual firms' capacity to innovate such as the size of the firm or the presence of urbanisation or localisation agglomeration economies. Theory would suggest that IKP and EI have positive effects on IO in companies.

Innovation production functions, or alterations of these functions, are used in this paper to formulate models to test the hypotheses outlined above. Equation 2 presents the first model to be estimated. A logit model is used to estimate this equation.

$$IO_i = \beta_0 + \beta_1 R \& D_i + \beta_2 EI_i + \beta_3 U_i + \beta_4 L_i + \beta_5 Z_i + \mu_i \quad (2)$$

Where:  $IO_i$  is an indicator of innovation output in business  $i$ ,  $R \& D_i$  is an indicator of the extent of Research and Development in company  $i$ ,  $EI_i$  is a measure of the extent of interaction between company  $i$  and its interaction agents,  $U_i$  is a measure of the degree of urbanisation in the area company  $i$  is operating in,  $L_i$  is a measure of the amount of skilled labour in the area company  $i$  is operating in and  $Z_i$  is a range of company-specific factors which may affect company  $i$ 's capacity to innovate.

The first hypothesis being tested is that interaction ( $\beta_2$ ) and R&D ( $\beta_1$ ) should positively influence the level of innovation output in SMEs. The second hypothesis being tested is that geography, in the form of urbanisation and localisation economies, can positively influence the likelihood of an SME innovating. This is measured by the  $\beta_3$  and  $\beta_4$  coefficients. Theory would indicate that the two coefficients should be positive, implying that these factors positively influence innovation (Parr, 2002).

Progressing from this, as R&D is deemed in the literature to be a vital input in the innovation production function the effects of geography, in the form of urbanisation and localisation agglomeration economies, on R&D performance is also analysed.

A variable controlling for interaction with external agents is also included. This is in an attempt to analyse the relationship between R&D and external interaction. Both of these are inputs in the innovation production function and thus are expected to both positively influence innovation. However, these two inputs could have a substitution or complementary relationship. Equation 3 is estimated utilising a logit model.

$$R \& D_i = \beta_0 + \beta_1 EI_i + \beta_2 U_i + \beta_3 L_i + \beta_4 Z_i \quad (3)$$

Where all variables are defined as above. Again this model is testing two hypotheses. The first being whether proximity to urbanisation and localisation economies affects the ability of an SME to perform R&D. This is assessed by the  $\beta_2$  and  $\beta_3$  coefficients. The *a priori* expectations for these coefficients are that both should be positive. The second hypothesis being tested is that external interaction may act as either a complement or a substitute to an SME engaging in internal R&D. A positive  $\beta_1$  coefficient would imply a complementary relationship between R&D and external interaction while a negative coefficient would imply a substitution relationship.

Finally, the concept that geographical proximity to interaction agents increases the frequency of interaction is examined. This paper applies an ordered probit model as an ordinal category was completed by respondents indicating their degree of interaction with external agents

(Kennedy,1992). This paper also considers whether proximity to urbanisation factors affects the frequency of interaction. Model 4 details this method of analysis.

$$EI_{ij} = \beta_0 + \beta_1 R_i + \beta_2 EI_{ik} + \beta_3 GP_{ij} + \beta_4 U_i + \beta_5 Z_i \quad (4)$$

Where  $EI_{ij}$  is an indicator of the interaction between company  $i$  and interaction agent  $j$ ,  $EI_{ik}$  is an indicator of the interaction between company  $i$  and interaction agent  $k$  where  $k \neq j$ ,  $GP_{ij}$  is an indicator of the geographical proximity between company  $i$  and interaction agent  $j$  and all other variables are defined as above.

The main element of interest in this model is the  $\beta_3$  coefficient. This coefficient implies whether geographical proximity to interaction agents increases the frequency of interaction between firm  $i$  and the external agent  $j$ . The hypothesis being tested is that proximity to interaction agents should facilitate easier communication, and, therefore, increased levels of interaction. This would imply that the  $\beta_3$  coefficient should be significantly positive.

### *Section 3: Data utilised by this research paper.*

This paper utilises data from the DRIVE for Growth survey. It was distributed to companies in the South-East and South-West of Ireland by the South-East and South-West Regional Authorities. The survey was designed in the form of a questionnaire and was conducted between November 2006 and January 2007. Table 1 details the response rate for the survey.

Table 1: Survey Response Details

	South-East	South-West	Total
No. of Firms the Survey was Addressed To	542	1077	1619
Number of Respondents	61	162	223
Response Rate	11%	15%	14%

In the survey respondents were asked to include details about the size of their business, the proportion of the workforce with third level qualifications, the amount of man hours their employees spend in training, the age of their business and the sector they operate in. A number of these factors are utilised as control variables in the analysis undertaken by this paper, in order to allow for business specific effects.

Businesses provided information on their level of product and process innovation. Product innovation was measured as the number of new, or improved, goods or services a business had introduced to the market in the past two years. Process innovation was defined in the survey as the four components Schumpeter (1934) identified: the introduction of a new method of production, the opening of a new market, the acquisition of a new source of supply of raw materials or the carrying out of the new organisation of any industry. Businesses were asked to rank the frequency with which they implemented new process innovations over the last two years, either continuously, frequently, regularly, rarely or never. This approach to measuring innovation is consistent with the methodology used by Roper (2001), Freel (2003) and Jordon and O'Leary (2007).

Table 2: Product and Process Innovators

	Product Innovation	Process Innovation
	Percent	Percent
Non innovators	43.95	34.98
Innovators	56.05	65.02

Table 2 details the levels of product and process innovation in the companies surveyed. A company that process innovates was defined as a company which introduced new process innovations regularly, frequently or continuously. A company was defined as a product innovator if it had introduced a new product to the market in the last two years. Companies also indicate whether they perform R&D. A total of 63% of SMEs perform R&D while 33% of these possess a dedicated R&D department.

Businesses provide information on the frequency of interaction with external agents in relation to product and process innovation. Respondents were asked whether they interacted with external agents, continuously, frequently, regularly, rarely or never. Table 3 details the frequency of SME interaction with external agents in percentage terms.

Progressing from interaction the survey also required businesses to specify their proximity to their most important interaction agents. Proximity was measured in four categories. Whether the interaction agent was local (less than one hour drive from the business), whether it was in the same region as the company, whether it was outside the region but within Ireland or whether it was outside Ireland. The approach used by this paper is similar to Kleinknecht and Poot's (1992) analysis of regional effects on R&D. Table 4 details the proximity of SMEs to their most important interaction agents.

Six indicators of urbanization economies (U) are employed. Population density is calculated as the number of persons per square kilometre in the electoral district of the business (CSO, 2006a). For enterprises located in the cities of Cork and Waterford the average population density in the city is applied. The mean density is 1,286 persons per square kilometre.

The next set of urbanization indicators is the distance of responding enterprises to the nearest Institute of Technology, University and international airport. The South-West region has Institutes of Technology in Cork and Tralee and a university in Cork while the South-East has Institutes of Technology in Waterford and Carlow. The distance to the nearest Institute of Technology and university is used irrespective whether these institutions are in the same regions as the responding business. The only airports in the regions are Cork International Airport and Waterford Airport. However, Dublin and Shannon airports are closer for some enterprises. These distances are calculated using AA Roadwatch [available at <http://www.aaireland.ie/routes/>]. The minimum distance between a business and the nearest of these key infrastructural facilities is 2 kilometres and the maximum distance is 150 kilometres.

Whether the business is located in an industrial estate is also included. Industrial estates are present in cities and many towns in both regions. According to IDA Ireland industrial estates are designed to a high standard of services infrastructure for both manufacturing and international services sectors (IDA IRELAND, 2008). One third of responding enterprises are located in an industrial estate.

The final urbanization proxy included is the availability of broadband. This is a key infrastructure that is more likely to be available in urban settings in Ireland, which has a low broadband penetration rate by international standards (European Competitiveness Telecommunication Association, 2007). The availability of broadband is determined through the use of two broadband comparison websites; Get Broadband [available at <http://www.getbroadband.ie>] and Try Switch [<http://www.tryswitch.ie>]. The availability of mobile internet providers is not considered due to relatively poorer quality and slower speeds.

The availability of a skilled labour, which is a form of localization economy, is proxied as the percentage of total regional employment in the same sector as the responding SME (CSO, 2006b). A total of 22 sectors are used, which is the greatest possible sectoral disaggregation available, for each of the NUTS 2 regions. The mean percentage of skilled labour is 5.5%, with a standard deviation of 3.2.

Table 3: Frequency of Interaction for Product and Process Innovation (%)

Frequency of Interaction	Supplier		Customer		Competitor		HEIs		Agency	
	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
Never	13	16	10	20	34	48	39	49	39	44
Rarely	8	6	3	8	26	22	25	23	24	24
Regularly	18	29	19	22	20	17	17	14	17	15
Frequently	34	34	30	28	17	9	13	9	13	14
Continuously	27	15	39	22	4	4	6	5	5	4

Table 4: Proximity to Interaction Agents for Product and Process Innovation (%)

	Supplier		Customer		Competitor		HEIs		Agency	
	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
International	46	45	29	34	27	32	24	23	6	10
National	32	34	36	33	41	39	40	34	44	48
Regional	11	12	20	17	19	18	23	28	31	28
Local (>1 hour drive)	11	9	15	16	13	11	13	15	19	14

## *Section 4: Results of the Empirical Analysis*

Table 5 present a logit estimation of equation 2<sup>2</sup>. It can be observed that interaction with customers and agencies increases the likelihood of a business product innovating by 40% and 17% respectively. The positive customers affect is intuitively expected. Product innovations are new products delivered to markets. It would be expected that an important element of introducing a new product to a market would be customer feedback, the product is aimed at customers, and therefore, their opinion may be vital to its success.

Turning to process innovation it can be observed that interaction with suppliers and agencies increases the likelihood of a business innovating by 21% and 16% respectively. Again these results are intuitively correct. Process innovation often involves an improvement in the way products are produced. For this to be successfully implemented it would be expected that consultation with suppliers would be essential.

From the above analysis it can be observed that interaction can be deemed to increase the likelihood of an SME both product and process innovating. This is consistent with Kline and Rosenberg's (1986) theory of the Chain Link Model, which concludes that interaction reduces uncertainty and increases innovation. It is also consistent with the empirical findings of Jordan and O'Leary (2007a), Jordon (2007), McCann and Simonen (2005), Freel (2003) and Roper (2001).

Performing R&D is found to consistently increase the likelihood of an SME product and process innovating by 17% and 37% respectively. The theory of the innovation production function suggests that R&D is an important input in the innovation process. These results are consistent with the findings of Freel (2003); who uses R&D expenditure as a proxy for the R&D capability of a firm. He finds that increased levels of R&D expenditure results in an increased likelihood of a firm innovating. Therefore, while his R&D proxy differs from the approach used by this paper his conclusion is the same, that R&D is an important input in the innovation process.

Analysing the control variables it can be observed that the larger the SME, in terms of the number of employees, the more likely the SME is to innovate. However, the results suggest that the proportion of the workforce with third level education does not actually affect the probability of an SME innovating. This result is counter intuitive as it would be expected that a highly educated workforce would be more innovative. Cohen and Levinthal (1990) suggest that absorptive capacity, which third level education proxies for, is critical for the innovation process.

Of key importance to this paper, is the implication, derived from the results, that urbanisation agglomeration economies may positively influence SME innovation

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<sup>2</sup> As this paper utilises cross sectional data all standard errors in this paper are calculated using White's Heteroskedastic Consistent standard errors. These estimates are considered robust in the sense that they provide correct standard errors in the presence of violations of the assumption of homoskedasticity (Long and Freese, 2001).

performance. Proximity to a university was found to increase the probability of an SME product innovating while proximity to an airport was found to increase the likelihood of an SME process innovating. These results imply that an SME's location may be important in determining the likelihood of the SME innovating. While only one urbanisation variable in each regression is significant a Wald Test applied to the urbanisation variables indicates that the urbanisation proxy variables are jointly significant. However, it must be noted that this is weak evidence of an urban effect and the author suggests that this concept may form the basis for further research in this area.

Research by Jordan and O'Leary (2007) found that population density increased the likelihood of an SME product innovating. While this variable was not significant in this analysis the conclusions drawn from this are similar. Their results imply a possibility that firms in urban areas may be more likely to innovate. The results displayed in Table 5 imply that SMEs located in close geographical proximity to universities are more likely to product innovate. As the universities analysed in this paper are typical of large urban concentrations this implies that proximity to urban areas is important for product innovation. Thus both papers suggest that there may be a possible urban effect on innovation output.

Regarding localisation economies Jordan and O'Leary (2007), similarly to this paper, found that a local pool of skilled labour did not affect the likelihood of a firm product innovating. McCann and Simonen (2005) found that proximity to a skilled pool of labour actually reduced the likelihood of an SME product innovating. This paper found an insignificant relationship between proximity to a skilled pool of labour and the likelihood of an SME product innovating. These results contradict theory, which would suggest that proximity to a skilled pool of labour should increase the likelihood of an SME product innovating.

Table 5: Logit Model of the Probability of a Company innovating with Strength of Interaction, R&D and Geography.

Dependent Variable (1,0) Name of the explanatory variables	The Probability of product innovating		The Probability of process innovating	
	Coefficients of Model 2 (standard errors in parentheses)	Marginal Effects dy/dx	Coefficients of Model 2 (standard errors in parentheses)	Marginal Effects dy/dx
Intercept/Constant	-0.552 (1.122)		0.3139988 (1.108911)	
Interaction Agents				
Supplier	-0.770 (0.566)	-0.158 <sup>†</sup>	0.976* (0.599)	0.213 <sup>†</sup>
Customer	1.710** (0.758)	0.403 <sup>†</sup>	-0.102 (0.523)	-0.020 <sup>†</sup>
Competitor	0.549 (0.428)	0.120 <sup>†</sup>	-0.405 (0.512)	-0.083 <sup>†</sup>
HEIs	0.208 (0.444)	0.046 <sup>†</sup>	0.054 (0.536)	0.010 <sup>†</sup>
Agency	0.783* (0.431)	0.167 <sup>†</sup>	0.885* (0.540)	0.161 <sup>†</sup>
Research and Development				
Perform R&D	0.722** (0.387)	0.165 <sup>†</sup>	1.782*** (0.430)	0.376 <sup>†</sup>
Firm Specific Variables				
Number of Employees	0.005* (0.003)	0.001	1.005* (0.003)	0.001
Third Level Education	0.006 (0.006)	0.001	0.010 (0.007)	0.001
Sector				
Agriculture	0.000 Reference		0.000 Reference	
Manufacturing	-0.562 (0.900)	-0.127 <sup>†</sup>	-0.839 (0.812)	-0.171 <sup>†</sup>
Services	-0.601 (0.931)	-0.133 <sup>†</sup>	-0.954 (0.848)	-0.185 <sup>†</sup>
Urbanisation Factors				
Broadband	0.397 (0.588)	0.092 <sup>†</sup>	0.001 (0.752)	0.001 <sup>†</sup>
Population Density	-0.001 (0.001)	-0.001	-0.001 (0.001)	-0.001
Distance to IT	-0.008 (0.014)	-0.001	0.008 (0.011)	0.001
Distance to University	-0.008** (0.004)	-0.001	0.001 (0.005)	0.001
Distance to Airport	-0.002 (0.014)	-0.001	-0.025*** (0.010)	-0.005
Industrial Estate	0.347 (0.467)	0.076 <sup>†</sup>	0.754 (0.473)	0.139 <sup>†</sup>
Localisation Factors				
Sector Share Region	-0.005 (0.035)	-0.001	-0.040 (0.040)	-0.001
Number of Observations	167		159	
Log Likelihood	-88.0665		-74.0027	
Pseudo R <sup>2</sup>	0.2005		0.2688	
LR Chi <sup>2</sup>	32.89 (0.0116)		44.99 (0.0002)	
Wald Test of Urbanisation Factors	11.20 (0.0824)		12.62 (0.0494)	

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

<sup>†</sup> is for discrete change of dummy variable from 0 to 1.

Progressing from external interaction this paper now analyses the effects of interaction and geography on the likelihood of an SME performing R&D. As performing R&D was found to positively influence both product and process innovation, as noted in Tables 5, it is important to ascertain whether geography affects R&D performance. Also, since both R&D and external interaction positively influence innovation, this paper analyses the exact nature of the relationship between these two inputs in the innovation production. A logit model is applied to Equation 3 to assess these two research questions, with the estimates displayed in Table 6.

It can be observed in Table 6 that for product interaction four of the five interaction variables are significant: suppliers, competitors, HEIs and agencies. Of these the supplier, HEI and agency variables exhibit positive coefficients. Interaction with each of these agents increases the likelihood of an SME innovating by 6%, 7% and 7% respectively. However, the competitor coefficient displays a negative coefficient indicating that interaction with competitors actually reduces the probability of an SME performing R&D by 7%.

Turning to process interaction it can be seen that only two of the five interaction variables are significant: suppliers and agencies. Both of these agents exhibits a positive coefficient with the marginal effects indicating that interaction with suppliers increases the probability of performing R&D by 6.1% while interaction with agencies increases the probability of performing R&D by 9.8%.

Love and Roper (1999), where their results were significant, concluded that R&D and networking were substitutes. Audretsch et al (1996), however, found evidence that the relationship between R&D and interaction varied across sectors. They found a complementary effect for high technology companies and a substitution effect for low technology companies. In this analysis none of the sector specific variables are significant indicating that there is no sector specific effect. They also indicate that, for SMEs, the majority of external interaction agents act as complements to internal R&D.

It can also be noted for both product and process interaction that third level education is significantly positive. This suggests that the larger the proportion of the SME's workforce with third level education the more likely the SME is to perform R&D. This is intuitively correct as it would be expected that, in order to perform R&D, highly skilled and educated workforce would be required. This implies that the proportion of the workforce with third level education has a positive indirect affect on innovation by increasing the likelihood of an SME performing R&D.

Love and Roper (1999), in their analysis, found that the graduate share of employment in companies significantly affected the likelihood of an SME performing R&D, which is consistent with the findings of this paper.

When analysing the urbanisation and localisation variables it can be observed, in Table 6, that none of these factors are statistically significant. This implies that urbanisation factors do not play an important role in determining whether an SME performs R&D. Also, proximity to a skilled pool of labour was found to have no significant effect on R&D performance.

Concerning urbanisation agglomeration economies Kleinknecht and Poot (1992) found that proximity to urban areas exerted no influence on R&D performance in companies in the Netherlands. This is consistent with the findings in Table 6 which suggest that SMEs in urban areas are no more likely to perform R&D than those located in rural areas.

Table 6: Logit Model of the Probability of a Company Performing R&D with Strength of Interaction and Geography.

Dependent Variable (1,0)	The Probability of Performing R&D with product interaction		The Probability of Performing R&D with process interaction	
Name of the explanatory variables	Coefficients of Model 3 (standard errors in parentheses)	Marginal Effects dy/dx	Coefficients of Model 3 (standard errors in parentheses)	Marginal Effects dy/dx
Intercept/Constant	-2.941 (0.826)		-1.926 (0.763)	
Interaction Agents				
Supplier	0.252* (0.151)	0.059 <sup>†</sup>	0.260* (0.154)	0.061 <sup>†</sup>
Customer	0.253 (0.168)	0.059 <sup>†</sup>	0.130 (0.140)	0.030 <sup>†</sup>
Competitor	-0.317* (0.183)	-0.074 <sup>†</sup>	-0.185 (0.190)	-0.043 <sup>†</sup>
HEIs	0.309** (0.158)	0.072 <sup>†</sup>	-0.010 (0.161)	-0.022 <sup>†</sup>
Agency	0.288* (0.166)	0.067 <sup>†</sup>	0.417*** (0.164)	0.098 <sup>†</sup>
Firm Specific Variables				
Number of Employees	0.002 (0.001)	0.001	0.001 (0.001)	0.001
Third Level Education	0.015*** (0.005)	0.003	0.014*** (0.005)	0.003
Sector				
Agriculture	0.000 Reference		0.000 Reference	
Manufacturing	0.620 (0.673)	0.142 <sup>†</sup>	0.530 (0.661)	0.122 <sup>†</sup>
Services	-0.220 (0.742)	-0.051 <sup>†</sup>	-0.297 (0.733)	-0.069 <sup>†</sup>
Urbanisation Factors				
Population Density	-0.001 (0.001)	-0.001	-0.001 (0.001)	-0.001
Distance to University/IT	0.122 (0.373)	0.028 <sup>†</sup>	0.025 (0.347)	0.006 <sup>†</sup>
Localisation Factors				
Sector Share Region	0.020 (0.030)	0.004	0.013 (0.030)	0.003
Number of Observations	206		206	
Log Likelihood	-115.3461		-120.18849	
Pseudo R <sup>2</sup>	0.1670		0.1321	
LR Chi <sup>2</sup>	36.79 (0.0002)		32.12 (0.0018)	

\*\*\* significant at the 1% level, \*\* significant at the 5% level, \* significant at the 10% level,  
<sup>†</sup> is for discrete change of dummy variable from 0 to 1.

Table 6 suggests that performing R&D is not affected by geography. This paper now turns to the analysis of whether interaction with external agents is constrained geographically. Table 7 presents the results of an ordered probit estimation of equation 4. It can be observed that for interaction for product innovation none of the proximity variables are statistically significant. This implies that proximity to an interaction agent does not increase the frequency with which the SME interacts with that agent. This suggests that SMEs are just as likely to interact with external agents located abroad as they are with agents located in their local area. This contradicts the theory outlined in Section 2 of this paper which suggests that proximity to an interaction agent should foster more frequent interaction with that agent.

It can also be observed that interaction between external agents appears to exhibit a complementary relationship, with SMEs more likely to interact with external agent  $j$  if they already interact with external agent  $k$ . An example of this is that SMEs are more likely to interact with suppliers if they already interact with their customers and competitors. This type of relationship is present for all five external agents, with each agent being linked with at least two other external agents.

Similar results can be observed for interaction for process innovation. It can be observed that in this case two interaction agents exhibit significant proximity variables. The results imply that proximity to competitors increases the frequency of interaction. This suggests a geographical constraint exists for process interaction with competitors. A similar result can be observed for interaction with HEIs. It can be seen that an SME is more likely to interact with HEIs if the SME is located less than one hours drive from the HEI. These two results are consistent with economic theory which would suggest that interaction is geographically constrained. However, while proximity to these agents increases the frequency of interaction it can be observed in Table 5 that interaction with these agents has no significant affect on the likelihood of the SME innovating. This suggests that this more frequent interaction is not transformed into innovation output. Implying that proximity to these agents is not important for innovation.

Interaction agents also exhibit a complementary relationship in this analysis, which is similar to the conclusions obtained for interaction for product innovation. While the overall relationship remains the same the specific effects differ slightly. This is to be expected as interaction for product innovation and interaction for process innovation are distinctly different and thus it follows that inter agent relationships should also differ.

Jordan and O'Leary (2007) found similar results when analysing proximity to interaction agents. They found that all of the proximity variables were insignificant except for proximity to innovation support agencies. This is consistent with the findings presented in Table 7. Jordan and O'Leary (2007) and Jordan (2007) also found a complementary relationship to exist between interaction agents. This is consistent with the findings of this paper.

Table 7: Ordered Probit Model of the Effects of Geography on the Frequency of Interaction for Process Innovation

Name of the explanatory variables	Suppliers		Customers		Competitors		HEIs		Agencies	
	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
Proximity Variable										
Abroad (outside Ireland)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Within Ireland	-0.339	-0.205	0.110	0.218	-0.037	0.573*	0.163	0.164	0.489	0.159
	(0.223)	(0.222)	(0.237)	(0.293)	(0.309)	(0.352)	(0.539)	(0.403)	(0.389)	(0.432)
Within Region	0.022	0.016	0.058	0.285	0.115	0.924**	0.086	0.468	0.454	0.059
	(0.388)	(0.347)	(0.328)	(0.318)	(0.421)	(0.451)	(0.505)	(0.376)	(0.356)	(0.454)
Local (<1 hour drive)	-0.424	-0.298	0.290	0.059	0.321	0.797**	0.652	0.812*	0.559	0.201
	(0.362)	(0.347)	(0.350)	(0.369)	(0.570)	(0.412)	(0.491)	(0.441)	(0.456)	(0.461)
Interaction Agents										
Suppliers	n/a	n/a	0.241***	0.384***	0.428***	0.409***	-0.094	0.024	0.209*	0.149
			(0.084)	(0.111)	(0.124)	(0.146)	(0.135)	(0.164)	(0.113)	(0.142)
Customers	0.433***	0.343***	n/a	n/a	0.318**	0.169	0.295**	0.176	0.364**	0.336***
	(0.102)	(0.088)			(0.124)	(0.133)	(0.132)	(0.138)	(0.171)	(0.133)
Competitors	0.273***	0.290***	0.284***	0.245***	n/a	n/a	0.249*	0.295**	0.097	0.171
	(0.110)	(0.110)	(0.086)	(0.095)			(0.143)	(0.103)	(0.118)	(0.136)
HEIs	-0.001	-0.041	0.107	-0.040	0.098	0.083	n/a	n/a	0.288***	0.332***
	(0.094)	(0.111)	(0.084)	(0.107)	(0.098)	(0.097)			(0.106)	(0.136)
Agency	-0.058	-0.086	0.181**	0.424***	0.256***	0.241**	0.133	0.255*	n/a	n/a
	(0.097)	(0.094)	(0.081)	(0.109)	(0.115)	(0.119)	(0.117)	(0.138)		
Sector										
Agriculture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Manufacturing	0.028	-0.084	0.238	0.688	-0.177	0.022	-0.684*	-0.120	-0.396	0.144
	(0.374)	(0.280)	(0.317)	(0.452)	(0.438)	(0.411)	(0.417)	(0.323)	(0.420)	(0.357)
Services	-0.127	-0.560**	0.288	-0.323	-0.363	-0.331	-0.919**	-0.560*	0.026	0.280
	(0.368)	(0.294)	(0.337)	(0.449)	(0.434)	(0.364)	(0.432)	(0.313)	(0.420)	(0.370)
Control Factors										
Proximity to University/IT	-0.079	-0.299	0.469**	0.894***	0.099	-0.121	-0.464	0.237	-0.217	-0.534*
	(0.228)	(0.200)	(0.219)	(0.224)	(0.267)	(0.337)	(0.351)	(0.310)	(0.285)	(0.304)
Region	-0.047	0.080	0.018	0.048	0.345	0.253	0.320	0.622*	-0.173	0.223
	(0.200)	(0.224)	(0.207)	(0.265)	(0.240)	(0.318)	(0.339)	(0.355)	(0.335)	(0.353)
Number of Observations	135	131	150	124	94	74	68	64	75	67
Log Likelihood	-168.81	-155.71	-161.33	-151.51	-112.95	-88.82	-90.68	-83.10	-98.93	-81.67
Pseudo R <sup>2</sup>	0.1097	0.1182	0.1360	0.1653	0.1827	0.1689	0.1369	0.1443	0.1520	0.1762
LR Chi <sup>2</sup>	41.59	44.99	50.80	60.33	50.51	40.48	38.88	42.57	45.12	28.97
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0023)

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

## *Section 5: Conclusions*

This research paper examines the effects of geographical proximity on innovation output in SMEs located in the South-East and South-West of Ireland. This paper analyses the effects of geography on innovation directly as well as its indirect affects on two key innovation inputs: R&D and external interaction.

The first key finding presented in this paper is the possible positive affect urban areas have on innovation output. Table 5 presents weak evidence that urban areas may increase the likelihood of a business innovating. Proximity to a university increases the likelihood of an SME product innovating and proximity to an airport increases the likelihood of an SME process innovating. A Wald test, analysing the joint significance of the urbanisation proxies, was consistently significant; indicating that as a group these variables positively affect the likelihood of an SME innovating.

While this result is relatively weak, given that in each regression only one proxy is significant, it nonetheless has important implications. Should urban areas increase the likelihood of SMEs innovating this could indicate that SMEs located in rural areas may require more innovation related government assistance relative to SMEs located in urban areas. However, due to the weakness of the results this paper proposes that this specific area could form the basis for further research. This research could take the form of further empirical analysis or through a case study approach.

Regarding localisation agglomeration economies this paper finds no evidence to suggest that proximity to a skilled pool of labour did not affect the likelihood of an SME innovating. However, it is possible that some form of localisation effect is embodied in the interaction variables utilised in this paper. Therefore, while the availability of a skilled pool of labour is insignificant in explaining innovation output other localisation affects may positively affect an SMEs innovation performance.

The second important implication of this paper is that R&D performance is important for an SME's innovation output but that R&D is not affected by geography. The empirical results presented in Tables 6 indicate that SMEs which perform R&D are more likely to innovate. Progressing from this the empirical results also suggest that proximity to urban areas or a skilled pool of labour do not affect the probability of an SME innovating. This result indicates that SMEs located in rural areas are just as likely to perform R&D as those located in urban areas and *vice versa*. These results imply that while R&D is important for innovation it is not affected by geographical location.

Finally this paper finds that external interaction with a number of key agents increases the likelihood of an SME innovation. However, the geographical location of these external agents does not affect the frequency with which an SME interacts with them. Initially estimation of Equation 2 indicated that interaction with customers and agencies increased the likelihood of an SME product innovating while interaction with suppliers and agencies increased the likelihood of an SME process innovating. Further analysis, displayed in Table 7, highlighted that interaction with these specific external agents was not geographically constrained. It was found that

proximity to these agents did not increase the frequency of interaction between an SME and the agent. This suggests that geographical proximity is not important for external interaction.

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