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THE ROLES OF INTERACTION AND PROXIMITY FOR INNOVATION BY IRISH HIGH-TECHNOLOGY BUSINESSES: POLICY IMPLICATIONS

Declan Jordan and Eoin O'Leary[*]

1. Introduction

This paper presents new survey-based evidence on the increasingly topical question of what drives innovation in Irish high-technology businesses. The extraordinary performance of the Irish economy since the 1990s has been inextricably linked to highly successful foreign-owned businesses, in sectors such as pharmaceuticals, electronics and computers (Gallagher, Doyle and O'Leary, 2002). It might be expected that innovation in these multi-nationals is largely sourced in other group companies located abroad. It is therefore pertinent to ask, in the context of the recent policy recommendations of the Enterprise Strategy Group (ESG) (2004), the extent to which these Irish subsidiaries source innovation in Ireland. This may be through their own research and development efforts and/or through interaction for the purposes of promoting innovation with other locally or regionally based businesses, Third Level Colleges and innovation support agencies, such as IDA Ireland and Enterprise Ireland. Moreover, it may be equally important to ask, in the context of the long-standing

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emphasis on improved performance of indigenous industry, whether indigenous high-technology businesses interact locally or regionally in order to promote innovation.

Beginning with Culliton (1992) and continuing to the present, through, for example, Forfás (2004a) and the ESG (2004), Irish industrial policy has consistently promoted and supported clusters and networks. In recent years substantial State funding has also been devoted to research and development. The National Development Plan 2000-2006 (2000) allocated €2.5 billion and the government established Science Foundation Ireland. The ESG (2004) has proposed further State investment in research and development as well as new initiatives including building enterprise capability, funding collaboration between industry and Irish Third Level Colleges, introducing tax credits for research and development. There is a consensus in the Irish, and indeed the European, policy community that developing innovation through clusters and networks will be important for future Irish and European competitiveness (Bergin *et al.*, 2003; Forfás, 2003; National Competitiveness Council, 2003; European Commission, 2003).

By presenting survey based evidence on the sources of innovation in Irish high-technology industry, this paper makes an important contribution to this debate. It begins by outlining the design of the survey instrument and then presents the results. The policy implications of the results are then discussed.

2. Survey of Innovation in Irish High-Technology Businesses

The survey, conducted towards the end of 2004, was targeted at Irish high-technology businesses, which have been crucial to the recent strong performance of the Irish economy. For example, Information and Communications Technologies (ICT) and Chemicals (which includes Pharmaceuticals), between them, accounted for approximately 90 per cent of the growth in industrial output and employment during the second half of the 1990s (Department of Enterprise, Trade and Employment, 2003, p.67). The particular sectors chosen for the survey are classified as *Chemicals and Pharmaceuticals, ICT* and *Electronic Devices and Engineering.*[1] These sectors are identified by the ESG (2004, pp.41-45)[2] as having future growth opportunities. The list of businesses in the selected sectors was constructed from the IDA Ireland database[3], which relates to foreign-owned businesses, and the

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

[2] 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.

[3] www.idaireland.com.

Enterprise Ireland (EI) SourceIreland website,[4] for indigenous companies.[5] 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 per cent of the population of *ICT* and *Electronic Devices and Engineering* and 73 per cent of *Chemicals and Pharmaceutical* businesses are covered in the resulting database used for the survey.[6] In terms of employment, the survey is representative of the population, although there are a small number of very large businesses in the survey.[7]

A self-administered questionnaire, containing 25 questions on levels of product and process innovation and their sources, was circulated to 857 businesses.[8] 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 per cent is as good as can be expected. As can be seen from Table 1, the response rate is relatively evenly spread across sectors and types of 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
Overall Total	857	184[3]	22

1 A detailed account of the population, the survey instrument and the survey findings are available from the authors on request.

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

3 One respondent was anonymous and could not be classified by sector or by location.

4 www.enterprise-ireland.com/sourceirelandsearch.

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

6 The population of businesses was constructed using the Census of Industrial Production (CIP), 2002 (CSO, 2004) for manufacturing local units and the National Software Directorate (www.nsd.ie) for software.

7 In each sector mean employment reported in the CIP, 2002 (CSO, 2004) is similar to the 5 per cent trimmed mean for respondent employment.

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

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 per cent of whom had a third level degree. The 86 foreign-owned respondents had an average of 182 employees, 29 per cent 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 in third level are statistically significant at the 95 per cent level. Geographically, respondents are spread throughout the country, with 48 per cent in the Dublin/Mid-East regional authority areas, 22 per cent in the South-West, 10 per cent in the West and the remaining 20 per cent spread between the Border, the Mid-West and the South-East.

Following studies such as Roper (2001), MacPherson (1998) and the Community Innovation Survey conducted by the Department of Trade and Industry (2004) in the UK, product innovation is defined as the introduction of new or improved goods/services to the market over a reference period, which is taken as 2001 to 2003 in the survey. Process innovation, which is less tangible 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 output, are closely linked to what managers might be expected to observe in their businesses. It avoids some of the thorny issues involved in trying to elicit whether an innovation is new to the market and whether its impact is commercially significant (Kline and Rosenberg, 1986; Gordon and MacCann, 2005). Given the breadth of this definition, it is not surprising that 80 per cent of respondents were product innovators with 76 per cent introducing process innovations, either regularly, frequently or continuously between 2001 and 2003. Similar results are found in other national and international studies (Forfás, 2005; Becker and Dietz, 2004).

In order to determine the sources of both product and process innovation, businesses were asked whether they undertook research and development, either formally through dedicated research and development 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, academic researchers (in universities and

Institutes of Technology) 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 scale from continuously, to frequently, regularly, rarely and never. This approach to the study of interaction is slightly 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 categorised 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.[9]

3. Innovation and the Roles of Interaction and Proximity

Table 2 presents the percentage of respondents who undertook research and development by sector and type of business. This shows that 67 per cent of businesses indicated that they undertook research and development between 2001 and 2003. At the 99 per cent confidence level, indigenous businesses were more likely than

Table 2: Businesses Conducting Research and Development, by Sector and Type of Business (Per Cent of Respondents)

Chemicals and Pharmaceuticals		**58**
of which	Foreign	48
	Indigenous	75
ICT		**74**
of which	Foreign	60
	Indigenous	83
Electronic Devices and Engineering		**65**
of which	Foreign	50
	Indigenous	78
Total		**67**
of which	Foreign	52
	Indigenous	80

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

foreign-owned businesses to perform research and development. There was no significant difference in the likelihood of performing research and development across sectors.[10]

Table 3 presents the frequency of interaction for product innovation by interaction agents, sector and type of business in terms of percentage of respondents. This shows a striking pattern across the three sectors and for both foreign and indigenous businesses. For a clear majority of businesses, 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, Third Level Colleges and innovation support agencies, as indicated by the majority of businesses never or rarely interacting. This difference is significant at the 99 per cent level. There are no statistically significant exceptions to these clear trends.

Table 3: Frequency of Interaction for Product Innovation by Interaction Agent, Sector and Type of Business (Per Cent of Respondents)[1]

	Group	Suppliers	Customers	Competitors	Third Level	Agencies
Chemicals and Pharmaceuticals						
Foreign:						
Never/Rarely[2]	0	11	11	81	67	63
Regularly to Continuously[2]	100	89	89	19	33	37
Indigenous:						
Never/Rarely	n.a.[3]	13	13	69	56	44
Regularly to Continuously	n.a.	88	88	31	44	56
ICT						
Foreign:						
Never/Rarely	21	24	13	68	71	75
Regularly to Continuously	80	76	88	32	29	25
Indigenous:						
Never/Rarely	27	30	8	62	75	48
Regularly to Continuously	73	70	93	38	25	52
Electronic Devices and Engineering						
Foreign:						
Never/Rarely	0	15	9	78	72	61
Regularly to Continuously	100	85	91	22	28	39
Indigenous:						
Never/Rarely	n.a.	12	10	59	59	51
Regularly to Continuously	n.a.	88	90	41	41	49

[1] Numbers may not add to 100 per cent 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.

[3] Not available for confidentiality reasons.

Table 4 presents the time distance between businesses and their most important interaction agents for product 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

[10] This and subsequent tests are based on the Pearson Chi-Squared test.

than one hour and usually more that four 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. This result holds for all sectors and types of businesses and is significant at the 99 per cent level. For competitors, with whom it was seen in Table 3 that businesses do not interact strongly, the most important agent is located more than four hours away for a clear majority of businesses. For both Third Level Colleges 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. 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.

Table 4: Time-Distance from Most Important Interaction Agent for Product Innovation, by Sector and Type of Business (Per Cent of Respondents)[1]

	Group	Suppliers	Customers	Competitors	Third Level	Agencies
Chemicals and Pharmaceuticals						
Foreign:						
<1 hour[2]	0	5	14	0	33	20
1 to 4 hours[2]	0	24	18	18	47	60
> 4 hours[2]	100	71	68	82	20	20
Indigenous:						
<1 hour	n.a.[3]	13	20	17	20	36
1 to 4 hours	n.a.	7	40	17	30	55
> 4 hours	n.a.	80	40	67	50	9
ICT						
Foreign:						
<1 hour	5	20	30	27	13	56
1 to 4 hours	5	13	10	0	38	33
> 4 hours	91	67	60	73	50	11
Indigenous:						
<1 hour	25	36	15	20	53	76
1 to 4 hours	0	8	21	20	24	10
> 4 hours	75	56	64	60	24	14
Electronic Devices and Engineering						
Foreign:						
<1 hour	7	12	13	33	40	24
1 to 4 hours	4	46	33	17	27	65
> 4 hours	89	42	54	50	33	12
Indigenous:						
<1 hour	n.a.	25	8	22	48	61
1 to 4 hours	n.a.	31	34	26	36	36
> 4 hours	n.a.	44	58	52	16	4

[1] Numbers may not add to 100 per cent due to rounding.

[2] Respondents indicated one-way driving distance in 5 categories as follows: <1/2 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.

[3] Not available for confidentiality reasons.

Tables 5 and 6 present the frequency and proximity of interaction for process innovation. From Table 5 it is clear that in the vast majority of cases interaction with other group companies, suppliers and customers is, once again, regular, frequent or continuous. Interaction for the purposes of process innovation with competitors, Third Level Colleges and innovation support agencies,

occurs rarely or never in the majority of cases. This difference is significant at the 99 per cent level. There are no statistically significant exceptions to these clear trends. A significant exception is indigenous *ICT* businesses, 59 per cent of which never or rarely interact with suppliers.

Table 5: Frequency of Interaction for Process Innovation by Interaction Agent, Sector and Type of Business (Per Cent of Respondents)[1]

	Group	Suppliers	Customers	Competitors	Third Level	Agencies
Chemicals and Pharmaceuticals						
Foreign:						
Never/Rarely[2]	11	7	41	89	85	78
Regularly to Continuously[2]	89	93	59	11	15	22
Indigenous:						
Never/Rarely	n.a.[3]	19	38	75	63	50
Regularly to Continuously	n.a.	81	63	25	38	50
ICT						
Foreign:						
Never/Rarely	4	33	8	84	70	70
Regularly to Continuously	96	67	92	16	30	30
Indigenous:						
Never/Rarely	30	59	26	77	85	82
Regularly to Continuously	70	41	74	23	15	18
Electronic Devices and Engineering						
Foreign:						
Never/Rarely	13	24	34	93	73	65
Regularly to Continuously	87	76	66	7	27	35
Indigenous:						
Never/Rarely	n.a.	33	29	78	83	71
Regularly to Continuously	n.a.	68	71	22	17	29

[1] Numbers may not add to 100 per cent 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.

[3] Not available for confidentiality reasons.

Table 6 indicates that once again for agents with whom interaction is strong in Table 5 (i.e. other group companies, suppliers and customers), the location of the most important interaction agent is not local and may be international. This result holds for all sectors and types of businesses and is significant at the 99 per cent level. A significant exception is indigenous *ICT* businesses, 43 per cent of whom interact with suppliers located less than one hour from their business. The weak interaction with competitors occurs over long distances. For Third Level Colleges and innovation support agencies the most important source of interaction is again spatially spread, although there is a tendency for the interaction by indigenous *ICT* and *Electronic Devices and Engineering* businesses to be local in the majority of cases.

Table 6: Time-Distance from Most Important Interaction Agent for Process Innovation, by Sector and Type of Business (Per Cent of Respondents)[1]

	Group	Suppliers	Customers	Competitors	Third Level	Agencies
Chemicals and Pharmaceuticals						
Foreign:						
<1 hour[2]	4	5	11	0	40	17
1 to 4 hours[2]	4	33	17	20	40	58
> 4 hours[2]	92	62	72	80	20	25
Indigenous:						
<1 hour	n.a.[3]	0	15	30	30	27
1 to 4 hours	n.a.	20	54	10	20	55
> 4 hours	n.a.	80	31	60	50	18
ICT						
Foreign:						
<1 hour	5	13	24	33	11	38
1 to 4 hours	5	13	12	22	44	50
> 4 hours	90	73	65	44	44	13
Indigenous:						
<1 hour	25	43	15	19	58	79
1 to 4 hours	0	10	26	19	33	7
> 4 hours	75	48	59	63	8	14
Electronic Devices and Engineering						
Foreign:						
<1 hour	4	18	14	18	36	41
1 to 4 hours	3	36	27	9	29	35
> 4 hours	93	46	59	73	36	24
Indigenous:						
<1 hour	n.a.	21	26	28	60	58
1 to 4 hours	n.a.	36	32	22	25	30
> 4 hours	n.a.	42	42	50	15	12

[1] Numbers may not add to 100 per cent due to rounding.

[2] Respondents indicated one-way driving distance in 5 categories as follows: <1/2 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.

[3] Not available for confidentiality reasons.

4. Policy Implications

This paper presents new evidence, from a survey of 184 foreign and indigenous high-technology businesses on the critical issue of the roles of interaction and proximity in promoting innovation in Ireland. High-technology sectors are regarded by policy makers as crucial for future Irish competitiveness. Overall, while care must be taken in generalising from these results given the small sample size, they are remarkably consistent across sectors and for both foreign-owned and indigenous industry. They may be summarised as follows:

- Interaction for the purposes of both product and process innovation is strong between high-technology businesses and other group companies, suppliers and customers as indicated by the finding that, on average, interaction was regular, frequent or continuous with these agents for 81 per cent of businesses.
- This strong interaction with other group companies, suppliers and customers occurred over long distances as indicated by the average driving time from high-technology businesses to the most important of these agents being greater than four hours in 67 per cent of cases. This clearly

implies that such interaction does not occur locally or regionally within Ireland and may be international.

- Interaction for both product and process innovation with competitors is weak, with less than a third of businesses reporting at least regular interaction. When such interaction occurs, it does so over long distances.
- 68 per cent of businesses rarely or never interact with Third Level Colleges and innovation support agencies in the promotion of both product and process innovation. This interaction is spread between local, regional and more distant agents.

These results have important implications that merit debate in policy circles. They suggest the absence of strong interaction for the purpose of promoting innovation between locally or regionally based concentrations of suppliers, customers, competitors, Third Level Colleges and agencies and Irish high-technology businesses.

Policy prescriptions, since the publication of the Culliton Report (1992), have stressed the importance of local or regional clusters around internationally competitive businesses for improved national competitiveness, and in particular for embedding foreign-owned businesses. These prescriptions were strongly influenced by the work of Porter (1990). Subsequent research by the National Economic and Social Council on the applicability of Porter's cluster approach to Ireland is somewhat critical (see for example, O'Malley and Van Egeraat, 2000).

More recently, in the context of innovation, which has become a pressing policy issue post 'Celtic Tiger', the National Competitiveness Council, in its statement to the ESG, recommended support for clusters and networks (2004, p. 3). Forfás has recommended that the government focus on inter-firm networks as a key building block in the development of the innovation capacity of Irish industry (2004a, p. 7). The ESG has also advocated networks involving industry, academic and public sector co-operation to drive the development of knowledge and expertise (2004, p. 53). This continuing policy consensus has been influenced, as it has been in other EU countries, by the performance of particular industrial clusters, which have been associated with strong innovation performance, such as Silicon Valley, Emiglia-Romagna in Italy and the science-based cluster in Cambridge, UK. These clusters have been highlighted by the work of authors such as Scott (1988) and Castells and Hall (1994). However, from the perspective of innovation, Gordon and McCann (2005) have argued that these are an idealized type of cluster, which may not be superior to alternative agglomerations, arising from localization, urbanization or, what Parr (2002) refers to as, activity complex economies.

Irish regional policy has also advocated clusters, with the National Spatial Strategy envisaging gateways as having "large clusters of national/international scale enterprises, including those involved in advanced sectors" (2002, p. 40). O'Leary (2003) has criticised the formulation of this strategy as being divorced from the mainstream policy goals of growth and competitiveness. In this

regard it is notable that the ESG attaches little importance to the role of geographic proximity for the promotion of innovation. For example, it includes the National Spatial Strategy as an essential condition, but not one of the five key sources of competitive advantage (ESG, 2004, pp. 97-98). Ultimately, whether geographic proximity is important for innovation in Ireland is a question that can be informed by surveys, such as this.

The findings of this survey raise questions about the particular type, if any, of local/regional clusters and networks, which might reasonably be expected for the promotion of innovation in Irish high-technology businesses. Given the long-standing industrial policy of building competitive advantage on the back of foreign direct investment by successful high-technology businesses, it is perhaps not surprising that the survey found that interaction is strong and occurs between these businesses and other group companies over long distances.[11] In addition, the limited size of the domestic market and the overriding importance of international selling, might suggest the finding that the most important interactions by foreign-owned and indigenous businesses with customers are not local or regional, is to be expected.

However, despite repeated efforts devoted to building backward linkages locally and regionally, especially between foreign-owned and indigenous businesses, it is notable that the survey finds interaction between high-technology businesses and suppliers for the purpose of promoting innovation occurs over long distances. This is a cause for concern, particularly in the context of continued state funding devoted to developing networks and clusters.[12] In addition, the finding of weak interaction with innovation support agencies is important, as these institutions, as part of their role, facilitate the process of developing linkages at local/regional level.[13]

The idea that businesses interact, whether formally or informally, with competitors in order to promote their own innovation receives little support, with the survey showing that such interaction is weak, and where it occurs, not local. 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, 2004a), where the businesses are small and flexible, enabling alliances to form easily. These special cases may not be easily generalised (Gordon and McCann, 2005). In the case of Ireland, the applicability of this concept is open to question, as typically high-technology businesses located in the country are a mix of very large foreign-owned and smaller indigenous businesses, operating in particular international market niches, with few competing with each other.

[11] Love and Roper (2001) also find that technology transfer within multinational enterprises in Ireland is relatively high.

[12] For example, the ESG proposes that €20 million per annum over 5 years be devoted to building networks (2004, p. 73).

[13] For example, EI have been responsible for the National Linkage Programme.

The survey findings are important given the substantial recent state funding of basic research by Irish Third Level Colleges through such mechanisms as Science Foundation Ireland which reached €599 million in 2003 (Forfás, 2004b). These findings suggest that the links with Third Level Colleges may be weaker than might be expected and emphasise the need to achieve a better understanding of how such linkages can be fostered, in order to achieve the best possible future return. International evidence indicates that research and development spillovers are significant across international boundaries (see for example, Coe, Helpman and Hoffmaister, 1997). Recent history testifies to this, as Ireland, through for example its hosting of established foreign-owned businesses, has clearly benefited from international knowledge spillovers, which may have originated, either directly or indirectly, from research and development activity by Third Level Colleges abroad.

There is some international evidence of positive spillovers from university research to businesses innovation (Jaffe, 1989; Audretsch and Stephan, 1996, Anselin, Varga and Acs, 2000). However, the extent to which a region can benefit from research and development in Third Level Colleges depends on factors such as the relevance of the research to businesses, businesses' absorptive capacity, the strength of local knowledge dissemination networks and the integration of public and private knowledge mediating institutions (Roper, Hewitt-Dundas and Love, 2003, p. 114). The survey finding of weak interaction between high-technology businesses and both Third Level Colleges and innovation support agencies, casts doubt on the existing strength of Irish regional innovation systems. The greater emphasis placed by the ESG on the funding of applied research and in-firm research and development (ESG, 2004, p. 69) indicates some cognisance of this problem.

Overall, the survey results suggest a limited role for geographical proximity in regard to innovation by Irish high-technology business. This may be partly due both to the distinctive development of Ireland's internationally competitive industry, with the dominance by foreign-owned businesses, and to the small size of the country. However, it may also be attributable to Ireland's undeveloped regional innovation systems, which currently seem to have little to offer these businesses in pursuit of enhanced innovation performance. This issue warrants urgent attention by local, regional and national policymakers.

A clear message from these results is that more research should be undertaken on these important issues. This might include analysis of the relative importance for innovation by high-technology businesses of in-house research and development and interaction with the different agents identified. In addition, larger and more detailed surveys and case study research are required on how high-technology businesses interact with agents and, perhaps more importantly, how Third Level Colleges, innovation support agencies and suppliers interact with these businesses. The overriding objective of further research must be to identify realistic policies to improve local/regional interaction in Irish regions.

It should be added finally, that support for innovation should be seen in the overall context of the provision of physical and human infrastructure to support these businesses. It may very well be that the ideal policy is, for example, highly efficient transport and communications infrastructures or suitably trained labour pools, that facilitate, albeit indirectly, the innovation performance of these businesses. State funding of research and development in Third Level Colleges and of networks to support high-technology business should only be committed if the return is justified following detailed analysis of economic costs and benefits.

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