Journal of the Statistical and Social Inquiry Society of Ireland
Vol. XXXVII

IS IRISH INNOVATION POLICY WORKING? EVIDENCE FROM IRISH TECHNOLOGY BUSINESSES

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(read before the Society, 25 October 2007)

***Abstract*:** In the last decade Irish innovation policy has been focused on Higher Education Institutions (HEIs). This paper explores the effects of HEIs, in the context of interaction with other interaction agents, on the innovation output of Irish high-technology businesses. Based on a survey of 184 businesses in the *Chemical and Pharmaceutical*, *Information and Communications Technology* and *Engineering and Electronic Devices* sectors, the paper estimates the importance of in-house R&D activity and external interaction with HEIs, support agencies and other businesses for product and process innovation. A key finding is that the greater the frequency of direct interaction with HEIs the lower the probability of both product and process innovation in these businesses. There is some evidence of a positive indirect HEI effect, through complementarities of interactions with suppliers and support agencies. However, while external interaction is important for innovation output, there is little evidence that geographical proximity matters. These findings have important implications for Irish innovation policy. Last year's *Strategy for Science, Technology and Innovation: 2006 to 2013* committed an additional €1.88 billion for research and commercialisation programmes in HEIs. The econometric results presented suggest that this substantial public investment in HEIs may have a disappointing, and perhaps even a negative, effect on the innovation output of Irish business, thus undermining future Irish prosperity. In addition, the absence of evidence supporting the existence of Irish clusters and networks for innovation suggests that policymakers long-standing support for these have been misguided. The paper concludes by advocating that innovation is a business rather than a technological phenomenon and argues for a changed role for HEIs to one of responding to innovative businesses.

Keywords: Innovation, Research and Development, Interaction, Innovation Policy
JEL Classifications: O31, O32, O38

1. INTRODUCTION

This paper employs survey-based evidence on Irish high-technology businesses to explore the drivers of innovation in what are regarded by policymakers as the key sectors for Ireland's future competitiveness. It employs multivariate logit techniques to estimate the importance for these businesses of research and development (R&D) activity and external interaction with other businesses, HEIs and support agencies for the probability of product and process innovation. It further investigates the role of geographic proximity for the innovation output of these businesses. These are crucial questions for policymakers given the now well-established state support for business R&D expenditure, higher education R&D expenditure and networking.

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The next section sets the policy context for the paper. This is followed in sections 3 and 4 by the conceptual framework and a description of the survey. Section 5 presents the survey results for the levels of product and process innovation and the extent of R&D activity. It also presents the levels of interaction and the proximity of interaction agents. Section 6 then turns to the key questions on the effectiveness of business R&D, interaction and proximity for the innovation output of high technology businesses. Section 7 draws out the policy implications of the findings.

2. THE POLICY CONTEXT

As part of its strategy to develop as a knowledge and innovation-based economy, the Irish government is increasingly targeting investment in science and technology, the promotion of which is now at the heart of Irish enterprise development policy. The government is committed to €20 billion new investment under the Enterprise, Science and Innovation priority in the new National Development Plan (2007).

Last year the Minister for Enterprise, Trade and Employment, stated that

> *"Science, Technology and Innovation are vital to our economic and social progress. In an increasingly globalised world, it is recognised that high levels of investment in research and innovation are essential.....Growing research capability is a core component of the European Union's drive to become the most competitive and dynamic, knowledge-driven economy. Ireland has fully embraced that challenge and this strategy represents our comprehensive plan to guide us towards that goal."*
> *(Strategy for Science, Technology and Innovation 2006-13*, 2006: 3)

As a result, in the *Strategy for Science, Technology and Innovation 2006-13*, the Irish government has committed €1.88 billion to fund research. A substantial majority of that funding (81%) is targeted at higher education infrastructure and research and commercialization in higher educational institutes (HEIs) with the remaining 19% being devoted to enterprise supports (2006: 13 & 86).

The emphasis placed by policymakers on innovation as a key source of future Irish competitiveness has its origin at the beginning of the millennium, when the so-called 'Celtic Tiger' growth spurt looked to have ended. The policy shift towards funding research in HEIs was initiated under the last National Development Plan, 2000-2006 (2000), with the foundation and funding of Science Foundation Ireland (SFI) and the expansion of the Higher Education Authority's Programme for Research in Third Level Institutions (PRTLI).

SFI was established in 2001 to undertake and support strategic research of world class status in niche areas of ICT and biotechnology, including the underlying scientific disciplines (Forfás, 2005). Since its establishment, SFI has approved over 1,600 awards across all its programmes, representing a substantial investment outlay of over €825 million (Forfás, 2006). Annual spending has increased from €10 million in 2001 to €135 million in 2006. In 2006, there were 1,400 researchers supported by SFI, mostly in HEIs, some of whom have come to Ireland from abroad.

PRTLI was initiated in 1998 with the aim of achieving a permanent transformation in the Irish research environment. Administered by the Higher Education Authority, these programmes represent a significant commitment of State resources to research in higher education by offering HEIs an opportunity to build infrastructure and develop the careers of Ireland's brightest researchers. By 2006, a total of €605 million was allocated to these programmes (Higher Education Authority, 2006).

The upshot of these developments is that the Irish government has played a leading role in increasing the level of R&D funding in the country. Between 1997 and 2006, gross expenditure on R&D in Ireland increased by 7.6% per annum at constant prices. The increased contribution of public funding to R&D in HEIs is clear, rising from 20% of gross expenditure in 1996 to 26% in 2006. Despite this increase there remains a widely held concern that Irish R&D expenditure still lags by international standards. For example, in 2006, gross expenditure on R&D was 1.56% of Irish GNP, compared to the EU 25 average[1] of 1.77% (Forfás, 2007).

The consensus is that the progress already made ought to be continued. For example, a recent review of the Irish research infrastructure in ten broad disciplinary areas by international experts stated that:

> *"We have found a research system in impressive transition as a result of the major injection of funds over the past few years. This investment is beginning to transform the research base in Ireland, supporting a growing influence and recognition in the now-global research enterprise. However given the historical deficits in infrastructure funding, Ireland is still some way behind other developed nations competing and collaborating in international research programmes. Recent investments have had a strong positive impact, but these investments must be properly supported and maintained. It is also important to recognize that the research base remains narrow at the highest international level."*
>
> Higher Education Authority (2007: 11)

Business spending on R&D, which is approximately two thirds of gross expenditure on R&D, has also been increasing, albeit at a slower rate than higher education funding. It is concentrated in the Software, Computer, Electronics and Pharmaceutical sectors, which accounted for 72% of total business R&D spending in 2005 (Forfás, 2006). Both IDA Ireland and Enterprise Ireland have been actively involved in supporting R&D spending.

IDA Ireland, which has played a key role since the 1970s in attracting foreign direct investment to Ireland, is currently aiming to make Ireland "one of the new global centres for science-based R&D and for innovation" (IDA Ireland, 2007: 14). For example, in 2006, it supported 54 R&D investment projects, including major international businesses such as CISCO, IBM and Bristol-Myers Squibb, and global research organisations, such as Georgia Tech Research Institute and Bell Labs in Ireland. R&D grants by IDA Ireland increased sharply from €140 million in 2004 to €470 million in 2006 (IDA Ireland, 2007).

Enterprise Ireland increasingly aims to strengthen the research and technology base in the indigenous sector and to assist in the commercialization of ideas in HEIs. In 2006, it approved €53 million in 194 in-company R&D projects and €30 million for 155 research projects aimed at bringing new technologies to market (Enterprise Ireland, 2007). It aims to double the number of businesses committing R&D spending of €100,000 or greater and to treble the number spending in excess of €2 million by 2010 (Enterprise Ireland, 2005).

Looking forward the strong policy emphasis on high-technology sectors, which was identified in the report of the Enterprise Strategy Group (2004), looks set to continue. The *Strategy for Science, Technology and Innovation: 2006 to 2013*, in suggesting that nearly all of the gains in manufacturing output between 1997 and 2003 was attributable to technologically intensive sectors, goes on to assert that sectors such as ICT, Life Sciences and Medical Technologies "are also sectors where research has the potential to make a serious impact on productivity, growth and competitiveness" (2006: 38).

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[1] Based on GDP.

The foregoing suggests that Irish policymaking in relation to innovation is based on three main tenets. These are: (i) that gross expenditure on R&D should be increased, (ii) that agency support should be targeted either at HEIs or at businesses interacting with HEIs, and (iii) that high-technology sectors have the greatest potential for innovation and growth. By estimating the importance of R&D and interaction with HEIs for the innovation output of Irish high-technology businesses, this paper makes an important contribution to the debate about the effectiveness of this policy.

3. CONCEPTUAL AND MODELLING FRAMEWORK

Schumpeter famously defines innovation as consisting of five categories:

> *"(1) the introduction of a new good – that is one with which consumers are not yet familiar – or of a new quality of good. (2) The introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. (3) The opening of a new market. (4) The conquest of a new source of supply of raw materials or half-manufactured goods (5) The carrying out of a new organisation of any industry."*
> (Schumpeter, 1934: 66)

This definition suggests two important distinctions. The first is the difference between product and process innovation. Product innovation relates to Schumpeter's first category. The remaining four refer to process innovation. This distinction is now common in the international literature (see for example Roper 2001, Gordon and McCann, 2005 and the EU's Community Innovation Survey, Cordis, 2007).[2] The second concerns Schumpeter's insistence that the important criterion for 'newness' is commercial rather than technological. From the perspective of a business, innovation is the introduction of a product or process that is new to it.[3]

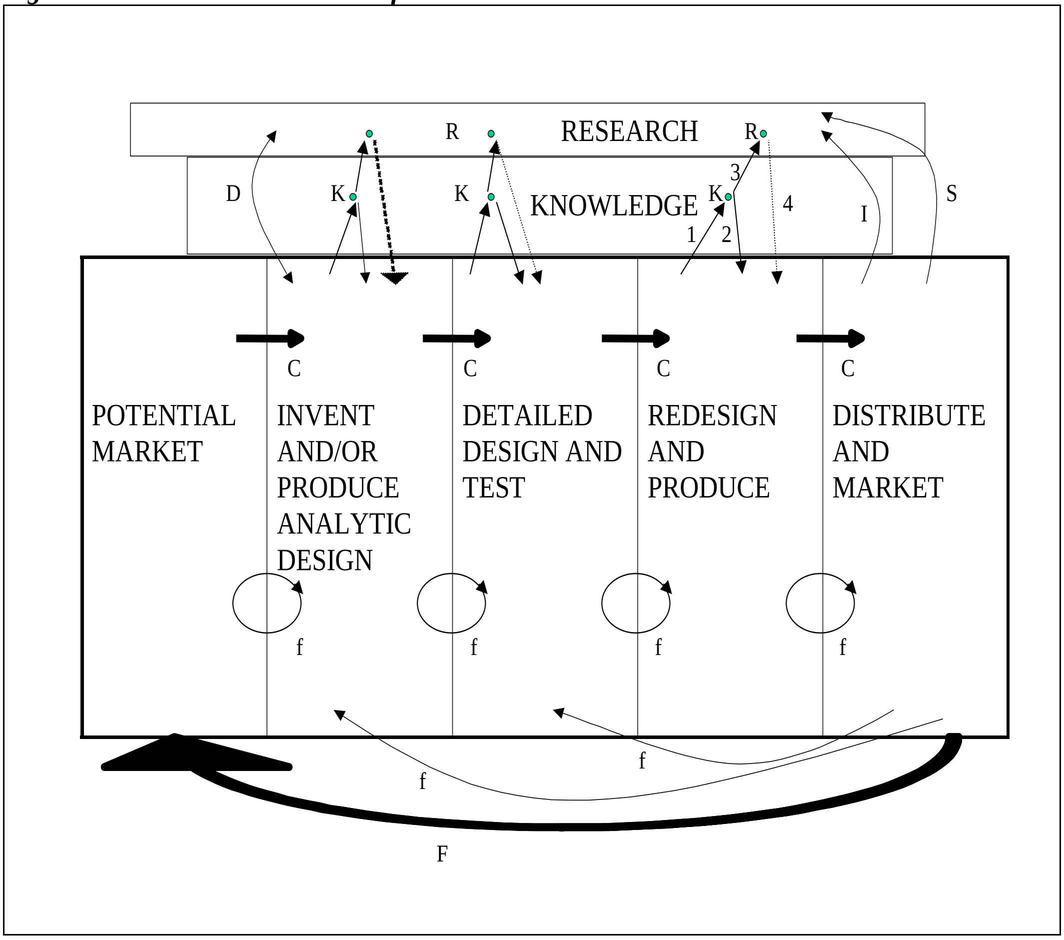
The 'chain-link' model introduced by Kline and Rosenberg (1986) is a useful framework for understanding how innovation occurs. Presented in Figure 1, it shows a central chain of innovation (represented by **C**) involving the identification of a potential market followed by design and testing of the idea, leading to market entry. Crucially, at each stage in the development of the idea there are feed-back loops (**f**) to depict the trial and error nature of the process. The most important source of feed-back (**F**) is from testing the idea in the market. The links to the knowledge and research panels along the top of the figure signify the circumstances under which the existing stock of knowledge (**K**) or research (**R**), which might be thought of as new knowledge, is required. This might occur where problem-solving is necessary as the idea is developed. Thus, the problem might be solved by reference to the existing stock of knowledge (arrow **1** to node **K** and arrow **2** back). For example, this could be achieved through reading scientific publications or attending conferences. If the problem cannot be solved from the existing stock of knowledge, it might be necessary to have research undertaken (arrow **3** to **R**). The outcome of this research is uncertain as the problem may be insoluble (hence arrow **4** back is dashed).[4]

[2] Note however that the distinction is not clear-cut, as product innovation may lead to process innovation and vice versa (Gordon and McCann, 2005).

[3] Other distinctions, such as global versus local innovation (Stoneman, 1998) or radical versus incremental innovation are less relevant here. The former refers to the novelty of the innovation from the market perspective while the latter is a technological classification.

[4] The bigger size of the central chain compared to the research panel in the figure echoes the stylized fact that two thirds of R&D spending is typically devoted to D, with one-third spent on R (Rosenberg, 1994: 141).

Figure 1: The Chain Link Model of Innovation



Source: Kline and Rosenberg (1986:290)

The 'chain-link' model does not specify the unit of analysis. It could represent a single business or a number of businesses. The flexibility of the model allows us to surface two key points concerning how innovation occurs. First, the role of the HEI, which might be seen in the knowledge and research panels of Figure 1, is to build the stock of knowledge, through publication and scientific communication, and, when requested, to respond to businesses' need to problem-solve. A further function might be, through teaching, to contribute to what is referred to as the absorptive capacity of the workforce. This refers to the ability of the workforce to adapt to innovation occurring outside the business (Cohen and Levinthal, 1989, 1990). Second, the importance attached to feed-back in the model suggests that, in the context of a trial and error process, businesses benefit from interaction with customers, competitors and suppliers. Learning, which is at the heart of the innovation process, is interactive and social in nature (Lundvall, 1988). According to Nonaka et al. (2001), tacit knowledge, which is a sustainable source of competitive advantage, is best communicated through personal interaction. Interaction with customers, suppliers, competitors and HEIs may be mediated by what may be referred to as innovation supporting agencies (see for example, Porter and Emmons (2003) discussion of institutions for collaboration).

The work of Krugman (1991), Porter (1990) and Scott (1988) suggests that knowledge flows take place more easily over shorter distances, primarily due to the advantages of face-to-face interaction (Gordon and McCann, 2005). This suggests that businesses would benefit from geographic proximity to interaction agents, including customers, suppliers, competitors and HEIs. Knowledge flows from geographically proximate interaction agents may not exhaust the full range of potential benefits that might arise from the location of businesses. The literature on localization economies suggests that the local availability of a skilled labour pool specific to the industry of the business may benefit it, as knowledge is embodied in workers (Marshall, 1980 and Porter 1990). Similarly, urbanization economies might include the availability in an urban setting of a labour supply with diverse skills and efficient transport and communications infrastructure, which may facilitate business innovation (Jacobs, 1969 and Gordon and McCann, 2005).[5]

The standard approach in the literature to modelling innovation is to use an innovation production function (see for example Acs and Audretsch, 1988, Roper, 2001 and McCann and Simonen, 2005). This models innovation output as a function of the R&D effort of the business and external sources of knowledge through interaction. In addition, the model controls for characteristics of the business that might affect its innovation output, such as size, age and sector. In this paper the innovation production function takes the form:

$$IO_i = \alpha_0 + \alpha_1 Z_i + \alpha_2 R\&D_i + \alpha_3 EI_i + \mu_i \qquad \text{[Equation 1]}$$

where IO_i is an indicator of innovation output in business i.
Z_i is a range of business-specific factors that may affect business i's capacity to innovate.
$R\&D_i$ is an indicator of R&D effort in business i.
EI_i is an indicator of the extent of interaction for innovation in business i with customers, suppliers, competitors, HEIs and support agencies.
μ_i is the error term.

In estimating this equation for the survey of high-technology businesses, the hypothesis being tested is that α_2 and α_3 are positive, implying both internal and external sources of knowledge have a positive effect on innovation output. Given the policy emphasis identified in section 2, the coefficient on interaction with HEIs is of particular interest.

In order to analyse the role of geographic proximity, the first step is to investigate whether proximity facilitates interaction. This is depicted as follows:

$$EI_{ij} = \gamma_0 + \gamma_1 Z_i + \gamma_2 R\&D_i + \gamma_3 EI_{ik} + \gamma_4 GP_{ij} + e_i \qquad \text{[Equation 2]}$$

where EI_{ij} is an indicator of interaction between business i and interaction agent j.
EI_{ik} is an indicator of interaction between business i and interaction agent k, where $k \neq j$.
GP_{ij} is an indicator of the geographical proximity between business i and interaction agent j.
e_i is the error term.

The key hypothesis is, all other things equal, that γ_4 is positive, implying that the closer the interaction agent to the business the more frequent is the interaction.

The second step is to investigate the role of localization and urbanization in determining innovation output. This can be approached by including indicators of these forms of external agglomeration economies as additional independent variables in Equation 1.[6] The hypothesis here is that the greater the degree of agglomeration the greater the level of innovation output. The

[5] See Parr (2002) for a comprehensive definition of agglomeration economies and O'Leary (2007) for a fuller discussion of them in an Irish context.

[6] The measures used to capture both localization and urbanization economies are outlined in section 6 and presented in detail in the Appendix.

next section outlines the survey and the measures used for innovation output, R&D, interaction and geographic proximity.

4. THE SURVEY

The survey, conducted towards the end of 2004, was targeted at Irish high-technology businesses.[7] The particular sectors chosen are classified as *Chemicals and Pharmaceuticals, ICT* and *Electronic Devices and Engineering.*[8] These sectors are identified by the Enterprise Strategy Group as having future growth opportunities (2004: 41-45).[9] The list of businesses in the selected sectors was constructed from the IDA Ireland database,[10] which relates to foreign-owned businesses, and the Enterprise Ireland (EI) SourceIreland website,[11] for indigenous companies.[12] While most of the businesses included may be classified as manufacturing, some may also provide services. In addition, some businesses, such as those in the software sector, are classified as services. It is estimated that 38% of the population of *ICT* and *Electronic Devices and Engineering* and 73% of *Chemicals and Pharmaceutical* businesses are covered in the survey.[13] In terms of employment, the survey is representative of the population, although there are a small number of very large businesses present.[14]

A self-administered questionnaire, containing 25 questions on levels of product and process innovation and their sources, was circulated to 857 businesses.[15] Table 1 details the response rate achieved by sector and type of business. In the context of a lengthy questionnaire and survey fatigue by businesses (CSO, 2001), a total of 184 responses with an overall response rate of 22% is quite satisfactory. As can be seen from Table 1, the response rate is relatively evenly spread across sectors and types of business.

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[7] See Jordan (2007) for a full description of the survey design and implementation.

[8] *Electronics Devices and Engineering* includes Medical Devices.

[9] The ESG also identified Food and Consumer Goods, neither of which is considered to be high-technology, according to the OECD classification (OECD, 2004). The ESG also identified Internationally Traded Services as having growth opportunities. A sizeable number of businesses were identified ranging across a variety of sub-sectors such as Financial Services, Education Services and Creative Industries (2004, xii). Investigation of these businesses was considered to be outside the scope of this study.

[10] www.idaireland.com

[11] www.enterprise-ireland.com/sourceirelandsearch

[12] This involved identifying and removing businesses double-counted on the databases and removing businesses that, for the purposes of this study, were inappropriately classified.

[13] The population of businesses was constructed using the Census of Industrial Production (CIP), 2002 (CSO, 2003a) for manufacturing local units and the National Software Directorate (www.nsd.ie) for software.

[14] In each sector mean employment reported in the CIP, 2002 (CSO, 2004) is similar to the 5% trimmed mean for respondent employment.

[15] The survey was addressed to establishments, with respondents being requested only to consider the activity at the particular location of their business.

Table 1: Responses by Sector and Type of Business[1]

	Sample	Responses	Response Rate %
Chemicals and Pharmaceuticals			
Foreign[2]	86	27	31
Indigenous[2]	97	16	17
Total	183	43	24
ICT			
Foreign	129	25	19
Indigenous	222	40	18
Total	351	65	19
Electronics Devices and Engineering			
Foreign	156	34	22
Indigenous	167	41	25
Total	323	75	23
Total	**857**	**184[3]**	**22**

Note 1: A detailed account of the population, the survey instrument and the survey findings is available from Jordan (2007).

2: Foreign-owned and indigenous businesses are from the IDA and EI databases respectively.

3: One respondent was anonymous and could not be classified.

Given the obvious differences in the development of both indigenous and foreign-owned businesses, it is important to note the different characteristics of these respondents. The 98 indigenous respondents had an average of 49 employees in 2003, 54% of whom had a third level degree. The 86 foreign-owned respondents had an average of 182 employees, 29% of whom had third level education. The average age of indigenous businesses was 14 years compared to 23 for foreign-owned. *ICT* respondents were significantly smaller businesses and a greater proportion of their workforce had third level education. These differences in age, employment and proportion with third level qualifications are statistically significant at the 95% level. Geographically, respondents are spread throughout the country, with 48% in the Dublin/Mid-East regional authority areas, 22% in the South-West, 10% in the West and the remaining 20% spread between the Border, the Mid-West and the South-East.

In line with studies such as Roper (2001), MacPherson (1998) and the EU's Community Innovation Survey (Cordis, 2007), product innovation is defined as the introduction of new or improved goods/services which may be new to the market or new to the businesses in the reference period, 2001 to 2003. Process innovation, which is less visible from outside a business and, as a result, more difficult to measure, is defined as the introduction to the business of a new method of producing or delivering existing goods/services, the re-organisation of support activities, management structures or distribution channels, the introduction of existing goods/services to new markets and the introduction of new sources of supply of materials or other inputs over the same period (Schumpeter, 1934, Kline and Rosenberg, 1986, Gordon and McCann, 2005 and Department of Trade and Industry, 2004). Businesses were asked to indicate whether they introduced process innovations continuously, frequently, regularly, rarely, or never in the reference period. These comprehensive definitions of what may be referred to as innovation outputs reflect what managers might be expected to observe in their businesses.

In order to determine the sources of both product and process innovation, businesses were asked whether they perform R&D, either formally through dedicated R&D departments, or otherwise. They were then asked their frequency of interaction with other group companies (which might be especially important for foreign subsidiaries), suppliers, customers, competitors, HEIs (including Irish universities and Institutes of Technology and foreign HEIs) and innovation support agencies (such as IDA Ireland and EI). Interaction includes meetings, networking or other communications that affect innovation. It ranges from social or informal, perhaps unintentional, networking to formal or contractual collaboration that might generate new knowledge used for product or process innovation. Frequency of interaction was measured on a five point scale from continuously, to frequently, regularly, rarely and never. This approach to the study of interaction is more detailed than generally found in the literature, which typically involves asking businesses whether or not they engage in interaction (see for example MacPherson, 1998, Love and Roper, 2001 and Freel, 2003).

In order to understand the importance of local and regional sources of innovation, businesses were asked to estimate the one-way driving time from their most important interaction agents for both product and process innovation. Driving times were categorized in intervals of less than half an hour, a half to one hour, one to two hours, two to four hours and greater than four hours. The lower end of this range represents local interaction, with the upper end including interaction with agents outside the state. This method of measuring the importance of geographical proximity follows that of MacPherson (1998). It is preferred to the standard measure, which involves asking businesses whether they are co-located with interaction agents.[16]

5. RESULTS ON INNOVATION OUTPUT, R&D, INTERACTION AND PROXIMITY

Table 2 presents the percentage of respondents engaged in product and process innovation. A total of 80% of respondents are product innovators with 76% introducing process innovations, either regularly, frequently or continuously between 2001 and 2003. There are no significant differences in the sample when classified by sector, ownership, age and size.[17] These results are similar to those of the Forfás Innovation Survey (Forfás, 2006). This large scale survey,[18] reports innovation activity rates[19] for the high-technology sectors of *Chemicals*, *Medical Instruments*, *Computers and Computer Related Services* between 65% and 80% for the period 2002 to 2004.

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[16] Thus, in the standard measure, a business in east-Cork (South-West Region) interacting with an agent in west-Waterford (South-East Region) is not co-located, even though they are geographically close.

[17] This and subsequent tests in this section are based on the Pearson Chi-Squared test. For a more detailed discussion, see Jordan (2007).

[18] Over 2,300 firms employing greater than ten employees.

[19] Defined as introducing either new product or process innovation.

Table 2: Levels of Product and Process Innovation by Sector, Ownership, Age and Size (% of respondents)

	Product Innovation	**Process Innovation**
Total	80	75
Sector		
Chemicals and Pharmaceuticals	74	73
ICT	80	76
Electronic Devices and Engineering	84	75
Ownership		
Foreign	74	77
Indigenous	85	73
Age		
0 to 5 years	80	80
6 to 15 years	81	77
15 to 25 years	80	78
Greater than 25 years	79	65
Size		
Less than 10 employed	88	75
10 to 49 employed	82	73
50 to 249 employed	76	73
Greater than 250 employed	75	90

Table 3 presents the percentage of respondents undertaking R&D. This shows that 67% of businesses indicated that they performed R&D between 2001 and 2003, with 62% of these having a dedicated R&D Department. With two exceptions, there are no significant differences in the likelihood of performing R&D or having an R&D Department across sectors, ownership, age and size. However, at the 99% confidence level, indigenous were, perhaps surprisingly, more likely than foreign-owned businesses to perform R&D, while younger businesses more than older businesses were more likely to perform R&D.

Table 3: Research and Development Activity by Sector, Ownership, Age and Size (% of respondents)

	Perform R&D	R&D Department[1]
Total	67	62
Sector		
Chemicals and Pharmaceuticals	58	68
ICT	74	63
Electronic Devices and Engineering	65	57
Ownership		
Foreign	52	
Indigenous	80	73
		55
Age		
0 to 5 years	78	74
6 to 15 years	73	58
15 to 25 years	63	52
Greater than 25 years	51	59
Size		
Less than 10 employed	79	53
10 to 49 employed	70	54
50 to 249 employed	59	73
Greater than 250 employed	65	77

Note 1: Based on the % of those performing R&D.

Table 4 presents the frequency of interaction for product and process innovation by interaction agents in terms of percentage of respondents. This shows a striking pattern, which does not vary by sector or ownership. For a clear majority of businesses engaging in either product or process innovation, regular, frequent or continuous interaction occurs with other group companies, suppliers and customers. This strong interaction is in stark contrast to the noticeably weaker interaction with competitors, HEIs and innovation support agencies, as indicated by the majority of businesses never or rarely interacting. This difference is significant at the 99% level.

Table 4: Frequency of Interaction for Product and Process Innovation by Interaction Agent (% of respondents)[1]

	Group	**Suppliers**	**Customers**	**Competitors**	**HEIs**	**Agencies**
Product						
Never/Rarely[2]	11	17	9	68	67	56
Regularly to Continuously[2]	89	82	90	31	33	44
Process						
Never/Rarely[2]	14	32	29	83	79	71
Regularly to Continuously[2]	86	68	71	17	21	29

Note 1: Numbers may not add to 100% due to rounding

2: Respondents indicated frequency of interaction based on 5 categories as follows: never, rarely, regularly, frequently and continuously. For the purposes of this table the categories are grouped.

Table 5 presents the time distance between businesses and their most important interaction agents for both product and process innovation. This shows that for those agents with whom interaction is strong, there is a clear tendency for the most important agent to be located more than 1 hour and usually more that 4 hours driving time from high-technology businesses. Thus, for other group companies, suppliers and customers interaction occurs over relatively long distances, and clearly not locally. For competitors, with whom it was seen in Table 4 that businesses do not interact strongly, the most important agent is located more than 4 hours away for a clear majority of businesses. For both HEIs and innovation support agencies, where interaction is weaker, no clear pattern emerges, with the most important agent being spatially spread across local and international locations. These results hold for all sectors and types of businesses and the reported differences are significant at the 99% level. It should be noted that these results relate to the most important interaction agent, from the perspective of the businesses themselves. Thus, it is possible that interaction between these high-technology businesses and, for example, suppliers occurs locally, but this is not regarded by the businesses as most important for innovation.[20]

Table 5: Time-Distance from Most Important Interaction Agent for Product and Process Innovation (% of respondents)[1]

	Group	**Suppliers**	**Customers**	**Competitors**	**HEIs**	**Agencies**
Product						
<1 hour[2]	8	20	15	20	39	49
1 to 4 hours[2]	2	24	27	18	33	40
> 4 hours[2]	89	56	58	62	28	11
Process						
<1 hour[2]	7	18	19	22	43	46
1 to 4 hours[2]	1	20	27	18	31	37
> 4 hours[2]	92	55	54	61	26	17

Note 1: Numbers may not add to 100% due to rounding.

2: Respondents indicated one-way driving distance in 5 categories as follows:<½ hour; ½ to 1 hour; 1 to 2 hours; 2 to 4 hours and greater than 4 hours. For the purposes of this table the categories are grouped.

These descriptive results suggest two important questions, which were raised in an earlier paper (Jordan and O'Leary, 2005) and will be more fully investigated in the next section. First, the weak level of interaction between HEIs and high-technology businesses for both product and process innovation is particularly noteworthy. This result is broadly consistent with the Forfás Innovation Survey (Forfás, 2006). A maximum of one third of the sample of high-technology businesses engage regularly, continuously or frequently with HEIs. In the light of the policy emphasis, this result may be a cause for concern to policymakers, who might expect a higher proportion of HEIs interacting. However, the crucial question to be investigated is what effect interaction with HEIs has on the level of innovation output by Irish high-technology business. The second question concerns the absences of strong interaction between locally or regionally-based concentrations of suppliers, customers, competitors, HEIs and support agencies and Irish high-technology businesses. While once again this may be surprising, the important question is whether geographic proximity has a positive effect on innovation output. These questions are now addressed.

[20] See Jordan (2007) and Jordan and O'Leary (2005) for fuller discussions of the results in Tables 4 and 5.

6. THE EFFECTS OF R&D, INTERACTION AND PROXIMITY

This section explores the effectiveness of business R&D, interaction and proximity for the innovation output of high technology businesses. It first deals with the direct effects of R&D and external interaction, especially HEI interaction, on innovation output. Indirect HEI effects, through complementarities in the sources of knowledge for innovation, are then considered. The final part investigates the effects of geographical proximity on the frequency of interaction and whether agglomeration improves innovation output. In presenting the results, the approach in this section is to focus on the effects that are statistically significant. Interpretations of the results are discussed in the following section.

Equation 1 is first estimated for both product and process innovation. For product innovation, the dependent variable is a binary variable taking a value of 1 if the business indicates it introduced at least one new product in the reference period. For process innovation, the dependent variable is a binary variable taking a value of 1 if the business introduced new processes on a regular, frequent or continuous frequency and a value of 0 if the business never or rarely introduced new processes in the reference period.[21]

Table 6 presents the estimations of Equation 1. Two estimations are reported for each, based on different interaction variables. The first is an ordinal variable for each interaction agent representing interaction frequency, ranging from 1 to 5, where a value of 1 represents no interaction up to 5 representing continuous interaction. The second is a binary variable of the incidence of interaction with each interaction agent at each frequency level. This takes a value of 1 if the business interacted at the particular frequency level and 0 if not.[22] All the reported estimations are significant.[23]

[21] See Appendix 1 for variable definitions.

[22] The second variable facilitates the comparison of elasticities.

[23] The likelihood ratio chi-squared p-values are significant for all estimations, which indicate that the hypothesis that there is no difference between the estimated models and constant only models can be rejected and the estimated models are significant indicators of the probability of innovation. Tests for multicollinearity indicate that multicollinearity is not a problem in this model and variances and standard errors are not overstated.

Table 6: Logit Model of the Probability of Product Innovation and Regular Process Innovation

	Product Innovation		Process Innovation	
	Estimation 1	Estimation 2	Estimation 1	Estimation 2
Business Characteristics (Z)				
Age	0.0392*	0.0193**	-0.0280*	-0.0185*
Size	-0.0016	0.0002	0.0044**	0.0034*
Turnover Growth	0.0477	0.0482	0.0653	0.0492
Foreign Ownership	-1.4596	-1.1120*	0.3530	-0.1169
Workforce Education	0.0046	0.0041	-0.0017	0.0006
Sector[3]				
ICT	-0.6364	-0.3465	-0.1238	-0.2529
Chemicals and Pharmaceuticals	-1.2089**	-0.6646**	-0.1773	-0.2616
R&D				
Perform R&D	1.2089**	0.5754	2.4175*	1.5211*
R&D Department	0.7888	0.5541	-0.8182	-0.3584
External Interaction (EI)				
Ordinal Interaction Variables				
Supplier	0.4145*		0.5831*	
Customer	0.5786*		0.3934*	
Competitor	-0.3025		-0.1108	
Academic	-0.7119*		-0.6700*	
Agency	0.7803*		0.4271	
Binary Interaction Variables				
Suppliers				
Rarely		0.1609		0.1976
Regularly		0.8513**		1.3462*
Frequently		0.9307**		1.2298*
Continuously		1.1366*		1.2178*
Customers				
Rarely		0.6252		-0.4182
Regularly		0.9553**		0.2393
Frequently		1.3634*		0.8682*
Continuously		1.5212*		0.7851
Competitors				
Rarely		-0.2459		0.0245
Regularly		-0.3989		0.3056
Frequently		-1.0345		-1.0310
Continuously		-1.3065		
HEIs				
Rarely		0.4831		-1.0420*
Regularly		-0.6486		-0.5674
Frequently		-1.0351*		-1.9904*
Continuously		-3.6286*		-1.0442
Agencies				
Rarely		-0.1186		0.3401
Regularly		1.4456*		0.1737
Frequently		0.8946**		
Group Membership3	1.7386	1.0077**	-0.1720	0.2184
Constant	-2.9306*	-1.8104	-2.4507*	-1.2009
N	175	169	170	151
Log Likelihood	-57.189	-50.719	-70.9730	-63.1601
Pseudo R2	0.33634	0.40224	0.26994	0.30684
LR X2	57.95	57.34	52.47	62.66
	(0.0000)	(0.0013)	(0.0000)	(0.0001)

Notes: 1. * Significant at 5% level; ** Significant at 10% level.
2. The reference sector is *Electronic Devices and Engineering.*
3. A binary variable representing business i's membership of a group of companies is used as a proxy measure of interaction with other group companies.
4. Pseudo R^2 reported is the likelihood ratio index (i.e. $1\text{-}\ln L/\ln L_0$, where L_0 is the log likelihood computed with only a constant term).

In terms of the business characteristics (referred to as Z in Equation 1), it can be seen in Table 6 that for both estimations 1 and 2, age is positively associated with the introduction of new products and negatively associated with the introduction of new processes on a regular basis. This indicates that older businesses are more likely to introduce new products and less likely to introduce new processes than younger ones. Larger businesses are more likely to introduce new processes on a regular basis. In Estimation 2 there is a significantly negative effect of foreign ownership on the probability of product innovation, indicating that indigenous businesses are more likely to introduce new products than foreign-owned businesses. In terms of sectoral differences, the only significant effect is that businesses in the *Chemicals and Pharmaceuticals* sector are less likely to introduce new products relative to the reference sector, *Electronic Devices and Engineering.* None of the other business characteristic variables reported in the estimations are significant predictors of the probability of introducing new products. It is notable that workforce education, measured by the percentage of employees with a third-level degree or equivalent, has no effect on the probability of innovation.

Turning to the coefficient on R&D in Equation 1, it is noticeable that performing R&D has a positive and significant effect on the likelihood of introducing new products and processes.[24] The relatively large and positive association between R&D and the probability of innovation is consistent with other empirical innovation studies (Acs and Audretsch, 1988, Love, Ashcroft and Dunlop, 1996, Roper, 2001, Freel, 2003, Becker and Dietz, 2003). While performing R&D has a positive effect on the probability of innovation, there is no evidence that doing so within a dedicated R&D department affects innovation output. This indicates that R&D does not necessarily have to be formalised in an innovation active business. In addition, state aid for R&D proved to be insignificant in all the estimations.[25]

Regarding the coefficients on external interaction in Equation 1, Table 6 shows that the frequency of interaction with suppliers and customers positively affects the probability of introducing new products and processes. There is also a positive effect on product innovation from interaction with support agencies. It can be seen in Estimation 2 that more frequent interaction with suppliers and customers positively affects the probability of innovation, though the effect of interaction with suppliers is greater in relation to process innovation and the effect of interaction with customers is greater in relation to product innovation. This may not be surprising, since new processes may be tied to the adoption of new sources of supply or new equipment while businesses are more likely to learn of market opportunities for new products through customer interaction.

A particularly noteworthy result is the significant negative association between the frequency of interaction with HEIs and the likelihood of both product and process innovation. Estimation 1 in Table 6 indicates that the more frequently businesses interact with HEIs the less likely they are to introduce new products and processes. In Estimation 2 for product innovation it can be seen that interacting frequently and continuously with HEIs reduces the probability of product innovation relative to not interacting at all. Estimation 2 for process innovation shows that interacting rarely and frequently reduces the probability of process innovation relative to no interaction.

This finding differs from that of Jaffe (1989) and Acs, Audretsch and Feldman (1992), who find a strong positive relationship between interaction with HEIs and innovation output in the US. However, these studies do not control for the effect of interaction with other external interaction agents.[26] Compared to those studies that do control for these interactions, this is the first to find a negative effect of HEI interaction on innovation output. For example, McCann and Simonen

[24] Although not in estimation 2 for product innovation.

[25] In the survey business were asked how much financial support for R&D they received from support agencies. This variable was dropped from the final reported estimations as it did not add to their explanatory power.

[26] Also, they measure innovation output differently, using patent and commercial data respectively.

(2005) on Finland and Roper, Jun and Love (2006) on Ireland, and Jordan and O'Leary (2007a) on small and medium sized businesses in the South-West and South-East, find no significant effect.

Interestingly, Roper, Jun and Love (2006) present evidence that HEI interaction may have a positive indirect effect. They find that interaction with HEIs increases the probability of interaction with interaction agents that have a positive direct effect on innovation output. This raises the possibility of complementarities in the sources of knowledge for innovation. In order to investigate the presence of such complementarities, Table 7 presents a series of logit estimations for both product and process innovation on the probability of performing R&D and interacting with each interaction agent for product innovation and process innovation.

Table 7: Logit Estimation of the Probability of Performing R&D and Interacting for Product and Process Innovation

	Performing R&D	**Interaction for Product Innovation**				
		Customer	**Supplier**	**Competitor**	**HEIs**	**Agency**
Business Characteristics (Z)						
Age	-0.007	0.026	0.009	0.001	0.004	-0.006
Size	0.001	-0.001	0.001	-0.001	0.001	0.001
Education	0.014*	0.003	-0.001	0.011**	-0.003	0.011**
Sector						
ICT	-0.231	-0.108	-0.745**	-0.296	-0.324	-0.257
Chem/Pharm	-0.355	-0.369	0.077	-0.208	-0.075	0.238
R&D						
Perform RD		0.685**	0.321	-0.235	0.146	0.573**
Incidence of External Interaction (EI)						
Customer	0.923**	na	1.109**	0.846*	-0.066	0.739*
Supplier	0.288	1.066 *	na	0.551*	0.816**	-0.248
Competitor	-0.175	0.586****	0.534*	na	0.437*	0.448*
HEIs	0.041	-0.159	0.729**	0.436*	na	1.362*
Agency	0.621	0.616**	-0.238	0.505*	1.445***	na
Constant	-1.275*	-0.395	-0.229	-1.720*	-1.595*	-1.696*
N	180	180	180	180	180	180
Log-likelihood	-91.06	-28.73	-48.76	-101.88	-85.17	-73.64
LR $chi^2(10)$	42.32	38.73	35.82	41.39	51.57	62.14
Prob > chi^2	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Pseudo R^2	0.2003	0.3483	0.2911	0.1643	0.2970	0.3533

Note: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table 7 (continued): Logit Estimation of the Probability of Performing R&D and Interacting for Product and Process Innovation

	Performing	Interaction for Process Innovation				
	R&D	Customer	Supplier	Competitor	HEIs	Agency
Business Characteristics (Z)						
Age	-0.002	0.010	0.018***	-0.008	-0.006	-0.003
Size	-0.001	0.004**	0.001	-0.001	0.001	0.001
Education	0.017***	-0.004	-0.006	0.002	0.001	0.006
Sector						
ICT	-0.404	0.807**	-0.269	-0.146	-0.136	-0.582*
Chem/Pharm	-0.326	-0.209	0.909	0.042	0.005	-0.059
R&D						
Perform RD		0.263	-0.334	-0.120	0.474*	0.244
Incidence of External Interaction (EI)						
Customer	0.209	na	0.671**	0.908***	0.208	0.077
Supplier	-0.313	0.643**	na	0.107	0.594	0.607
Competitor	-0.061	0.924*	-0.003	na	0.139	0.598**
HEIs	0.452*	0.243	0.668*	0.136	na	1.426***
Agency	0.242	0.016	0.702**	0.630**	1.437***	na
Constant	-0.082	-0.683	0.161	-1.239***	-1.940***	-1.738***
N	175	175	175	175	175	175
Log-likelihood	-90.68	-70.86	-56.63	-104.25	-80.93	-76.37
LR $chi^2(10)$	33.31	34.83	49.86	28.41	62.84	79.63
Prob > chi^2	0.0002	0.0001	0.0000	0.0016	0.0000	0.0000
Pseudo R^2	0.1734	0.2033	0.3197	0.1231	0.3258	0.3702

Note: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

An indirect HEI effect may exist if interaction with HEIs has an effect on the probability of performing R&D and interacting with suppliers, customers and support agencies, since these sources of knowledge are reported in Table 6 as significant predictors of increasing the probability of innovation. In terms of performing R&D, HEI interaction for product innovation is insignificant, while for process innovation it has a positive effect. In relation to other interaction agents, it can be seen that HEI has a positive effect on the probability of interacting for both product and process innovation with suppliers and agencies. This provides evidence of a positive indirect effect on innovation of HEI interaction, through complementarity with supplier and agency interaction. HEI interaction does not affect the probability of interaction with customers for either product or process innovation.

It is interesting that workforce education is positively associated with the probability of performing R&D. It was reported in Table 6 that this variable does not have a direct effect on innovation output. The results in Table 7 suggest it does have an indirect effect by increasing the probability of a business performing R&D.

Turning to the effects of geography on interaction, Table 8 presents an estimation of Equation 2. This is an ordered probit estimation of the frequency of interaction with each interaction agent including the effect of geographic proximity on interaction. The hypothesis is that the coefficient on geographic proximity is positive.

Table 8: Ordered Probit Estimation of the Probability of Interaction at Each Frequency Level for Product and Process Innovation

	Customer		**Supplier**		**Competitor**		**HEIs**		**Agency**	
	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
Business Characteristics (Z)										
Age	-0.007	-0.003	-0.001	0.013 **	0.015 ***	0.013	0.005	-0.002	-0.008	-0.003
Size	-0.001	0.000	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	0.001
Foreign Ownership	0.050	-0.168	0.342	0.507 **	0.063	-0.741 **	0.099	0.130	-0.523 ***	-0.113
Turnover Growth	0.020	0.016	-0.023	0.030	0.082 **	0.104 *	0.066 **	0.034	0.027	0.019
Sector										
ICT	0.363	0.735 *	-0.256	-0.747 *	0.374	0.312	-0.239	0.298	0.027	0.046
Chem/Pharm	-0.153	-0.207	0.126	0.200	-0.436	0.184	0.046	-0.018	0.238	0.122
R&D										
Perform RD	0.468***	0.235	0.005	0.012	-0.169	-0.044	0.435	0.936 **	-0.085	0.168
R&D Dept	0.199	0.010	0.036	0.209	-0.086	0.192	-0.177	-0.601 ***	0.730 *	0.177
Frequency of External Interaction (EI)										
Customer	na	na	0.421 *	0.314 *	0.114	0.204	-0.120	-0.015	-0.061	-0.124
Supplier	0.387 *	0.320 *	na	na	0.097	0.030	0.333 *	0.216 ***	-0.116	-0.046
Competitor	0.103	0.328 *	0.072	-0.017	na	na	0.044	0.091	0.257 **	-0.032
HEIs	0.074	0.127	0.135	0.344 *	0.149	0.171	na	na	0.394 *	0.511 *
Agency	0.063	-0.124	0.009	-0.073	0.453 *	0.095	0.500 *	0.821 *	na	na
Proximity to Interaction Agent (GP)	0.115	0.034	0.001	0.106	0.151	0.052	-0.025	0.021	-0.179 ***	0.002
N	146	119	131	124	87	72	87	76	96	81
Log-likelihood	-144.86	-148.70	-154.88	-154.99	-114.66	-87.25	-108.02	-79.29	-116.33	-96.99
LR $chi^2(13)$	44.79	36.34	25.33	42.79	30.92	29.88	35.20	45.17	43.70	25.20
Prob > chi^2	0.0000	0.001	0.0209	0.000	0.0035	0.005	0.0008	0.000	0.0000	0.022
Pseudo R^2	0.1339	0.109	0.0756	0.121	0.1188	0.146	0.1401	0.222	0.1581	0.115

Note: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

There is no evidence that geographic proximity increases the frequency of interaction for product or process innovation with any of the interaction agents. The only significant effect is found for supporting agencies, which shows a negative association between proximity and interaction frequency, which suggests that the international offices of Irish support agencies have a larger impact. Overall, these results indicate that local or regional interaction does not have a positive effect on innovation output by Irish high-technology businesses.

Table 8 also sheds light on the nature of the indirect HEI effect identified in Table 7. This is that while interacting with HEIs increased the probability of interacting with suppliers for product innovation, there is no evidence from Table 8 that more frequent interaction with HEIs is associated with more frequent interaction with suppliers. This may reflect a project-based approach to HEI interaction, where HEIs are required to solve specific problems in the innovation process without developing an ongoing relationship.

While interaction for product and process innovation is not occurring on a local or regional basis, businesses may still benefit from localization and/or urbanization economies. Table 9 presents re-estimations of Equation 1 but including measures that might capture these effects. The localization indicator measures the extent of the local labour pool as the share of workers in the business sector in 3 regions, Dublin/Mid-East, South-West/South-East/Mid-West and Border/Midland/West. The urbanization indicators are population density of the business' location, the distance from the business to the nearest major airport, the percentage of workers employed in technical and professional occupations in the business' county, the percentage of workers in the business' county that have graduated from a scientific discipline and whether the business is located within the Greater Dublin Area or another hub or gateway as defined by the *National Spatial Strategy* (2002). Variable definitions are contained in the Appendix.[1]

[1] For a more detailed discussion of these variables see Jordan (2007)

Table 9: Logit estimation of the probability of introducing new products and new processes on at least a regular basis.

	Product Innovation		Process Innovation	
	Coefficients	Z-stat	Coefficients	Z-stat
Business Characteristics				
Age	0.0035	1.88***	-0.0352	-2.55**
Size	-0.0020	-1.59	0.0046	1.75***
Foreign Ownership	-2.0249	-1.34	0.4511	0.53
Sector				
ICT	-0.8122	-1.24	-0.3705	-0.63
Chemicals and Pharmaceuticals	-1.3153	-2.00**	-0.2992	-0.50
Research and Development				
Perform R&D	0.9022	1.42	2.5676	3.59*
R&D Department	0.6386	0.85	-0.7389	-1.15
Interaction				
Frequency of Interaction				
Supplier	0.3086	1.64***	0.7536	3.25*
Customer	0.5780	2.49**	0.3372	1.85***
Competitor	-0.2725	-0.98	-0.1549	-0.50
HEIs	-0.6582	-2.03**	-0.6003	-1.86**
Agency	0.7757	2.06**	-0.3988	1.22
Group Member	2.1212	1.39	-0.1529	-0.18
Agglomeration				
Labour Market Share	2.4063	1.07	0.1364	0.07
Population Density	0.0385	2.00**	0.0123	0.67
Distance to Airport	0.0110	0.98	-0.0053	-0.66
Technical Employment	-4.8775	-0.38	-3.0345	-0.28
Science Education	-7.5630	-0.32	15.4106	0.67
Hub/Gateway	-0.0778	-0.08	0.2244	0.27
Greater Dublin Area	-0.7173	-0.54	1.5408	1.23
Constant	-0.6397	-0.07	-8.0662	-0.92
N	180		175	
Log Likelihood	-56.796		-68.583	
Pseudo R^2	0.3595		0.3125	
LR Chi^2	63.75		62.35	
	(0.0000)		(0.0000)	

Note: * Significant at 1% level; ** Significant at 5% level; *** Significant at 10% level

The results reported in Table 9 are generally consistent with the logit estimation of the probability of introducing new products and processes as reported in Table 6.[2] With regard to the agglomeration variables, population density is the only indicator that has a significant positive relationship with the probability of product innovation. This indicates that high-technology businesses located in more urban areas are more likely to be product innovators than businesses in less densely populated or rural areas. This supports the view of urban areas as conducive to

[2] The only exception is that performing R&D is no longer a significant predictor of the probability of product innovation.

innovation. In this context, it is notable that the Greater Dublin Area dummy variable is insignificant, which suggests that it is urban location, rather than simply location within the Dublin area, or indeed in one of the gateways or hubs identified in the *National Spatial Strategy* (2002), that has a significant positive effect on innovation in Irish high-technology businesses.

The next section presents some policy conclusions and recommendations arising from the results reported in this section.

7. POLICY CONCLUSIONS

This paper is an important contribution to the debate on the efficacy of Irish innovation policy. The focus is on high-technology sectors as one of the main tenets of Irish policymaking has been to target these businesses. The key findings worthy of debate are that:

- Performing R&D in the business, as distinct from having a dedicated R&D Department, has a positive effect on innovation output.
- Workforce education does not have a direct effect on innovation output. However, a higher percentage of staff with third level education increases the probability of performing R&D.
- The greater the frequency of interaction with suppliers and customers the higher the probability of both product and process innovation in these businesses.
- There is no evidence that interaction with competitors affects innovation output.
- The greater the frequency of interaction with HEIs the lower the probability of both product and process innovation in these businesses.
- There is evidence of a positive indirect HEI effect, through complementarities of interactions with suppliers and support agencies.
- The greater the frequency of interaction with support agencies the higher the probability of product innovation. Agencies have a positive indirect effect through complementarities of interaction with customers and suppliers but this is mitigated by their effect on interaction with competitors and HEIs.
- While external interaction is important for innovation output, there is no evidence that geographical proximity matters.
- Population density, which captures urbanization economies, is the only form of agglomeration measure that has a positive effect on innovation output.

The finding that performing R&D is important for innovation, rather than having a dedicated R&D Department, has implications for policymakers. By concentrating on the measurement of spending by dedicated R&D Departments in businesses, policymakers are in danger of understating the level of effort that is devoted to this important activity. It was reported in Section 5 that 67% of businesses indicated that they performed R&D even though only 62% of these have a dedicated R&D Department. Significantly, in surveys of smaller businesses the differences may be much larger. For example, in a survey of small and medium sized enterprises in the South-West it was reported that 65% performed R&D with only 35% of these having R&D Departments (Jordan and O'Leary, 2007b).

Workforce education, measured as the percentage of the workforce with third level education, is a proxy for the absorptive capacity of businesses. This is a common practice in the literature (see for example Roper, 2001 and Freel, 2003). The lack of a direct effect from this measure should be treated with caution as the measure does not account for the capabilities that workers acquire 'on-the-job'.

In relation to market-based interaction agents, the findings clearly show that interaction with suppliers and customers have positive effects on innovation output and that interaction with competitors have no effect. These results are broadly similar to McCann and Simonen (2005), Roper, Jun and Love (2006) and Jordan and O'Leary (2007a). In terms of interaction with suppliers and customers, there is no evidence from this sample that geographical proximity is important. In regard to customers, this may not be surprising given the limited size of the domestic market and the overriding importance of international selling. However, the results for suppliers may be viewed as disappointing in the context of the cluster and network policies that have been in vogue since Culliton (1992).

The idea that businesses interact with competitors in order to promote innovation receives no support. The notion of collaboration between competitors has arisen from a number of celebrated examples in places such as Silicon Valley, Emiglia-Romagna and Cambridge (Scott, 1988; Castells and Hall, 1994 and Forfás, 2004), where the businesses are small and flexible, enabling alliances to form easily. These special cases may not be easily generalized (Gordon and McCann, 2005). In the case of Ireland, the applicability of this concept is in question, based on this evidence. Typically high-technology businesses located here are a mix of large foreign-owned and smaller indigenous businesses, operating in international market niches and seldom competing with each other.

The most interesting finding of the study is the negative HEI effect. This result may occur because businesses may turn to HEIs when faced with particularly difficult or complex problems during the process of innovation. Thus, in the context of the chain-link model, the problem posed by the business may be insoluble. As a result, the likelihood of developing a commercial product or process from the interaction may be low. Alternatively, the result may reflect differences in work practice and objectives between businesses and academics that hamper the commercial development of new products and processes. These differences may be compounded by the lack of an on-going relationship between businesses and HEIs that is a feature of business to business interaction. Business may only turn to HEIs occasionally that is when they have a problem they cannot otherwise solve themselves. Notwithstanding the explanation, these results suggest that the substantial public investment on research in Irish HEIs may have a disappointing, and perhaps even a negative, effect on the innovation output of Irish business, thus undermining future Irish prosperity.

It may appear that the import of this worrying finding may be lessened by the positive indirect HEI effect. This implies that the probability of interacting with suppliers and support agencies, which has a positive effect on innovation output, is enhanced by interaction with HEIs. This indirect effect might give some comfort to policymakers. However, the results on geographical proximity shed another light on it. The finding that proximity does not matter implies that Irish high-technology businesses are interacting over long distances so that the important interaction agents for these businesses, be they suppliers, customers, support agencies or indeed HEIs, are as likely to be located in other countries as they are locally.

The implication of this finding for Irish HEIs is that in terms of positively affecting business innovation, they should not restrict themselves to local businesses. However, from the Irish taxpayers perspective, international spillovers from investment on public R&D in Irish HEIs, which are well documented (see for example Coe, Helpman and Hoffmaister, 1997), represents a poor return to the Irish economy. It should be remembered however that Ireland, through its hosting of established foreign-owned businesses, has benefited greatly from such international spillovers, which may have originated, either directly or indirectly, from research activity by HEIs located abroad.

In order for research in Irish HEIs to be a positive force in enhancing Irish innovation output and, in turn, Irish prosperity, structures and strategies need to be developed that enable them to be more responsive to the needs of innovating Irish business. The chain-link model is a useful framework for conceptualizing the HEI role in business innovation. Although, perhaps due to difficulties of measurement, the attempt to measure the contribution of business' absorptive capacity to their innovation output yields mixed results here, there is a danger that policymakers may loose sight of how the role traditionally fulfilled by HEIs has a potentially positive impact on innovation output. This refers to HEIs as educators of the potential workforce of businesses and to the publication and dissemination of HEI research.

As regards Irish businesses, the implication is that when engaging in external interaction, they do not restrict their attention to agents such as suppliers, customers and HEIs that are local. This result questions the appropriateness of support agencies offering incentives to businesses to form local/regional clusters or networks, including suppliers, customers, competitors and HEIs in order to promote innovation. The limited size of the domestic market and the overriding importance of the international market imply that the suppliers, customers and competitors that Irish business are likely to interact would be located abroad. The evidence pointing to the importance of urbanization rather than localization economies suggests that Irish policymakers should think more in terms of creating the conditions for a vibrant 'local buzz' (Storper and Venables, 2002) and effective 'global pipelines' (Barthelt, Malmberg and Maskell, 2004) in Ireland's urban centres. It may well be that the ideal policy delivers highly efficient transport and communications infrastructures and suitably trained general labour pools, that facilitate the innovation performance of businesses based in these urban centres.

These findings based on a survey of 184 Irish high-technology businesses are by no means the last word. Clearly, analysis should and will be undertaken on other samples. For example, a survey of small and medium sized businesses in the South-West and South-East regions as part of the 'DRIVE for growth' project has shown results that are not significantly different from those reported here (Jordan and O'Leary, 2007a). In addition, Roper has been involved in a number of Irish studies (see for example Roper, 2001 and Roper, Du and Love, 2006). The methodologies used in these studies should be employed in larger samples of Irish businesses, including the recent large-scale Forfás survey of 2,324 businesses (2006). This kind of analysis, as well as extensions to it, including investigations of the links from innovation output to business and sectoral/national productivity, are likely to become a regular feature of the policy debate in years to come.

In addition, it is important to probe deeper into the reasons behind the emerging consensus of no positive effect of HEI interaction on Irish innovation performance. In order to understand the reasons for this, it is necessary to investigate the institutional contexts involved, the reasons for and barriers to collaboration and the evolving nature of collaboration between businesses and universities over time. As such it requires the use of survey, interview and case study research methods.

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APPENDIX

Variable Definitions

Variable Name	*Definition*
Innovation Output Indicators	
Product Innovator	A dummy variable taking a value of 1 if the business introduced a new or improved product in the three year reference period.
Regular Process Innovator	A dummy variable taking a value of 1 if the business introduced new or improved processes on a regular, frequent or continuous basis in the three year reference period.
Business Characteristics Indicators	
Age	The number of years at the start of the reference period since the business began operations in Ireland.
Size	The number of employees (full-time equivalent) at the start of the reference period.
Profitability	Net profit as a percentage of turnover in 2003. Measured using intervals of 5%.
Foreign Ownership	A dummy variable taking a value of 1 if the business is foreign-owned.
Group Member	A dummy variable taking a value of 1 if the business is a parent or subsidiary in a larger group of companies.
Workforce Education	The percentage of the workforce that have a third-level degree or equivalent qualification.
Turnover Growth	The rate of growth in turnover in the three-year period between 2001 and 2003.
Sector	A series of dummy variables; the sectors controlled for are *ICT* and *Chemicals and Pharmaceuticals*. The reference sector is *Engineering and Electronic Devices*.
R&D Indicators	
R&D	A binary variable taking a value of 1 if the business performed R&D in the three year period from 2001 to 2003.
R&D Department	A binary variable taking a value of 1 if the business had a dedicated R&D department in the three year period from 2001 to 2003.
R&D Spending	A series of binary variables of R&D expenditure as a percentage of turnover; categories are <5%, 6% to 10% and >10%. The reference group is no expenditure on R&D.

Interaction Indicators	
Interaction Frequency	An ordinal variable for each interaction agent representing interaction frequency on a five point scale, ranging from never to rarely, regularly, frequently and continuously. A value of 1 represents no interaction up to 5 representing continuous interaction. The frequency of interaction is considered for both product and process innovation.
Incidence of Interaction	A dummy variable for each interaction agent taking a value of 1 if the business indicates that it interacted at any frequency with the interaction agent in the reference period.
Localisation Indicators	
Labour Share	The percentage of total persons engaged in the business' sector by region. Confidentiality issues limit the extent to which the CSO can report total persons engaged by NACE code and by region. The fist sector includes NACE Codes 22 and 30. The second sector is NACE Code 24 and the third sector includes NACE codes 29 and 31-35. To achieve an appropriate sectoral classification, three regional categories were derived from the eight NUTS 3 regions. The categorisation is based on existing NUTS 3 regions, the geographical spread of the businesses in the survey data and, as far as possible, aggregation between contiguous regions where there is a large amount of commuting. The three regional categories are *Border, Midlands and West (BMW)*, *Dublin and Mid-East* and *Mid-West, South-East and South-West*. The source is the Census of Industrial Production, 2002 (CSO, 2003a) based on a special request by the authors. The unavailability of more detailed regional data on numbers employed limits the extent to which the presence of localised skilled labour markets can be identified.
Urbanisation Indicators	
Population Density	Population density is measured as the population divided by the area of each electoral division. An adjustment is made for electoral divisions within city boroughs. For city boroughs the mean population density of all electoral districts in which there are businesses within the survey is used. This adjustment is made because, for the purpose of this study, differences in population densities between urban areas and rural areas is more relevant than differences between administrative districts within urban areas. The source is Volume 1 Table 6 of the Census 2002 (CSO, 2003b)
Distance to Airport	The estimated one-way driving time, expressed in minutes, from the business to the nearest major airport. Major airports are selected based on passenger numbers, number of routes

	served and number of airlines. The major airports are Dublin, Shannon, Cork and Belfast International. The source for driving time is the AA Roadwatch Route Planner available at www.aaroadwatch.ie/routes.
Technical Employment	The number of persons over 15 years of age employed in technical and professional occupations as a percentage of the number of persons over 15 years of age employed in all occupations in the business' county in 2002. The source is Census 2002, Volume 6 Table 2 (CSO, 2003b).
Science Education	The percentage of total third-level graduates in the business' county in 2002 that have graduated from a scientific discipline. The source is Census 2002, Volume 6 Table 2 (CSO, 2003b). Subjects included as being from scientific discipline are *Life Sciences and Medical Laboratory Science*, *Physical Sciences and Chemistry*, *Mathematics and Statistics*, *Computing and Information Technology*, *Engineering and Architecture* and *Medical and Related Qualifications*. The qualification classifications excluded are *Education*, *Art*, *Humanities*, *Social Sciences, Business and Law*, *Agriculture, Forestry, Fishery and Veterinary*, *Tourism and other*, *Other third level qualifications* and those that did not state the qualification classification. The total number of persons with a third level qualification in the county is divided by the total number of persons with any third level qualification in the county.
Hub/Gateway	A dummy variable taking a value of 1 if the business is located in a hub or gateway, other than Dublin, identified in the National Spatial Strategy. (Source: Department of Environment and Local Government, 2002: 58)
Greater Dublin Area	A dummy variable taking a value of 1 if the business is located in the Greater Dublin Area identified in the National Spatial Strategy. (Source: Department of Environment and Local Government, 2002: 58)

FIRST VOTE OF THANKS PROPOSED BY MR. JOHN TRAVERS, CEO FORFÁS.

Introduction

Firstly, can I congratulate the authors, Declan Jordan and Eoin O'Leary on a very fine articulation of an important research paper and piece of analytical work.

Their paper deals with a highly relevant aspect of government policy. Based on a survey of 184 businesses in the *Chemical and Pharmaceutical, Information and Communications Technology and Engineering and Electronic Devices* sectors conducted in 2004 it explores the relationships between Higher Education Institutions (HEIs) and the innovation performance of Irish high-technology firms. Arising from the survey work undertaken the paper puts forward a number of interesting findings in relation to the relative importance of the higher education sector as a partner in the innovation activities of a set of high-tech enterprises and in relation to the importance, or otherwise, of the geographical proximity of other participants with which the enterprises engage in the innovation process. The paper points to an apparent disconnect between the higher education sector and the enterprises covered in the survey undertaken in respect of the innovation performance of these enterprises. It goes on to draw a number of provocative policy conclusions from this analysis.

It is good to see the increasing level of academic research interest in the field of innovation policy. It is extremely important to have well-informed debate on the issues raised in the paper and, in particular, on the objectives and outcomes of government investment in supporting measures that increase the innovation capacity of the economy. There are, undoubtedly, significant issues to be addressed if the linkages between the higher education sector and the enterprise sector are to be strengthened to the benefit of both. In Ireland, as in other countries, an important aim of government innovation policy is to strengthen the mutually beneficial collaborations that take place between industry and academia. The mutual beneficial aspects of the collaborations are important to keep in mind. This is a policy objective which shapes the activities of all R&D funding agencies. It is an objective which represents a stern challenge, not just in Ireland but, to a greater or lesser degree, in all knowledge-based economies.

In Ireland, the Advisory Science Council has recently highlighted two specific aspects of this challenge in its report "Promoting Enterprise - Higher Education Relationships":

- The need for a substantial improvement in the capacity, in the level and in the sophistication of R&D undertaken by the business sector;
- The need for intermediary structures between higher education institutions and enterprises to facilitate greater linkages between the two sectors, particularly in the applied research space.

Few dispute the fact that there is a need for stronger alignment between these two sectors. In my comments on the valuable Jordan and O'Leary paper, I will draw attention to some of the policy actions already in place to support this objective. I also point to what I think are some of the limitations of the research described in the paper by Jordan and O'Leary and in the policy conclusions which they attempt to draw from their analysis. I suggest that the paper takes a somewhat narrow view of what constitutes government innovation policy and that the analysis tends to focus on just one dimension of the very complex set of relationships between industry and higher education institutions. A number of the assumptions in the paper in relation to the scope and range of innovation policy appear to be incomplete with the result that the policy implications drawn from the analysis tend to be over-stated in important respects.

Nevertheless, the paper represents a welcome contribution to the debate on national innovation policies. Such debate is not only desirable, but is absolutely essential if these policies are to be sharpened and improved to the benefit of Ireland's future development and prosperity. Declan Jordan and Eoin O'Leary are to be strongly commended for the work they have undertaken in this area.

Assumptions Regarding Policy Objectives

The authors set out some of the key elements of STI policy and the focus of recent and planned investment in this area. Specifically, they refer to investment in the Higher Education (HE) sector through Science Foundation Ireland (SFI) and the Programme for Research in Third Level Institution (PRTLI) and public investment in private sector research through IDA Ireland and Enterprise Ireland. Based on their overview of some recent policy papers and data on investment in R&D, they set out their interpretation of the tenets of government policy in relation to innovation as follows:

- Gross expenditure on research and development (GERD) should be increased;
- Agency support should be targeted at Higher Education Institutes (HEIs) or at businesses interacting with HEIs;
- High-technology sectors have the greatest potential for innovation and growth.

This interpretation of government policy is much too narrow in various respects. The policy implications put forward at the end of the paper are based on the false premise that government policy is narrowly confined as described by the authors of the paper. Furthermore, the paper appears to assume that government innovation policy(ies) is/are static and unresponsive to emerging trends and based on a linear model of investing in higher education research that is expected, in a mechanistic fashion, to produce a flow of products and processes in high-technology enterprises. If the underlying premise put forward by the authors were correct the conclusions of the paper might be appropriate. However, Government policies on innovation are much wider, more dynamic, more complex and more sophisticated than that which the paper seems to assume.

A more careful consideration of government policy would show that there are multiple objectives underpinning an integrated science, technology and innovation strategy. While ultimately, policy in this area is about underpinning national competitiveness, widely defined, it is inappropriate to judge the success or otherwise of recent increased investment in this area purely on the basis of whether companies interacting with the higher education sector had a higher or lower number of product and process innovations (as compared to other enterprises) in the time period concerned without any control for *lag effects, the significance of the innovations, the nature of the linkages with the HE institutions or, most importantly, without taking into account the wider scope and objectives of Government innovation policies.*

The Strategy for Science, Technology and Innovation (SSTI) sets out quite clearly the broad array of policy objectives that are being addressed. Accordingly, it is difficult to understand the basis for the narrow interpretation of government policy adopted in the paper. For example, some of the main policy objectives set out in SSTI include:

- Increased participation in the sciences by young people by taking action as early as primary school to foster interest in the sciences;

- Increased numbers of people qualifying in the science, technology and engineering disciplines including numbers qualifying at advanced level (PhD);

- Building a sustainable, world class research system across the spectrum of humanities, physical and social sciences in the universities and institutes of technology which supports excellent science whether it be "frontier research" or more applied research;

- Upgrading the physical infrastructure and facilities available to support research in the public research system;

- Creating a transformation in the quality and quantity of research undertaken by the enterprise sector (indigenous and multinational) such that the R&D undertaken by that sector will continue to account for at least two-thirds of R&D undertaken nationally (a target associated with the Lisbon Strategy to which many other European countries continue to aspire);

- Increasing the output of economically relevant knowledge and know-how from the HE sector and other public research institutions and putting in place mechanisms to facilitate stronger industry-academic collaboration and interaction;

- Increased participation in trans-national research activity and raising the visibility of Irish science abroad;

- Greater exploitation of all-island synergies in STI policy.

Similarly, the Report of the Enterprise Strategy Group, to which the paper refers, by no means confines policymaking in relation to innovation to the high-technology sectors as the paper appears to suggest. The areas identified in that report with high potential for future growth include those in internationally-traded services, high-value manufacturing in a number of sectors (including but not confined to those covered in the survey which underlies the Jordan/O'Leary paper e.g. areas within the food industry, engineering and consumer goods) and locally-trading businesses (the major source of employment growth in the economy). The Report of the Enterprise Strategy Group devotes significant consideration to the importance of innovation under the headings of:

- Innovation and Entrepreneurship
- Workplace Innovation
- Innovation in the Public Sector.

A further example of the narrow focus of the paper in making comment on government innovation policy may be discerned by the fact that the paper fails to make reference to the development strategy for the international financial services industry in Ireland – *Building on Success* – published under the aegis of the Department of the Taoiseach in September 2006. This important policy document, prepared in consultation with the industry, devotes a full chapter to the topics of product development, innovation and R&D in the services sector with particular regard to the financial services industry, one of the most significant growth sectors in the Irish economy over the past twenty years. The industry is, of course, geographically clustered in the IFSC area in Dublin for a number of reasons and there are strong linkages between the FDI and Irish-owned firms located there and an array of professional service providers in the Dublin area and more widely. The government/industry strategy report identifies five key drivers of innovation in financial services (new facilitative technologies, complexity solving capacity, mass customisation solutions, blended product/services offerings and regulatory changes). Again, an approach to innovation policy is set out in the report which extends well beyond the three, rather narrow, tenets of innovation policymaking assumed in the Jordan/O'Leary paper. In doing so, it emphasises the importance of the essential links between R&D in the sector and the teaching/education role of third level institutions. It draws on another important report on innovation policy published by Forfás, also in September 2006 – *Services Innovation in Ireland: Options for Innovation Policy* which again, is a document of relevance which finds no echo in the paper.

In a wider context there is, I would suggest, widespread agreement that industrial policy (now better labelled enterprise policy) in Ireland has been a highly successful facet of policymaking generally in Ireland over a number of decades, particularly in the area of the attraction of foreign direct investment and the many direct and indirect benefits that have accrued from that. Innovation was not a term in vogue when the first elements of that policy were formulated many decades ago but, retrospectively, it is a term that applies very well to it and to its evolution over time. The feedback loops described in the Chain Link Model of Innovation as set out in the Jordan/O'Leary paper could well be used to describe, in many respects, how this evolution took place.

When the first, faltering steps were taken to attract foreign direct investment to Ireland more than 40 years ago, success was slow in coming. A cost-benefit analysis undertaken in the mid-1960s might, with some justification, have concluded that industrial policy, as then articulated, was a failure. The highly positive outcomes of that policy and its evolution did not occur in a simple, linear fashion and they took time to come to fruition. And, of course, more widely, if one if one was to search for the most significant sources of product and process innovation in Irish business over the past 40 years, it would be difficult to exclude the impact, both directly and indirectly, of industrial policy from the reckoning. There is no guarantee that industrial policy, widely-defined, will be as effective in the future as it has been in the past. That is why any complacency about apparent policy success past, present or prospective must be avoided. It is also why the issues raised in the Jordan/O'Leary paper are well worthy of debate and require a considered response from our policymakers. Policymaking and policy implementation are complex, dynamic processes within which innovation is itself an endogenous variable.

I, therefore, hope that it is clear that Ireland's policy in the area of innovation, like that of many other countries, is built around the concept of a "system of innovation" where the direct transfer of knowledge between the higher education sector and industry is just one element (albeit a very important one) within a complex and dynamic system.

Accordingly, it may be regarded as somewhat ambitious to attempt to critique that policy, as the Jordan/O'Leary paper attempts to do, almost solely on the basis of three main factors:

1. A relationship between particular segments of the industry sector and the HEI sector;
2. Survey data confined to a particularly short period of time by reference to the time when significant increases in funding for R&D and new policy initiatives were first put in place, and
3. Survey data relating to only one element of the innovation process (i.e. R&D expenditure) at a time when that particular element was undergoing a period of rapid transition and change.

Some of the other policy assumptions put forward by the authors may also be based on a misunderstanding of current policy:

- The authors suggest that there is a bias in favour of enterprises with dedicated R&D departments. But it is not clear that any such bias or discrimination exists. The enterprise development agencies support the R&D and innovation activities of a wide array of companies from very small to very large and of varying capability levels. Support is not conditional on an enterprise having a dedicated R&D department. Neither are the significant tax credits now available to business for R&D investment purposes.

- Similarly, it is suggested that government support is focused on “high-technology” sectors. While it is true that Science Foundation Ireland (SFI), on its establishment in 2001, initially concentrated, largely for operational reasons, on promoting and supporting research in the areas underpinning ICT and biotechnology. However, the remit of SFI is not confined to these areas. More recently, SFI has moved on to support research in more widely-based research projects in areas such as mathematics, engineering and more widely. Significant resources are also allocated to other fields of science (food, forestry, marine, health, energy etc.) through specialist agencies and through the general University funding arrangements operated by the Higher Education Authority (HEA). The enterprise development agencies (IDA Ireland and Enterprise Ireland) do not discriminate between sectors when it comes to support for research and innovation. Appropriate projects in all areas under the remit of the agencies (i.e. manufacturing and internationally-traded services) are supported where it is clear that the investment involved is likely to enhance the competitive position of the firms concerned and to add economic value more widely in Ireland. Accordingly, the contention in the Jordan/O’Leary paper of sectoral bias in Irish innovation policies is not well-founded.

Significance of the Findings in Relation to Linkages between Industry and the Higher Education Institutes (HEIs)

The authors have taken on an admirable and challenging task in attempting to model critical aspects of the innovation process. The conceptual framework they propose - the Chain Link Model of Innovation - provides an appropriate and useful framework in highlighting the complexity of the innovation process and the interactions that take place between different participants in that process.

The links between firms and higher education institutions described in the Model can be broken down in turn into a wide range of knowledge interactions. For example, 15 different types of such interactions are listed in one study by Schartinger and others[1] covering the following areas:

- Contract research and consulting
- Employment of graduates by firms
- Conferences attended by both industry and academic researchers
- New firm formation by researchers from academia
- Joint publications
- Informal meetings, talks, communications
- Joint supervision of PhDs and masters theses
- Training of employees of enterprises
- Mobility of researchers between industry and academia
- Sabbatical periods for researchers at both sides
- Collaborative research, joint research programmes
- Lectures at universities by employees of enterprises
- Use of public research facilities by industry
- Licensing of patents held by HEIs to enterprises
- Purchase of prototypes developed in HEIs

It is a highly difficult task to try to capture effectively such a complex set of interactions in a mathematical model. Inevitably, the interactions have to be simplified. The authors choose to focus on the frequency of interaction with different potential partners in the innovation process – customers, suppliers, competitors, development agencies and higher education institutions. These

[1] Schartinger et al. cited in “Fostering Industry-Science Relations”, Joanneum Research, May 2006

interactions are measured on a uniform five-point scale. The analysis presented suggests that these interactions are in some way comparable across the very different types of actors.

As pointed out by the authors, the headline survey findings are broadly consistent with other surveys which also point to stronger connections between enterprise and customers and suppliers compared to those that enterprises hold with higher education institutions in the innovation process. This is a consistent finding across all innovation surveys. It is a finding that is not particular to Ireland. The authors go further than others, however, in the model they develop and the policy implications that they draw. This is particularly the case in the proposition put forward that the interaction of enterprises with higher education institutions is negatively associated with product and process innovation.

It is not fully clear what significance and policy importance should be attached to this particular proposition. The authors rightly suggest that the validity of this proposition should be further evaluated by undertaking similar analyses on larger datasets. This is an area where caution needs to be exercised in too readily drawing extreme policy conclusions on the basis of the econometric data of a simplified model of the innovation process. Suggesting, as the authors do, that the innovation output of Irish business may be negatively affected and that future national prosperity may be undermined by continued investment in higher education research does seem, at face value, to be an over-interpretation of the econometric results.

The authors also suggest that policy makers may have lost sight of the traditional teaching role of higher education institutions and their role in publishing and disseminating their research. Their paper, however, offers no evidence to support the contention that the increased investment in higher education research has been at the expense of the teaching role of these institutions or has discouraged the publication and dissemination of research findings. On the contrary, since the publication and dissemination of research results is one of the criteria on which support decisions from government research funds are based it would appear self-evident that government funding is highly supportive of this process. It is also the case that one of the important objectives of government innovation policies is to strengthen the complementarity between the research and educational capabilities of third-level institutions. This is an objective clearly articulated in a range of policy documents. One of the clearly expressed purposes in the establishment of Science Foundation Ireland by Forfás in 2001, for example, was to support research activities which enhance and strengthen the teaching faculty and capability of our Universities. Today, SFI operates a range of well regarded funding programmes which well support this objective. These programmes have already served to recruit a significant cadre of world-class, research-active academics to be part of the teaching faculty of our Universities.

The Jordan/O'Leary paper suggests that policy needs to change in order to put the enterprise sector "in the driving seat" and that the role of Higher Education Institutions (HEIs) should be one of responding to innovative businesses.

There is, in fact, already a strong policy agenda and set of associated practical measures in Ireland to forge stronger links between the HE sector and the enterprise base. Some initiatives are focused more on the HE sector (involving, for example, putting resources in place in our Universities which actively seek to identify research activities with commercial potential and which teach researchers how to search for findings which are likely to be of interest to enterprises). Other initiatives are more industry-led (involving companies or groups of companies identifying specific research needs and receiving support to access appropriate technology and research solutions from Universities and Institutes of Technology). The evaluation of these activities is an area of rich potential for fruitful research. For some initiatives, such as the Centres for Science, Engineering and Technology (CSETs) supported by SFI and the enterprise development agencies, both the industry and academic partners are each required to be strongly involved in a balanced partnership. Recent survey data from SFI indicate that SFI funded researchers are engaged in more than 500 separate industry-university collaborations involving some 400 separate companies. This is remarkable given the relatively short period during which SFI funding has been available.

On a wider note, while the case for increasing the capability of Irish Universities and Institutes of Technology to respond effectively to the research and innovation needs of the Irish enterprise sector is manifest it would surely be a retrograde step, from both an academic and economic perspective, to attempt to confine the research activity of the third-level sector to simply that role. Such an approach would ignore the capacity of University research activity to be a source of innovation in its own right and a generator of knowledge and ideas from which new enterprises, new products and new processes can arise.

Significance of the Findings Regarding Proximity of Partners

The set of findings in the paper around the importance, or otherwise, of the proximity of the various participants in the innovation process and the findings regarding an "urban effect" are particularly interesting and provide an important contribution to debate. There are significant differences in the innovation literature on the importance, or otherwise, of geographic proximity to different actors and, clearly, survey findings will be highly context-specific. The Jordan/O'Leary survey findings provide interesting observations on this question from an Irish perspective. As the authors suggest, it would be useful to conduct complementary research using a variety of techniques to probe this issue further.

The policy implications already put forward in the paper on the basis of the survey findings described in the paper appear to be over-stated. In this context, the suggestion is made in the paper that Ireland operates a closed innovation system and is interested almost exclusively in fostering linkages between HEIs and enterprises which are confined only to Ireland. Such a contention is incorrect. SFI and other science funding agencies allocate significant resources to supporting working relationships between Irish scientists and those in other countries. For example, a full chapter in SSTI deals with the internationalisation of Irish science and discusses the complementarity between national STI policy and European policy in this area. EU member states, including Ireland, invest considerable resources at Community level in order to facilitate collaborative research on a trans-national basis, encourage the inward and outward flow of researchers and organise competitive research programmes at a European level to stimulate excellence in research. A wide range of programmes are also in place to facilitate research collaboration with scientists in the US, India, China and other important global players.

While it is an objective of policy in Ireland, as it is in most other countries, to have as much knowledge exploited within the country as possible, no false barriers have been raised to restrict the flow of knowledge arising from research and avoid it leaving the country. On the contrary, Ireland is an extremely small player in the global research system and we benefit far more from our access to the global knowledge base than we contribute to it.

The suggestion is made in the paper that attempts to build local linkages and clusters are a wasted effort. This is a curious interpretation of the survey findings. It flies in the face of what is known to be happening on the ground in Ireland. While enterprises have many linkages outside Ireland, it does not follow that efforts to also facilitate and stimulate local linkages and clusters are a wasted effort. There are spillover benefits to the Irish economy from such linkages and collaborations including economies of scale and of scope in the provision of infrastructure, training, educational and other support services. There is no reason why internationally-focused enterprises in Ireland (indigenous and multinational) cannot have active linkages in Ireland in addition to their linkages overseas. It is well known and accepted that the availability of sub-supply inputs and services within Ireland is one of the factors taken into account when FDI decisions are being taken by overseas investors and that such linkages are strongly further developed once an FDI project locates in Ireland.

Conclusion

The paper by Jordan and O'Leary contains many interesting findings about aspects of the innovation process within firms and their external linkages with other participants in the process. The headline survey findings are broadly consistent with a number of other studies on the innovation process both nationally and internationally. This is, particularly, the case in respect of the relative importance of HEIs and other public institutions relative to customers and suppliers in the innovation process. The authors attempt to explore connections between their headline findings through econometric modelling guided by the conceptual framework of the "Chain Link Model of Innovation".

In doing so, the authors raise interesting and provocative questions about the focus of government policy in this area. While the questions raised are certainly worthy of debate, the paper itself presents, in many ways, an overly-simplified view of current policy. It does not take sufficient account of the wide scope and the dynamic nature of that policy and of the continuing developments taking place to align the interests of the higher education sector and the enterprise sector to the benefit of both.

The suggestion at the end of the paper that there is now an "emerging consensus of no positive effect of HEI interaction on Irish innovation performance" is one of a number of conclusions put forward by the authors. The suggestion appears to involve an interpretation of the survey findings that well go beyond the underlying substance.

Declan Jordan and Eoin O'Leary are to be congratulated on the important issues raised in their paper and on the many questions posed for consideration and debate in relation to Irish innovation policy. It is, undoubtedly, the case that the significant increase in R&D expenditure now taking place relative to former years requires to be subjected to rigorous questioning and evaluation. The undertaking of such evaluation by people with expertise, like Declan Jordan and Eoin O'Leary, from outside the realm of policymaking is particularly important and appropriate and requires to be strongly encouraged and facilitated. The authors have made an important contribution to the robust debate that needs to take place on these matters in the paper presented here this evening. Hopefully, they will continue to undertake further work in this area and, in doing so, spark others to do the same. Such work can only serve to sharpen and improve Ireland's national innovation policies with all that these entail for further national development and prosperity.

In preparing this personal response to the very fine paper of Declan Jordan and Eoin O'Leary, I have drawn heavily on the advice of colleagues for which I am indebted – particularly that of Marcus Breathnach in Forfás, Enda McDonnell in Enterprise Ireland, Graham Love in SFI and Pat Frain and his colleagues in the Nova Centre at UCD. Needless to say, I am responsible for all sins of omission or commission in this short response.

On your behalf, and on my own, I again congratulate and thank Declan Jordan and Eoin O'Leary for the very fine paper they have presented to the Statistical and Social Inquiry Society of Ireland at the Royal Irish Academy here this evening.

SECOND VOTE OF THANKS PROPOSED BY PROF. STEPHEN ROPER.

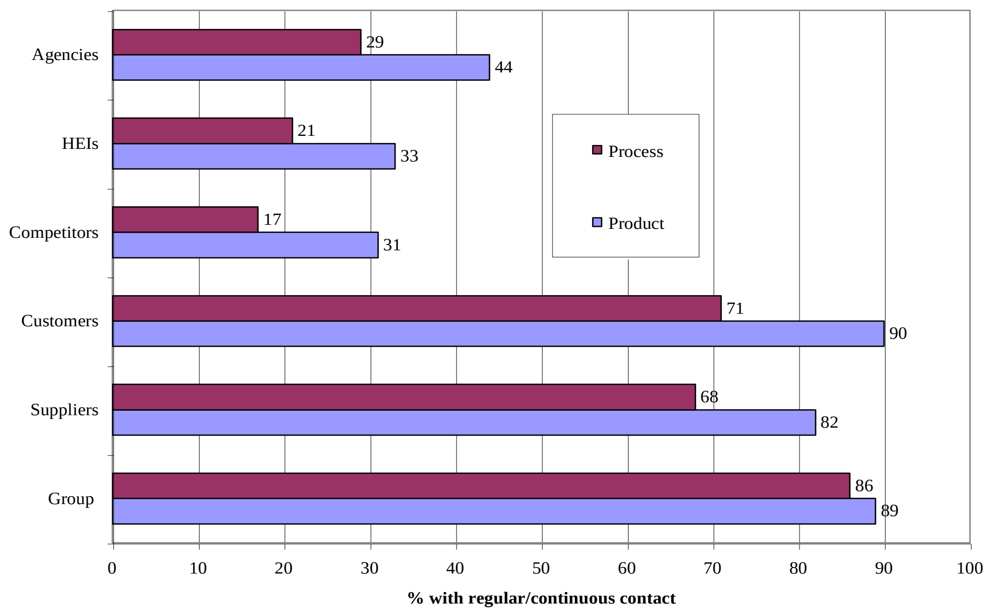
Let me start by echoing John Travers' thanks to Eoin O'Leary and Declan Jordan for presenting a stimulating and thought provoking piece of analysis. I regard this paper as making a useful contribution to the innovation studies literature as well as raising some important substantive issues. John Travers in his comments has focussed on the policy discussion in the paper and I will have something more to say about this in a few minutes. Before that I think it is appropriate to highlight what I regard as the academic contribution of the paper.

Methodological and Analytical Contributions

This paper is situated within a growing academic literature often referred to as 'innovation studies'. Growth of academic interest in this area has been stimulated both by the increasing policy interest in innovation – epitomised in some of John Travers comments – as well as the increasing availability of data on firms' innovation activities. Many analyses in this area draw on Community Innovation Survey data but the current study is based on broadly similar survey data compiled by the authors. This data relates to high-technology firms – both Irish and externally-owned and covers their innovation activity over a (standard) three-year period.

The primary data collection undertaken by Jordan and O'Leary give them the opportunity to adopt an individual approach to the measurement of firms' innovation activity, and I feel two aspects of this are particularly worthy of note. First, in the context of most innovation survey data – most notably the Community Innovation Surveys – firms' interaction with other organisations as part of their innovation activity is reflected in a series of simple dummy variables. These take value '1' if the firm does engage with, say, its suppliers in the innovation process and '0' otherwise. Jordan and O'Leary go further than this by allowing for the frequency of interaction between a firm and its innovation partners. This provides some new insight into the nature of firms' innovation activities as Figure 1 below illustrates.

Figure 1: Percentage of Firms with Regular or Continuous Interaction as Part of their Innovation Activity



Source: Jordan and O'Leary, 2007, Table 4.

In particular, this emphasises the difference in the intensity or regularity of firms' interactions with customers, suppliers and other group companies on the one hand and HEIs, competitors and development agencies on the other. Particularly notable here, in terms of the subsequent analysis of the paper, is the relatively low frequency of 'regular' or 'continuous' contact between firms and HEIs as part of their innovation activities.

A second aspect in which Jordan and O'Leary develop the standard innovation survey methodology is by incorporating some measures of the distance between the firm and their innovation partners. This is operationalised using a banded measure of driving time. Personally, I find this methodological innovation of less interest than the frequency of interaction variables but I recognise its potential value for drawing some inferences relating to clustering etc.

The analytic approach adopted in the Jordan and O'Leary paper is the now standard innovation production function with dependent variables which reflect the probability of product and process innovation. Earlier work undertaken on this theme is cited in the paper including previous papers by colleagues and myself. There is nothing wrong with the results reported in the paper although most recent studies would go beyond these bivariate dependent variables in a number of directions. First, some studies would encompass a wider range of types of innovation, recognising that innovation in marketing, design and organisation may also be important as well as product and process change. Secondly, many studies would – in addition to the binary innovation indicator – use more continuous indicators to give an indication of the quality or sophistication of firms' innovation activity. As it is the paper gives us an indication of the factors which shape the *extent* of innovation across the population of high tech firms in Ireland rather than the quality or success of that innovation.

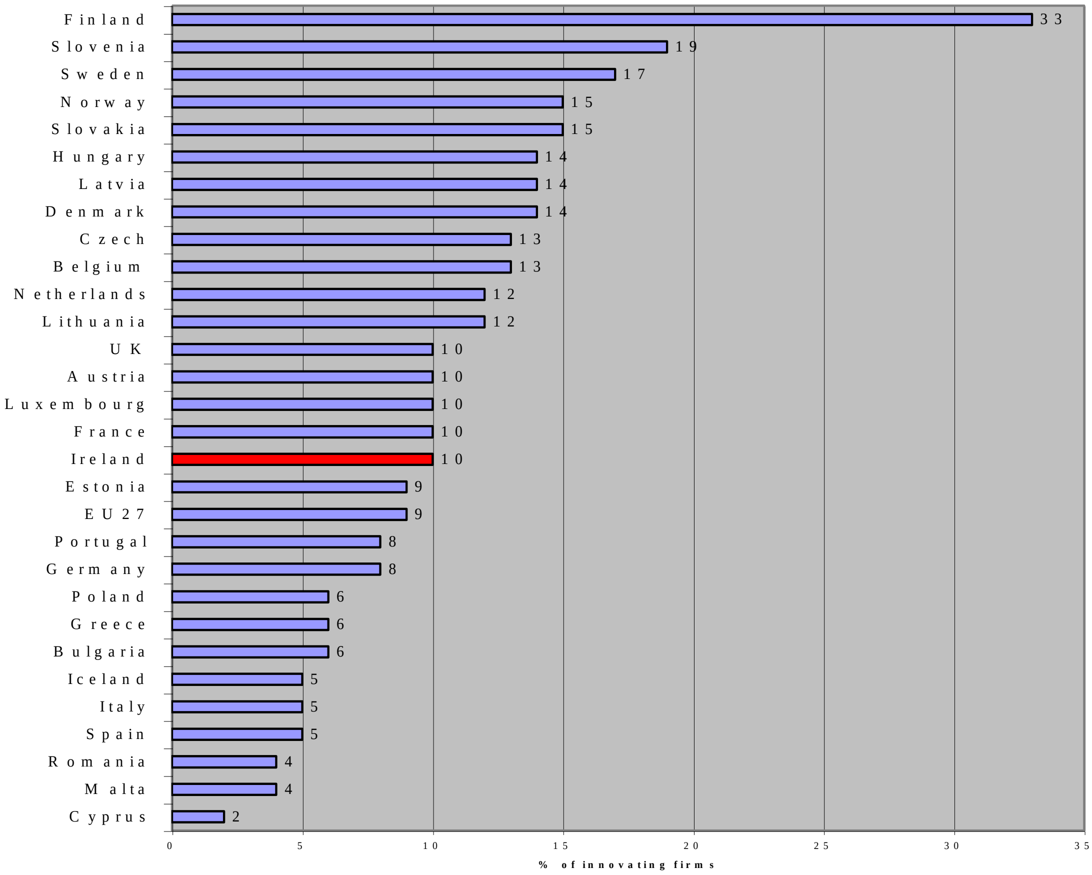
Substantive Comments

I propose not to comment on all of the individual results presented in the paper which - by and large - are very much what one might expect. Instead, I propose to focus on the less intuitive negative result relating to interaction with higher education institutions. First, I think it is necessary to be absolutely clear what we are talking about here so I want to spend some time thinking about the meaning and interpretation of the negative coefficients we observe in Tables 6, 7 etc. Our dependent variable here is the probability of either product or process innovation and the key point is that the greater the frequency of firms' interaction with HEIs the lower the probability of innovation. The HEIs involved here need not be Irish, however. Indeed, given the other results reported in the paper they are unlikely to be so. Nonetheless, the implication is that the more times a firm interacts with an HEI the lower the probability of innovation. This of course says nothing about the quality of innovation achieved by the firm, or whether innovation might be accelerated by working with an HEI. As John Travers points out here there are also some questions about causality common to all survey-based, cross-sectional studies like Jordan and O'Leary. Is it the case that less innovative firms tend to work with universities or that universities do actually reduce the probability that firms innovate? From the results presented in the paper it is also not possible to assess the size of the negative HEI effect. We need marginal effects from the Logit models to be able to see whether HEIs are reducing the probability of innovating by 20 per cent or 2 per cent. Adding these would be a useful addition to future drafts.

This all suggests – and the authors recognised in their presentation – that this is not therefore a definitive result. It is based on a relatively small sample of firms and there are clearly potential issues of causality. I think, however, that as Jordan and O'Leary suggest this result reflects other econometric evidence for Ireland based on much larger samples of firms which suggests that business-university interaction in Ireland has no significant impact on both the extent and quality of product and process innovation in Ireland (Roper et al., 2006). It also contrasts with recent evidence on the US state of Georgia which suggests positive impacts on innovation activity from firms' interaction with HEIs (Roper et al., 2007).

My feeling therefore is that, at best, university-business interaction is having a neutral and possibly negative effect on the innovation activities of Irish firms at present. Recent evidence from the 4th Community Innovation Survey adds another dimension to this debate emphasising the relatively small proportion of Irish firms which are actually working with universities as part of their innovation activity (Figure 2). In fact, this suggests that only around 1:10 Irish firms are working with universities as part of their innovation activity compared to 1:3 in Finland and 1:5 in Denmark. Moreover, where this interaction is occurring it is relatively infrequent, as Figure 1 suggests.

Figure 2: Percentage of Firms Collaborating with Universities



Source: Eurostat, CIS4 Data.

So, we have a situation in which only 1:10 Irish firms is working with universities as part of their innovation activity, and where they do work with universities the econometric evidence casts considerable doubts on the impact on firms' innovation activity. This I think raises two questions which are worthy of further research attention. First, why is the proportion of firms in Ireland working with universities is so much lower than that in other benchmark countries? And, second, what explains the relatively poor results of university-industry interaction in Ireland? Addressing these questions probably requires a move away from econometric and statistical approaches towards more qualitative, in-depth approaches

Both questions are, of course, particularly important in the current policy context in Ireland where investment in university R&D is being seen as one of the foundation stones of future prosperity. Moreover, an innovation system perspective suggests that strong connectivity between universities and firms is a pre-requisite for successful innovation. Therefore, while I recognise the points made by John Travers about the different innovation policy initiatives being implemented in Ireland, and the range of channels through which universities can benefit firms, I would still argue that the Jordan and O'Leary paper does pose an important challenge to the assumptions underlying innovation policy in Ireland. Perhaps more important, however, from a public finance standpoint is the risk that if, as the paper suggests, university-business interaction is not working effectively the benefits of NDP investments in higher education R&D may lost.

References

Roper, S., J. H. Love, et al., (2006), "The Innovation Value Chain", Aston Business School Working Paper WP0639.

Roper, S., J. Youtie, et al., (2007), "Knowledge, Capabilities and Manufacturing Innovation: A US-Europe Comparison", Forthcoming *Regional Studies*.

AUTHORS' RESPONSE TO DISCUSSANT AND PARTICIPANT COMMENTS

We would firstly like to thank the Society for accepting our paper. The topicality of the issues it addresses is demonstrated by both the quantity and quality of the responses it has elicited. We would like to thank both the invited discussants for their considered remarks and the participants to the lively discussion that followed who 'put pen to paper'.

We begin by considering the remarks made by John Travers. According to John, the policy community is aware that significant issues need to be addressed concerning the linkage between Higher Education Institutes and the enterprise sector. As testimony to this he quotes two challenges, recognized by the Advisory Science Council, of increasing the capacity of business to absorb research by Higher Education Institutes and developing intermediary structures to facilitate greater linkages between the two in the 'applied research space'. Even these challenges reveal the science push mindset that is at the heart of Irish innovation policy. If a market driven view of innovation was being followed a wholly different set of challenges would be proposed by policymakers. These would centre on supporting businesses that innovate, no matter what sector they are in or whether or not they are involved in technological innovation. In relation to Higher Education Institutes, it would involve encouraging them to be responsive to business innovation needs and developing undergraduates and postgraduates with relevant skills.

John proceeds to assert that we have an over-narrow interpretation of policy in this area. It was not our purpose in the paper to summarize all government documents relevant to the discussion. Instead we sought to identify the tenets or precepts of innovation policy. Nothing that we have heard during the debate or since has caused us to change our view that this policy is wrong-headed in seeking to promote Irish business innovation through support of research in Higher Education Institutes targeted at a number of high-technology sectors.

John proceeds to suggest that our model is too simplified to understand the complex sets of interactions that might take place between businesses and Higher Education Institutes. We make two points in response. First, we set out, as Stephen Roper confirms in his comments, to follow the approach adopted in international innovation studies of explaining business innovation performance based on research and development activity by the business and its interactions with customers, suppliers, competitors, innovation support agencies and Higher Education Institutes (as well as numerous control variables). Thus, our paper is not about the Higher Education Institute linkage *per se*, although given our findings it appears to have centred on this linkage. Second, we readily admit that further studies are required both using bigger data sets and more qualitative approaches to delve deeper into our surprising finding. These will be fruitful grounds for future research both by us and others. In particular it would be worthwhile if our analysis was conducted using data from the Irish element of the Community Innovation Survey 2004 – 2006 conducted by Forfás.

John ends his comments with some concerns about our conclusions on the importance of geographical proximity. He doubts whether attempts to build local linkages and clusters are a wasted effort. Our paper has shown that in terms of innovation, geographical proximity does not matter in the Irish case. We therefore question the fixation of Irish policymakers with clusters and the funding of same. The evidence on this issue has been building for a number of years. It concerns us that evidence-based policy does not seem to have emerged on this issue.

Turning to Stephen Roper's comments, we welcome his view that we are contributing to the international literature by our measurement (i) of the frequency of interaction between a firm and its interaction agents and (ii) of geographical proximity using time distance. Regarding the linkage between business and Higher Education Institutes, Stephen suggests that our research, alongside a number of other studies, raise important questions for future research: why is the proportion of Irish firms working with universities so low and what explains the poor results of university-business interaction in Ireland? We agree with his suggestion that answers to these questions will probably require a move away from econometrics to more qualitative, case study type approaches.

Finally, we would like to reply to Patrick Honohan's contention that we did not provide econometric evidence that the correlations we report are causal. We doubt whether causality can be demonstrated using econometrics. There is certainly a need for other methodologies as argued already. The suggestion by Patrick that our 'striking curiosum' may be explained by analysing indigenous and foreign-owned firms together has already been tested by us. Our regressions found that the ownership of the businesses had no significant effect on its innovation performance.