The effects of the frequency of spatially proximate and distant interaction on innovation by Irish SMEs

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Abstract

This paper introduces a new measure to test whether more frequent interaction has a positive effect on innovation by SMEs in the South-West and South-East of Ireland. Based on an original survey, it finds that more frequent interaction increases innovation likelihood, with the probability increasing at a diminishing rate. Distant interaction is more valuable than geographically proximate interaction, although there is a tendency for enterprises to concentrate either on local/regional or national/international interaction. The results question the hypothesis that local interaction is more productive and imply that policy should focus on facilitating SME access to distant agents.

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Introduction

This paper analyses the effects of frequency of interaction with geographically proximate and distant agents on the knowledge sourcing and transformation stages of the innovation value chain for small and medium sized enterprises (SMEs) in the South-West and South-East regions of Ireland.[1] LUNDVALL (1988) and KLINE and ROSENBERG (1986) suggest that interactive learning is crucial for innovation. This implies that more frequent interaction promotes innovation by facilitating the acquisition of tacit knowledge through learning (NONAKA, TOYAMA and KONNO, 2001; LUNDVALL, 2001). The work of KRUGMAN (1991), PORTER (1990) and SCOTT (1988) suggests that these knowledge flows take place more easily over shorter distances, primarily due to the advantages of face-to-face interaction (GORDON and MCCANN, 2005). However, BOSCHMA (2005) and BATHELT, MALMBERG AND MASKELL (2004) suggest that geographically distant interaction agents may also stimulate innovation. Thus, the question is does business innovation benefit more from more frequent interaction with agents, such as customers, suppliers, competitors, higher education institutes (HEIs) and innovation support agencies taking place locally, regionally, nationally and internationally?

A key contribution of this paper is to introduce a measure to account for both the frequency of interaction and the location of the interaction agent. First introduced in JORDAN and O'LEARY (2008), the measure of external interaction considers not just the incidence but also the frequency of interaction. Increased frequency of interaction may increase the likelihood of innovation. Combined with this is the geography of each agent, ranging from local/regional to national/international. The paper differs from the standard approach which focuses on the incidence of interaction and its effects on innovation (see for example MACPHERSON, 1998, FREEL, 2003 and ROPER, DU and LOVE, 2008).

The motivation in studying SMEs is to investigate the roles of research and development (R&D) and external interaction as sources of innovation (ROPER, DU and LOVE, 2008) and the extent to which SMEs are spatially embedded (FREEL, 2003) in two regions of Ireland, which is a small open economy. The paper investigates first, whether SMEs favour local or regional interaction over national or international interaction and second, whether greater levels of interaction frequency with geographically proximate or distant agents are associated with an improved likelihood of innovation. These contributions are made possible through the use of an original survey designed by the authors as part of the 'DRIVE for Growth', an Interreg III B North West European Area Project [see http://www.driveproject.eu/].

In an Irish context, there is limited evidence that geography matters for high-technology businesses regardless of size. JORDAN and O'LEARY (2008) find that geographic proximity to interaction agents does not increase the likelihood of innovation by these enterprises. In addition, in a study of manufacturing businesses on the island of Ireland ROPER (2001) finds that networks play an important part in determining innovation performance with little evidence of an urban hierarchy of innovation. This paper presents a more detailed analysis of the effects of geography and frequency of external interaction on innovation by Irish SMEs.

The next section presents the conceptual framework and the model to be estimated. This is followed by an outline of the survey and the measures used. The empirical results are then discussed and the final section concludes.

Modelling Innovation, Interaction and Geography

The innovation value chain is a useful way of conceptualizing innovation (ROPER, DU and LOVE, 2008). It envisages a process whereby enterprises source knowledge, transform this knowledge into innovation output and finally exploit innovation output for performance gains. This paper investigates the first two stages of the innovation value chain. It considers the roles of frequency of interaction and geography directly in the transformation of knowledge into innovation output and indirectly in the way in which enterprises source knowledge in the first instance.

The transformation of knowledge into innovation output involves the introduction of new products and/or processes as a result of the development of commercially useful knowledge sources both internal and external to the enterprise. Internal knowledge production can arise from Research and Development (R&D) activity. This refers to the process of identifying potential markets, engaging in research, bringing new products and processes to market and interpreting feedback from market and non-market participants (KLINE and ROSENBERG, 1986). Given the informal manner in which business is conducted in SMEs, it is important to measure the performance of R&D as opposed to the incidence of formal spending in a dedicated R&D department.[2] Knowledge transformation is also facilitated by the absorptive capacity of the workforce within the enterprise (COHEN and LEVINTHAL, 1990).

External sources of knowledge may be interaction with external agents such as customers, suppliers, competitors, HEIs and support agencies (JORDAN and O'LEARY, 2008; MCCANN and SIMONEN, 2005; FREEL 2003). External interaction with these agents is an important source of knowledge for product and process innovation (KLINE and ROSENBERG, 1986; LUNDVALL, 1988). Knowledge transformation is essentially about learning, which is a social process especially in the context of the transfer and accumulation of tacit knowledge (POLANYI, 1966). It is therefore important to investigate both formal and informal interaction. As a result in the survey on which this paper is based, interaction is defined to include meetings, networking or other communications that the enterprise perceives as affecting its level of innovation. Interaction may therefore range from social or informal, perhaps unintentional, networking to formal or contractual collaboration. This emphasis on informal as well as formal interaction is supported by the Oslo Manual (OECD, 2005). It is likely to be especially important for SMEs, who have fewer resources, compared to larger enterprises, to establish formal cooperative agreements.

It is hypothesized that increased frequency of interaction with an external agent will increase an enterprises propensity to introduce new products and processes. NONAKA, TOYAMA and KONNO (2001) imply that knowledge sharing is enhanced through shared experience and the building of trust which is facilitated by more frequent interaction over long periods. Moreover, LUNDVALL (1992) suggests that more frequent interaction increases the possibilities for mutual learning thereby resulting in a greater likelihood that tacit knowledge will be transferred.

Frequency of interaction is measured in this paper on a five point scale ranging from never, to rarely, regularly, frequently and continuously. Apart from stipulating a positive relationship between increased interaction frequency and innovation likelihood, the nature of this relationship at the margin has not been explored. Thus, if a business alters its level of interaction from never to rarely (ie less than once per year) or from rarely to regularly (at least once per year), what is the marginal effect on the probability of innovation? Given the complex and serendipitous nature of innovation, it is difficult to hypothesize ex ante whether the relationship is linear, increasing or decreasing. However, this worthwhile question can be illuminated using the approach adopted in this paper.

Geographic proximity refers to the spatial or physical distances between economic actors. According to GLAESAR, KALLAL, SCHEINKMAN and SHLEIFER, *"intellectual breakthroughs must cross hallways and streets more easily than oceans and continents"* (1992: 1127). BOSCHMA (2005) suggests that geographical proximity enhances interactive learning and therefore innovation indirectly by stimulating other dimensions of proximity such as cognitive, organizational, social and institutional proximity. Thus, geographical proximity may be associated with increased frequency of interaction and therefore with an increased propensity to innovate. However, as BOSCHMA (2005) argues, too much geographic proximity may also cause problems of spatial lock-in where "*regions become too inward looking, the learning ability of local actors may be weakened to such an extent that they lose their innovative capacity*" (2005: 70). These difficulties may be addressed by greater geographical openness.

This argument echoes that of BATHELT, MALMBERG and MASKELL (2004) that the co-existence of global pipelines and local buzz may yield competitive advantages to enterprises. It implies that enterprises may have both geographically proximate and distant interaction agents. Local and distant interactions may function in different ways. The former has been characterized as *"frequent, broad, relatively unstructured and largely automatic"* (BATHELT, MALMBERG and MASKELL, 2004: 40), while the latter may be more targeted due to the greater cost of interaction (2004: 43). In either case increased frequency of interaction may lead to improved innovation performance.

The key contributions of this paper are first, to consider the relationship between increased frequency of external interaction and the likelihood of product and process innovation. Second, the paper considers the relative importance of geographically proximate and distant interaction for innovation. These issues are investigated for a sample of 223 SMEs in two of Ireland's NUTS 3 regions. Resource limitations may constrain the amount of research and development activity conducted by these businesses (COHEN and KLEPPER, 1996; ROPER, DU and LOVE, 2008) thereby emphasizing the importance of external interaction for their innovation performance. SMEs may also be more spatially embedded than larger businesses as a lack of resources or a focus on local markets may limit the SME in terms of the reach of its search processes (KAUFMAN and TODTLING, 2001; FREEL, 2003). However, even for SMEs, there may be disadvantages of over-reliance on geographically proximate interaction (BOSCHMA, 2005; BATHELT, MALMBERG and MASKELL, 2004).

The paper begins at the knowledge transformation stage of the innovation value chain by testing the effects of the performance of R&D and the frequency of external interaction on innovation output. In order to test the effects of geography, the location of interaction agents is considered. In addition firm specific variables are included as controls. Equation (1) is estimated using a probit model:

$$IO_i = \alpha_0 + \alpha_1 R\&D_i + \alpha_2 GEI_{ij\,i} + \alpha_3 Z_i + \mu_i \qquad (1)$$

where IO_i are binary indicators of product and process innovation in business i, $R\&D_i$ is a binary indicator referring to whether or not the business performs R&D, GEI_{ij} are ordinal measures for the frequency of interaction between business i and external interaction agent j located locally/regionally or nationally/internationally. It is necessary to combine these categories due to a shortage of observations in each. The combinations chosen are best suited to testing the relative importance of proximity and distance. GEI takes the value of 0 where no interaction occurs, 1 if interaction is rare (ie less than once per year), 2 if regular (at least once per year), 3 if frequent (several times per year) and 4 if continuous (more than several times per year). Five interaction agents are considered namely, customers, suppliers, competitors, HEIs and support agencies. Z_i is a range of business specific factors, including size, sector and the percentage of the workforce with third level education, which is a proxy for the degree of absorptive capacity.

The key feature of this paper is to extend interaction analysis from the basic incidence of interaction to increasing levels of frequency. The coefficient α_2 indicates whether increased frequency of local/regional and national/international interaction with each of the five interaction agents is important for product and process innovation. It is hypothesized that the coefficient $\alpha_2 > 0$. In order to investigate the nature of this relationship at the margin, marginal changes in predicted probabilities of innovating are considered. The relative importance of increased frequency of interaction with proximate and distant agents is also considered. Finally, it is hypothesized that R&D (α_1) positively influences the level of innovation output in SMEs.[3]

Turning to knowledge sourcing, enterprises conduct R&D in the expectation of innovation output. The frequency of external interaction with geographically proximate or distant interaction agents may improve the likelihood of enterprises engaging in R&D. This raises the possibility that geography may also influence innovation output indirectly through its effect on R&D. Following ROPER and LOVE (2001) increased frequency of interaction and R&D may be considered substitutes or complements. Equation (2) uses probit models to estimate:

$$R\&D_i = \beta_0 + \beta_1 GEI_{ij} + B_2 Z_i + \varepsilon_i \qquad (2) - \text{need to add } \beta_2 \text{ for } B_2$$

If R&D and GEI are substitutes ($\beta_1 < 0$) enterprises may compensate for a lack of internal knowledge production by concentrating more on external interaction. If they are complementary then $\beta_1 > 0$, implying that external interaction supports an enterprise's performance of R&D. It is of interest to investigate how enhanced frequency of local/regional or national/international interaction affects R&D. Once again marginal changes in predicted probabilities of performing R&D are considered.

Equation (3) completes the analyses by considering how frequency of interaction with a given agent is affected by geographically proximate or distant interaction with other agents. It tests, for both local/regional and national/international interaction, whether increases in the frequency of external interaction with agents increases the probability of interacting with a given agent. It employs ordered probit models to estimate:

$$GEI_{ij} = \lambda_0 + \lambda_1 R\&D_i + \lambda_2 GEI_{ik} + \lambda_3 Z_i + \omega_i \qquad (3)$$

If interactions between respective agents are complements ($\lambda_2 > 0$) then enhanced frequency facilitated by local/regional or national/international interaction supports interaction with a given agent. If $\lambda_2 < 0$, interaction between different agents are substitutes. This equation also facilitates investigation of the strength and depth of local/regional and national/international interaction.

Description of the Survey

This paper uses survey data collected by the South-West and South-East Regional Authorities as part of the 'DRIVE for Growth' Project [see http://www.driveproject.eu/]. The Authorities cover the NUTS 3 areas of the South-West, consisting of Cork and Kerry, and the South-East, made up of Waterford, Kilkenny, Wexford and south Tipperary. These contiguous regions, with a combined population of just over 1 million, contain two cities in Cork, with a population of 250 thousand (ATKINS, 2008) and Waterford, with a population of over 120 thousand (SOUTH EAST REGIONAL AUTHORITY, 2006). Disposable income per capita in the South-West and South-East was 96% and 93% respectively of the Irish national average in 2006 (CENTRAL STATISTICS OFFICE, 2006a).

As part of the project a self-administered survey, known as the DRIVE survey, was circulated to 1,619 enterprises employing 250 persons or less in all sectors, excluding agriculture, forestry and fisheries and public services, during the winter of 2006/2007. Table 1 displays the number of surveys distributed. A total of 223 enterprises responded, with the response rate being 14%. This compares favourably to other innovation surveys such as FREEL (2003) and OERLEMANS, MEEWS and BOEKEMA (2001). Compared to studies using the EU wide Community Innovation Survey (KLOMP and VAN LEEUWEN, 2006 and LÖÖF and HESHMATI, 2006) this response rate is low. However, by introducing unique measures of interaction frequency the DRIVE survey makes a worthwhile contribution.

Of the total, 21% of respondents are traditional manufacturing, 27% are in modern manufacturing and 52% are in private services. The distinction between traditional and modern manufacturing is warranted given the dominance of high-technology manufacturing in the Irish enterprise base. It should be noted that the median age of enterprises is 15 years with a standard deviation of 28 years. The median number of employees is 17 (standard deviation of 98) and the average number of employees with third level education is 35 % (standard deviation of 34%).

[Table 1 around here]

Product and process innovation are defined in line with similar studies such as ROPER (2001) and JORDAN and O'LEARY (2008) and are based on SCHUMPETER'S (1934) definition of innovation. Product innovation is defined as the introduction of new or improved goods/services, which may be either new to the market or to the business, during the reference period, which is 2004 to 2006.[4] Process innovation is defined as (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 or (iv) the re-organization of management or distribution channels. Enterprises indicated the frequency with which they implemented new processes during the reference period on an ordered scale as follows: continuously, frequently, regularly, rarely or never.

The survey shows that 56% of the enterprises introduced a new product in the reference period. For the purposes of this paper process innovation is defined as the introduction of new processes either, regularly, frequently or continuously. A total of 65% of respondents indicated that they engaged in process innovation. Enterprises were asked to indicate whether they performed R&D during the reference period with 63% seeing themselves as doing so.

Respondents classified their frequency of interaction as continuously, frequently, regularly, rarely or never. Table 2 presents the frequency of interaction for product and process innovation by interaction agent. For a clear majority of enterprises, regular, frequent or continuous interaction occurs for both product and process innovation with suppliers (79% for both) and customers (88% and 72% respectively). This strong interaction is in contrast to the weaker interaction for product and process innovation with competitors (41% and 30% respectively), HEIs (36% and 28%) and agencies (35% and 33%). These differences are significant at the 99 % level[5].

[Table 2 around here]

Turning to geography Table 3 presents the location of the enterprises' most important interaction agent for both product and process innovation. Nearly 80% of enterprises indicate their most important supplier for product and process innovation is located outside their own region (ie either international or national). For customers and competitors this percentage is approximately two thirds. For HEIs it is 64% for product and 57% for process while for support agencies closer to 50% of enterprises engage in these forms of distant interaction for product and process innovation. These differences are also significant at the 99 % level[6].

[Table 3 around here]

Empirical Results

Table 4 presents the results for Equation (1). Of the twenty estimated α_2 coefficients, which measure the influence of interaction frequency on the likelihood of innovation, seven are statistically significant for product and process innovation. It is notable that the expected positive sign of α_2 is not evident in all cases, as a negative sign is

evident in two. National/international linkages with customers and agencies are beneficial for product innovation and with suppliers and agencies for process innovation, although distant linkages with competitors have a negative influence. There is a more mixed picture with local/regional linkages. No significant positive or negative linkages are observed for product innovation while the positive effects of supplier interaction for process innovation are mitigated by unfavorable effects from customers. On balance it appears that distant interaction is more valuable than geographically proximate interaction for the innovation performance of these SMEs. This provides some support for the hypotheses proposed by BOSCHMA (2005) and BATHELT, MALMBERG and MASKELL (2004) that global pipelines are an important source of knowledge for innovation.

[Table 4 around here]

The significance of national/international customers for product innovation points to the importance of interaction with distant customers for SMEs in the South-West and South-East regions of Ireland. This may not be surprising given the importance of exporting for Irish business, with approximately 50% of Irish SME turnover being exported.[7] The negative local/regional effect from interaction with customers for process innovation is disquieting. It may suggest an absence of sophisticated customers supporting process innovation in these regions (Porter, 1998). The international focus of nationally based innovation support agencies such as IDA Ireland and Enterprise Ireland may explain the positive effect of interaction frequency with national/international agencies for both product and process innovation. Irish enterprise policy places a significant emphasis on exporting (ENTERPRISE STRATEGY GROUP, 2004).

A common result in the literature is that interaction with suppliers is important for process innovation (see for example, Freel, 2004 and ROPER, DU and LOVE, 2008). This paper reveals that increased interaction frequency with both local/regional and national/international suppliers enhances the likelihood of process innovation, with national/international linkages being marginally more important. The results also show a negative effect from increased interaction frequency with national/international competitors for process innovation. This may be due to the conflicting objectives of such interaction. The potential benefits of pooling information may be offset by appropriation concerns from sharing information with competitors. This may result in the unintended consequences of formal or informal interaction outweighing the intended consequences (PARK and RUSSO, 1996).

The introduction in this paper of a measure to account for the frequency of interaction, enables light to be shed on the degree to which different frequencies of interaction with agents affects the probability of innovation. Thus for example, increased frequency of interaction with national/international suppliers for process innovation increases the innovation likelihood. Based on predicted probabilities it is possible to calculate the change in the effect at each level of interaction frequency since the interaction measures are ordinal (LONG and FREESE, 2001). These marginal changes are presented in Table 5. It can be seen that for interaction with national/international suppliers the probability of process innovation increases at the margin by 9.4% from no interaction to rare interaction, to an increase of 8.4% from

rare to regular interaction, to a lower rise of 7.1% from regular to frequent and finally diminishing to an increase of 5.6% from frequent to continuous interaction.[8]

[Table 5 around here]

This pattern of the probability of innovation increasing at a diminishing rate as the frequency of interaction increases is present for all interaction agents with which there is a positive association between interaction frequency and innovation output. This suggests that there may be diminishing marginal returns on the investment of effort, and perhaps resources to incremental interaction frequency. For example, as enterprises interact more frequently with customers or suppliers, there may be less and less new knowledge to be acquired for innovation. This implies that the greatest incremental gains in knowledge are to be achieved by interaction occurring less frequently.

Table 4 confirms a consistent result in the international literature, that performing R&D increases the probability of product and process innovation (see for example FREEL, 2003 for SMEs and ROPER, DU and Love, 2008 for enterprises of all sizes). Also, the higher the proportion of the workforce with third level education and the larger the business the more likely the SME is to process innovate.

The key importance of R&D raises the question of the extent to which performing R&D may in turn be influenced by the various forms of external interaction conducted by the firm. As such, at the knowledge sourcing stage of the innovation value chain, the frequency of external interaction may have an indirect influence on innovation. To test this, Table 6 presents the results for Equation (2).

[Table 6 around here]

Only six of the twenty estimated β_1 coefficients are significant. Increased frequency of interaction for product innovation with local/regional suppliers, national/international customers and local/regional and national/international agencies increases the likelihood of SMEs performing R&D. For process innovation only interaction with national/international customers increases the likelihood of an SME performing R&D. Once again, Table 7 shows that the probability of performing R&D increases at a diminishing rate as the frequency of interaction increases. For example, the predicted probability of performing R&D from increased interaction frequency with local/regional suppliers for product innovation increases by 7.84% from no to rare interaction declining to a marginal rise of 5.34% from frequent to continuous interaction. Overall, these results suggest that performing R&D is complementary to interaction with these external agents.

[Table 7 around here]

From Table 4 it can be observed that interaction with local/regional suppliers and agencies for product innovation and with national/international customers for process innovation are not statistically significant. These interactions therefore operate indirectly through their effect on the performance of R&D. However, interaction with local/regional competitors for product innovation reduces the likelihood of a firm performing R&D, thus signifying a substitution effect.

Overall this represents a modest widening of the effects of external interaction on the innovation performance of SMEs. It appears once again that national/international interaction matters more than local/regional interaction, thus pointing to the importance of forging linkages outside the region for the performance of the important function of R&D. It is worth noting that absorptive capacity, as measured by the proportion of the workforce with third level education, has a consistently positive effect on the performance of R&D. Indeed, Table 4 shows that this measure is also positive and significant for process innovation. This result is similar to JORDAN and O'LEARY (2008). It points to the importance of the SMEs internal resources for the innovation activities of Irish SMEs.

Table 8 presents the results for the firms' knowledge sourcing activities for product innovation. The first five columns analyse the determinants of local/regional interaction frequency for product innovation. It can be observed that twelve out of a possible forty estimated interaction coefficients (ie λ_2) are significant, with all exhibiting positive coefficients. The final five columns present the results for national/international interaction. In this instance nineteen of the forty external agents are statistically significant, with seventeen positive and two negative. This suggests that in general increased frequency of interaction between external agents is complementary (ROPER, DU and LOVE, 2008). The exceptions to this are firms interacting with local/regional HEIs are less likely to interact with national/international customers and competitors.

[Table 8 around here]

Overall, Table 8 indicates a tendency for enterprises to concentrate either on local/regional or national/international interaction. For local/regional interaction, of the twelve positive effects identified all but three of these are also at the local/regional level. This suggests that enterprises are more likely to interact at the local/regional level if they do so already with other agents. A similar, though not as prevalent, pattern can be observed in the final five columns of Table 7. Of the seventeen positive interaction effects, eleven are at the national/international level. This indicates that enterprises are more likely to interact with national/international agents if they are already interacting at this level with other agents. These results may reflect different market horizons of SMEs in the South-West and South-East regions. Those which focus locally or regionally may be more embedded in the local/regional economy. However, while those concentrating more on national/ international interaction appear to be less embedded, the evidence from Table 4 is that they are more likely to be innovative. For example, none of the local/regional external agents exerted a positive direct effect on product innovation.

Turning to the significant interactions as indicated in Table 4, the decision by SMEs to, for example, interact with national/international customers for product innovation is positively related to distant interaction with suppliers and competitors and to both proximate and distant interaction with agencies. These results suggest that while national/international suppliers and competitors and local/regional agencies have no direct impact on the probability of a firm innovating, they may have an indirect role. By interacting with these agents a firm is more likely to interact with national/international customers, thus increasing the probability that the firm will

product innovate. Similar indirect effects are also observable for other significant interactions that emerged in Table 4.

Table 9 presents the results for the firms' knowledge sourcing activities for process innovation. These are broadly similar to those for product innovation with the vast majority suggesting that interaction is complementary. The first five columns display the results for local/regional interaction for which sixteen out of forty are significant. For national/international interaction, nineteen of the interaction coefficients are significant.

[Table 9 around here]

Once again there is evidence that enterprises favour either local/regional or national/international interaction. Of the fifteen positive and significant interaction coefficients for local/regional interaction, eight are local/regional. In the final five columns, of the seventeen positive and significant coefficients, twelve are national/international. This suggests that interaction for process innovation is also geographically specialized, although not quite as marked as it seems to be for product innovation.

Turning to the significant interactions in Table 4, local/regional interaction with suppliers, which has a positive effect on process innovation, is positively related to local/regional interaction with competitors, thus suggesting the presence of indirect effects. This example once again suggests a myriad of indirect effects from interaction agents to other interaction agents and on to process innovation.

Concluding Comments

Based on an original survey of SMEs in the South-West and South-East regions of Ireland, this paper analyses the effects of the frequency of interaction with geographically proximate and distant agents for the knowledge transformation and sourcing stages of the innovation value chain. Its main contribution is to introduce a measure to account for both the frequency of interaction and the location of interaction agents. It might be expected that, other things being equal, increased interaction frequency would increase the propensity to introduce new products and processes (NONAKA, TOTAMA and KONNO, 2001 and LUNDVALL, 1992). In addition there are competing and widely documented hypotheses as to the importance of location for both the development of new products and processes and the sourcing of knowledge for innovation (KRUGMAN, 1991; PORTER, 1990; SCOTT, 1988; BATHELT, MALMBERG and MASKELL, 2004 and BOSCHMA, 2005).

It appears that distant interaction is more valuable than geographically proximate interaction for the introduction of new products and processes by these SMEs. This finding is reinforced when it comes to sourcing knowledge for research and development. Decisions by these enterprises to engage in external interaction appear to operate at two levels. Enterprises that interact locally/regionally with certain agents also tend to interact locally/regionally with others. Similarly, enterprises that interact nationally/internationally also tend to do so with others. These results are

suggestive of lock-in whereby SMEs are more inclined to engage in local/regional or national/international interaction, and less inclined to participate in both. Given that distant interaction is more valuable, these results suggest that local/regional lock-in is problematic for SMEs, whose innovative capacity may be stymied by being too inward looking.

These findings lead to a questioning of the received wisdom that the best sources of knowledge are local, thus implying that in the case of Irish SMEs global pipelines are more important that local buzz (BOSCHMA, 2005; BATHELT, MALMBERG and MASKELL, 2004). The paper echoes the emerging evidence in the international literature that distance may not be a barrier to knowledge flows and that global interaction is important for innovation (see for example GALLIE, 2009 and BRAMWELL, NELLES and WOLFE, 2008).

The survey facilitated analysis of five interaction agents situated locally/regionally and nationally/internationally for both product and process innovation. This fine-grained investigation of the importance of twenty external interaction possibilities for innovation by SMEs facilitates the testing of a hypothesis, that more frequent interaction increases the probability of innovation. In the majority of statistically significant cases, the results confirm the premise that more frequent interaction increases the propensity to innovate.

Interestingly the results show that the probability of innovation increases at a diminishing rate as the interaction frequency increases. This suggests that the greatest incremental gains are to be achieved from interaction occurring less frequently. More frequent interaction, defined as formal or informal meetings, networking or other forms of communications, is less productive at the margin for the enterprise than less frequent interaction. It would be of interest to extend the approach by measuring the cost of interaction. This would shed light on the extent to which the benefits exceed cost at the margin and would be especially worthwhile given the suggestion by BATHELT, MALMBERG and MASKELL that distant interaction may be more costly (2004: 43).

These results may underscore the earlier finding of the importance of distant as opposed to geographically proximate interaction, since all other things being equal, the decision to interact for the first time with, for example, a distant supplier will improve the likelihood of innovation more at the margin than the decision to interact frequently as opposed to regularly with a local supplier. The finding therefore questions the hypothesis that local interaction is more productive because it facilitates more frequent interaction.

In a minority of statistically significant cases, it is found that more frequent interaction decreases the probability of SMEs introducing new products and processes. This result, which applies for both local/regional and national/international interaction, is perhaps not surprising given that up to twenty interaction linkages are being investigated. It points to some potential pitfalls from interaction that is uncovered in this very detailed analysis of interaction. These findings would be overlooked in studies where combined measures of interaction are used.

The paper has important implications for policymakers. The greater importance of distant interaction casts doubt on the appropriateness of policymakers offering incentives to enterprises to form local/regional clusters or networks of suppliers, customers, competitors, HEIs and support agencies to promote innovation. This has been a feature of enterprise policy in Irish regions (see for example ENTERPRISE STRATEGY GROUP, 2004 and NATIONAL SPATIAL STRATEGY FOR IRELAND, 2002). The absence of evidence of strong local/regional linkages may not be surprising given the limited size of the Irish domestic market and the overriding importance of exporting. The relative importance of distant linkages points to policymakers putting greater emphasis on the development of efficient transport and communications infrastructures that facilitate easier access to distant agents.

The introduction of a measure to account for both the frequency of interaction and the location of the interaction agent is an important addition to the literature. The approach taken should be employed in larger samples of SMEs and indeed larger enterprises. This would facilitate separate analyses of the importance of local as opposed to regional, national and international interaction. It would also be informative to employ time distances measures of interaction proximity in place of the co-location measure used here.

This paper has shown that, in the majority of cases, increased frequency of external interaction increases the likelihood of innovation. A cross section study of this kind may be hampered in uncovering the importance of the depth of the relationship between the enterprise and the interaction agent. For example, a close relationship built up over a number of years may lead to infrequent but, as found in this paper, more productive interaction at the margin. This would not be distinguishable from other kinds of interaction. For example, a first chance meeting with an unfamiliar interaction agent may also be classified by the responding enterprise as an infrequent interaction. This suggests the importance of developing longitudinal data on interaction frequency and innovation performance, which might involve interview and case study as well as econometric methodologies.

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Appendix 1: Definitions of Sectors

Sectors in Survey:	Sectoral Dummies in Estimations:
Mining and Energy	Traditional Manufacturing
Food, Drink and Tobacco	
Textiles and Clothing	
Pharmaceuticals, Chemicals, Rubber and Plastic Products	Modern Manufacturing
Electronics	
Transport Equipment	
Other Manufacturing (including equipment)	
Construction	Services
Wholesale and Retail	
Financial Services	
Hotels and Restaurants	
Transport and Communication	
Other Market and Professional Services	
Software	

Table 1: Survey Response Details

	South-East	South-West	Total
No. of Businesses to which the Survey was addressed	542	1077	1619
Number of Respondents	61	162	223
Response Rate	11%	15%	14%

Table 2: 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 3: Proximity to Interaction Agents for Product and Process Innovation (%)

Proximity	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

Table 4: Probit Model of the Probability of a Firm Innovating

	Product Innovation	Process Innovation
Suppliers		
Local/Regional	-0.0712	0.0675*
	0.0457	0.0428
National/International	0.0171	0.0871***
	0.0306	0.0324
Customers		
Local/Regional	0.0255	-0.0824***
	0.0355	0.0346
National/International	0.0539*	-0.0196
	0.0301	0.0306
Competitors		
Local/Regional	-0.0325	-0.0210
	0.0600	0.0637
National/International	0.0253	-0.1074**
	0.0513	0.0529
HEIs		
Local/Regional	0.1075	-0.0040
	0.0711	0.0538
National/International	0.0083	0.0005
	0.0423	0.0526
Agencies		
Local/Regional	-0.0620	0.0601
	0.0488	0.0607
National/International	0.0942*	0.1330***
	0.0507	0.0551
Perform R&D	0.2988***	0.3812***
	0.0760	0.0672
Employees	0.0005	0.0012***
	0.0004	0.0004
Third Level Education	0.0017	0.0033***
	0.0012	0.0012
Sector[3]		
Advanced Manufacturing	0.0808	0.0153
	0.1004	0.0923
Services	-0.0414	-0.1255
	0.0962	0.1034
Obs.	219	219
R2	0.1913	0.2755
Chi2	52.26	73.11
Prob>Chi2	0.0000	0.0000

Note 1: All values are marginal effects derived from probit model.
Note 2: *** indicates significant at 1%, ** indicates significant at 5% and * indicates significant at 10%
Note 3: Basic manufacturing is the reference category

Table 5: Marginal Change in Predicted Probability of Innovating as the Level of Interaction Increases

	Product Innovation		Process Innovators				
	Customers national/inter.*	Agencies national/inter.*	Suppliers local/regional*	Supplier national/inter***	Customer local/regional***	Competitors national/inter**	Agencies national/inter***
None to Rarely	5.52%	9.33%	6.65%	9.38%	-8.20%	-11.00%	12.99%
Rarely to Regularly	5.39%	8.50%	5.89%	8.41%	-8.99%	-12.03%	9.87%
Regularly to Frequently	5.17%	7.30%	5.04%	7.10%	-9.33%	-11.99%	6.53%
Frequently to Continuously	4.86%	5.91%	4.15%	5.63%	-9.17%	-10.88%	3.74%

Note 1: Only the predicted probabilities of those variables which have a significant effect on the probability of product innovation in Table 4 are reproduced.

Note 2: From Table 4, *** indicates significant at 1%, ** indicates significant at 5% and * indicates significant at 10%

Table 6: Probit Model of the Probability of a Firm Performing R&D

	Product Interaction	Process Innovation
Suppliers		
Local/Regional	0.0791**	0.0647
	(0.0410)	(0.0428)
National/ International	0.0328	0.04
	(0.0275)	(0.0301)
Customers		
Local/Regional	0.0182	0.0206
	(0.0348)	(0.0363)
National/International	0.0688***	0.0565**
	(0.0295)	(0.0299)
Competitors		
Local/Regional	-0.0900*	-0.0518
	(0.0540)	(0.0638)
National/International	-0.0526	-0.0336
	(0.0459)	(0.0552)
HEIs		
Local/Regional	-0.0153	-0.0009
	(0.0601)	(0.0563)
National/International	0.0404	-0.0058
	(0.0386)	(0.0436)
Agencies		
Local/Regional	0.0690*	0.0318
	(0.0435)	(0.0541)
National/International	0.0833*	0.0608
	(0.0466)	(0.0425)
Employees	0.0005	0.0003
	(0.0003)	(0.0003)
Third Level Education	0.0042***	0.0039***
	(0.0012)	(0.0011)
Sector[3]		
Advanced Manufacturing	-0.1702*	-0.1953**
	(0.1027)	(0.1014)
Services	-0.1892*	-0.1552
	(0.1009)	(0.1032)
Obs.	219	219
R2	0.1549	0.1113
Chi2	40.82	30.70
Prob>Chi2	0.0002	0.0061

Note 1: All values are marginal effects derived from probit model.
Note 2: *** indicates significant at 1%, ** indicates significant at 5% and * indicates significant at 10%
Note 3: Basic manufacturing is the reference category