Cross Sectoral Differences in the Drivers of Innovation: Evidence from the Irish Community Innovation Survey

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Structured Abstract:
Purpose: The purpose of this paper is to analyse differences in the drivers of firm innovation performance across sectors. The literature often makes the assumption that firms in different sectors differ in their propensity to innovate but not in the drivers of innovation. We empirically assess whether this assumption is accurate through a series of econometric estimations and tests.

Design/methodology/approach: The data used is derived from the Irish Community Innovation Survey 2004-06. A series of multivariate probit models are estimated and the resulting coefficients are tested for parameter stability across sectors using likelihood ratio tests.

Findings: The results indicate that there is a strong degree of heterogeneity in the drivers of innovation across sectors. The determinants of process, organisational, new to firm and new to market innovation varies across sectors suggesting that the pooling of sectors in an innovation production function may lead to biased inferences.

Research limitations/implications: The implications of the results are that innovation policies targeted at stimulating innovation need to be tailored to particular industries. One size fits all policies would seem inappropriate given the large degree of heterogeneity observed across the drivers of innovation in different sectors.

Originality/value: The value of this paper is that it provides an empirical test as to whether it is suitable to group sectoral data when estimating innovation production functions. Most papers simply include sectoral dummies, implying that only the propensity to innovate differs across sectors and that the slope of the coefficient estimates are in fact consistent across sectors.

1. Introduction

This paper analyses sectoral differences in the propensity to innovate and the extent to which the mechanisms through which firms innovate vary across sectors. This is accomplished through the use of the Irish Community Innovation Survey (CIS) 2004-06. Four broad sectoral classifications are identified; *High-Technology Manufacturing, All Other Manufacturing* (AOM), *Wholesale, Transport, Storage and Communication* (WTS&C) and *Financial Intermediaries* (FI). Peneder (2010) alludes to tension between firm-level and sector-level studies of innovation activity. He notes that the former point to heterogeneous behaviour among individual firms while the latter show significant differences between sectors and observed consistencies in sectoral data. This tension, he argues, has important implications for innovation policy in that "industry characteristics matter and cannot be ignored [and] their accurate understanding helps to design policy programs and tailor them more effectively to the needs of targeted firms" (Peneder 2010: 324).

It has become standard in the literature to control for sector specific effects in innovation production function frameworks. Roper et al. (2008), Freel (2003), Love and Roper (2002) and Oerlemans et al. (1998) all control for sectoral differences in the propensity for firms to innovate. Doran and O'Leary (2011) and Hall et al. (2009) provide evidence of heterogeneity across sectoral classifications in the propensity to innovate, suggesting high-technology firms have a higher likelihood of certain forms of innovation. These studies essentially control for variation in the intercept coefficient by including a series of dummy variables in the innovation production function.

However, there has been relatively little discussion or analysis of the variation in the mechanisms through which firms in different sectors generate innovation output. In essence, while it is standard to control for differing propensities to innovate, no such consideration is granted to potential variation in the importance of innovation inputs across sectors. This paper aims to address this deficiency in the literature by assessing econometrically whether input coefficients in the innovation production function are stable or whether they vary depending on sector.

This paper identifies four types of innovation that are consistent with Schumpeter (1934) and the OECD (2005) distinctions between different forms of innovation output. These are new to market (NtM) and new to firm (NtF) product innovation, process innovation and organisational innovation. The data is derived from the Irish Community Innovation Survey (CIS) 2004-06, a firm-level dataset similar to that employed by Antonioli et al. (2011).

Innovation production functions are estimated using probit models incorporating intercept dummy variables to test for differing propensities to innovate across sectors. Subsequently sectoral restricted models are estimated and likelihood-ratio tests utilised to test for stability in coefficient estimates across sectors; thereby facilitating an analysis of whether the innovation activity of firms varies across sectors.

The remainder of the paper is structured as follows. Section 2 reviews relevant literature and places the contributions of this paper within this literature. Section 3 outlines the method, and the data used in this paper is summarized in Section 4. Section 5 presents the empirical results and discusses key findings. The final section concludes and provides policy implications based on the evidence presented.

2. Literature Review

Howells (2002) and Lissoni (2001) argue that innovation is of vital importance, not only for business success, but also for economic growth and social wellbeing. This paper, in analysing whether the determinants of innovation vary across sectors, aims to provide insight into whether firms differ across sectors in the mechanisms through which they generate innovation. This may contribute to better policy formation and targeting.

In this section, conceptual frameworks and empirical evidence on the drivers of business-level innovation are presented, followed by a discussion of why the relative importance of these drivers may vary sectorally. This section first considers the need to explore sectoral differences in the importance of the determinants of innovation and then presents the literature on what those determinants of business level innovation may be.

Sectoral Differences in Innovation and its Determinants

Kline and Rosenberg (1986) argue there are many "black boxes" through which firms generate differing forms of innovation and that the mechanisms through which these innovations arise may vary depending on innovation and firm type. This suggests a need to consider how firms' innovation activities may vary sectorally.

Sectoral differences have been an important empirical consideration since, at least, Pavitt (1984) identified four categories of firm (*science-based*, *specialised suppliers*, *supplier-dominated* and *scale-intensive* firms) based on sources and patterns of technological change. According to de Jong and Marsili (2006: 216) these sources and patterns "shape and differentiate the pattern of innovation of firms across sectors". There has been a movement in the systems of innovation framework from the national level [Lundvall (2007) and Nelson (2000)] to more disaggregated levels including regional (Cooke 2001; Asheim and Isaksen 2002) and sectoral (Malerba 2002; 2004; Montobbio 2004).

Malerba (2002), in promoting a sectoral system of innovation perspective, argues that sectors differ greatly in their knowledge bases, technologies, production processes, complementarities, demand, non-firm organizations, and institutions. Indeed, Malerba (2004) notes that innovation activity takes place in substantially differentiated sectoral environments; identifying that the sources of knowledge available to firms, the actors involved in the innovation process, and the institutions available to firms vary across sectors. Montobbio (2004) further notes that empirical analysis can provide stylised facts about different sectoral innovation activities.

An important concept underpinning sectoral differences in business performance, of which innovation is one measure, is the Structure-Conduct-Performance (SCP) paradigm. This concept suggests that a businesses' performance is conditioned by the behaviour of other businesses, including buyers and sellers, within the sector in which it operates and that this, in turn, is conditioned by the structure of that sector. This paradigm implies that, since there are sectoral differences in the structure and nature of competition in a sector and in the subsequent activities of businesses in that sector, there should therefore be observed differences in the performances of businesses across sectors. This paper sheds light on whether these differences are observed in the area of innovation performance by estimating whether there are sectoral variations in the likelihood of innovation and the factors that drive business innovation.

This leads us to our central hypothesis.

H_1: *The relative likelihoods and determinants of business level innovation vary across sectors.*

The Determinants of Business-Level Innovation

Schartinger et al. (2002), who consider the nature of industry-university linkages, provide an example of the relative importance of different sources of external knowledge across sectors. They find, in a study of Austrian businesses and universities, that "sectors of economic activity and fields of science engage in different types of interactions" (Schartinger et al. 2002: 235). They argue that the variety of industrial sectoral patterns should inform policy in relation to industry-university knowledge interaction. Sectoral differences may also arise from regulatory differences, such as those observed by Antonioli et al. (2013) in a study of environmental innovation in Italian firms.

Sectoral considerations for innovation studies have also emerged from literatures in regional science. Porter (1998) and Marshall (1920) have stressed the role of geographical concentration of related and supported industries as a source of innovation through their discussions of cluster theory and localisation economies. The confluence of sectoral and spatial effects on business-level innovation is explored by Anselin et al. (2000) who find empirical evidence for both sectoral and regional differences in the innovative process. Indeed there is also evidence that the positive effects of geographical concentration on individual businesses vary by sector [for example, Bönte (2004) and Görg and Ruane (2001)].

It is clear from the literature that business innovation is conditioned by the interaction between internal and external knowledge generation activities (Mancinelli and Mazzanti 2009). The importance of internal sources of knowledge is highlighted by Kline and Rosenberg (1986), who emphasize the sourcing of knowledge inside the business through the performance of R&D, which involves solving "problems all along the chain of innovation from the initial design to the finished production processes" (1986:303). Internal R&D activity is viewed as a crucial component in firms' innovation production as it allows firms to expand their knowledge base (Griliches 1992; Freel 2003).

Interaction with external agents may also act as an important source of knowledge for innovative firms. Lundvall (1988), Kline and Rosenberg (1986) and Nonaka et al. (2001), when viewing interactive learning as a positive source of knowledge, suggest that external linkages can be exploited for the advancement of business innovation. For firms to innovate they utilise, combine, and transform existing knowledge into new products or processes. However, internal knowledge is often not sufficient and acquiring new knowledge from outside the organisation may be required (Howells 2002). Bathelt et al. (2004) suggest that firms engage in external knowledge sourcing to supplement existing knowledge and/or to overcome deficiencies in internal knowledge. Similarly, Romijin and Albu (2002) and Gertler and Levitte (2005) note that external networking and interaction may be viewed as an important source of knowledge for innovation, with firms learning through interaction. Cohen and Levinthal (1989) emphasise the importance of R&D as a direct source of knowledge for innovation and for developing absorptive capacity which enables businesses to identify, evaluate, and exploit external sources of knowledge. The basis for interaction as a source of knowledge for innovation is knowledge spillovers. Through formal or informal, intentional or accidental, market mediated or non-market mediated interaction individuals learn and generate new knowledge.

Loasby (1993) contends that the processes of hypothesising, testing and criticising that leads to the growth of knowledge is inefficient if carried out by individuals in isolation. This is due to the importance of the social context within which knowledge creation occurs. He characterises the introduction by a business of a new product or process to the market as a system of conjecture, criticism, and testing. This process requires interaction between producers and consumers, as consumer behaviour is reflected in subsequent experiments and/or new product launches. Richardson (1972) states that businesses engage in a variety of technical, social, and legal links that evolve over time. Businesses invest in relationships with customers and suppliers, building up market assets, such as reputations and goodwill. Transactions within a network, either a market, business or scientific community, depend on and generate new knowledge.

Interaction is also critical for the growth of knowledge and innovation because of the social aspect of learning. Lundvall (1988), introducing the concept of innovation systems, places learning at the heart of the process of innovation. He argues that, since learning is interactive and social in nature, the process of innovation must be looked at in a social context. Learning is an important aspect of interaction between producers and users of innovation (von Hippel 1988). Users of innovation go through a three-step process involving awareness of new technologies, understanding of the potential usefulness of these technologies and developing know-how in relation to these technologies (Lundvall 1992: 59). Each step is likely to involve interaction with the producer of the innovation. Producers of innovation also go through a three-step process in technical learning. The first step is awareness of user needs. Second, the producer must understand how its competencies can be used or adapted to produce the technologies required by users. Third, the producer seeks feedback from the user on the effectiveness of the innovation and difficulties encountered in its use.

Interaction is a crucial element in each of the steps taken by users and producers. However, in order to communicate, both must learn a technical code. This is communicative learning. This framework underpins the third aspect of interactive learning, which is social learning.

There may be an imbalance in the technical knowledge of users and producers of innovation. This could result in the potential for opportunistic behaviour. A lack of trust inhibits technical and communicative learning, so users and producers must learn the social aspects of interaction, which is the basis of social learning. This can only be acquired through shared experiences and interaction. It is reasonable to expect that different sectors may have stronger or weaker structures to facilitate knowledge sharing and may have different institutional settings with incentives or disincentives for interaction for knowledge sharing.

Interaction for innovation may take place with market-based agents such as customers and suppliers or non-market-based agents such as higher education institutes or public research facilities. The form of interaction may range from contractual collaboration with an agent to social or informal, perhaps unintentional, networking. For the purposes of this paper, interaction is defined in the Irish CIS as active participation with other enterprises or non-commercial institutions on innovation activities, where both parties do not need to benefit commercially (Central Statistics Office 2009).

There are two hypotheses arising from this discussion on the roles of internal knowledge sourcing (R&D) and external knowledge sourcing (interaction) for business innovation, which are more specific in nature than H_1 and for which this paper tests.

H*$_2$*: The importance of internal knowledge sourcing (R&D) for business innovation varies across sectors.

H*$_3$*: The importance of external knowledge sourcing (interaction) for business innovation varies across sectors.

Apart from internal knowledge generation and external linkages, empirical studies have shown that a number of firm-specific factors may also affect innovation performance. These include domestic or foreign-ownership, which is an issue of particular relevance to Ireland given its reliance on foreign direct investment (Klomp and Van Leeuwen 2001; Jordan and O’Leary 2008; Roper et al. 2008). Also, the size of the firm may impact on innovation performance (Cohen and Klepper 1996). The analysis presented later controls for these factors.

3. Methodology

Analyses by Doran and O'Leary (2011) and Hall et al. (2009) identify different propensities to innovate for firms in different sectors. However, they do not assess whether the drivers of innovation vary across sectors. This paper moves beyond the traditional method of controlling for sectoral factors using dummy variables.

To analyse the effects of various innovation inputs and company specific factors on innovation performance this paper employs an innovation production function (Oerlemans et al. 1998; Roper 2001; Love and Mansury 2007). Following from Freel (2003), Mansury and Love (2008) and Hall et al. (2009) the innovation production function specified in equation (1) relates the probability of a firm engaging in innovation activity to a number of key explanatory factors. A multivariate probit model is used to estimate equation (1).

$$IO_{ih} = \alpha_{0h} + EI_{ih}\beta_h + R\&D_{ih}\chi_h + Z_{ih}\delta_h + S_{ih}\phi_h + \varepsilon_{ih} \qquad (1)$$

IO_{ih} is a binary indicator of whether firm *i* engaged in one of four forms of innovation, where *h* indicates the type of innovation. These are new to firm (NtF), new to market (NtM), process or organisation innovation. These varying forms of innovation are considered as it is possible that each of these types of innovation are the result of different combinations of innovation inputs. Further to this, the propensity of firms across different sectors to engage in each type of innovation may vary (OECD 2005). Therefore, in order to fully address the variation in innovation output and behaviour across sectors, it is important to analyse the unique process through which firms decide to engage in each form of innovation.

EI_{ih} is a series of binary variables indicating whether firm *i* engaged in cooperative activity with external knowledge sources (see the data section for a description of these different external knowledge sources) for innovation type *h*. While the expected result based on previous studies is that β_h will have a positive effect on the likelihood of innovating, it may be that the importance of each external agent will vary depending on the type of innovation considered.

It is also widely held in the literature that R&D has a strong positive impact on innovation performance (Cohen and Klepper 1996). Therefore, this paper includes $R\&D_{ih}$; a binary indicator of whether firm *i* engaged in R&D activity during the reference period for innovation type *h*. Again it is expected that R&D will have a positive impact on the probability of innovation, but its importance may vary across the different types of innovation. Z_{ih} is a vector of company specific factors including the size of the firm and whether the firm is indigenous or foreign owned. Pattnayak and Thangavelu (2011) note that there may be a distinction between the innovation performance of indigenous and foreign owned businesses. We also include measures of turnover per worker and capital intensity per worker in 2004. Turnover per worker is measured in Euro and is derived from the Irish CSO's central business register. Following from Doran and O'Leary (2011), we use the measure of capital expenditure for product and process innovation in the CIS as an indicator of capital intensity, as the Irish CIS does not include a measure of the capital stock of the firm. The CIS survey asks firms for the level of '*capital expenditure by the firm on the acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes*'. While it is also possible that factors such as R&D subsidies may imapct the likelihood of innovation as suggested by Aerts and Schmidt (2008), the Irish CIS does not contain any information on R&D supports so this can not be considered in this paper.

Finally, S_{ih} is a series of binary variables indicating the sector in which the firm operates. Four sectors are identified by this paper; (i) high-tech manufacturing, (ii) all other manufacturing, (iii) wholesale, transport, storage and communication and (iv) financial intermediaries. High-tech manufacturing is used as the base category with a series of three dummy variables indicating each of the remaining sectors.

As the key focus of this paper is to analyse sectoral difference in the innovation performance of Irish firms, equation (1) is initially estimated and special consideration is given to the S_{nih} variables. In doing so this paper identifies the differences among sectors regarding their propensity to engage in each of the four types of innovation activity. However, this paper further develops upon this sectoral analysis by acknowledging that while firms in different sectors may have differing propensities to engage in various forms of innovation they may also engage in the same innovation activity differently. For example, firms in the *High-Tech* sector and *Wholesale, Transport, Storage and Communication* sector may have similar propensities to process innovate, but the mechanisms through which they develop this innovation may differ.

To investigate whether this is the case, equation (2) is estimated for each of the individual sectoral classifications.

$$IO_{ih} = \alpha_{0sh} + EI_{ih}\beta_{sh} + R\&D_{ih}\chi_{sh} + Z_{ih}\delta_{sh} + \varepsilon_{ih} \qquad (2)$$

Where each variable is defined as above with the addition of the subscript s; here s indicates that, for each sector, different coefficients may be observed. As four sectors are identified in this paper, equation (2) is estimated four times, once for each sector, again using a multivariate probit model. By allowing for a variation in the coefficients across sectors, differences in firms' innovation strategies and value chain can be observed.

Likelihood-ratio tests are employed to ensure the variance in coefficients across sectors is significantly different (Long and Freese 2001; Greene 2008). These compare the restricted estimation of equation (1), for all sectors, to the unrestricted estimations of equation (2), the individual sectoral estimations. The test assesses whether the composite models, comprised of the sectoral estimations of equation (2), provide a better estimation than the aggregate model specified in equation (1). The null hypothesis of the test is that the aggregate model applies to each of the sectors analysed and that there is parameter stability across sectors. This is expressed as:

$$\log L(\hat{\theta}) = \sum_{j=1}^{k} \log L_j(\hat{\theta}_j) \qquad (3)$$

Equation 3 states that the sum of the log likelihood of the composite sectoral models equals the log likelihood of the aggregate model. Should the likelihood-ratio test indicate a significant difference in the coefficient estimates across the sectoral regressions this would imply non-rejection of the hypothesis that there are significant differences in the mechanisms through which firms in different sectors innovate. If the likelihood-ratio tests indicate that there is no significant differences across the estimations this suggests that firms, regardless of the sector in which they operate, innovate in the same way.

The method used in this paper has advantages over the use of interaction variables as it avoids the problems of potential multicollinearity among the interaction terms, while also facilitating an overall statistical test of parameter stability. This would result in 24 additional variables being included in the model which are all products of existing variables, thus raising the likelihood of multicollinearity being observed and incorrect inferences being drawn from the data. The use of interaction terms would also reduce degrees of freedom, although this is less an issue given the number of observations in this data set.

A further issue worth noting is that endogeneity may be present in our model. Endogeneity occurs where the error term is correlated with one or more of the independent variables. For instance it may be that firms which undertake R&D are more likely to innovate and that innovative firms are more likely to engage in R&D. This type of relationship would yield endogeneity as the R&D variable would be correlated with the error term. In such cases inferences about causality must be avoided and the discussion should focus on association between the variables. There is a large empirical literature on the estimation of innovation production functions with some, such as Crépon et al. (1998), deriving credible instruments through the use of a system of equations while others, such as Roper et al. (2008), acknowledge the presence of endogeneity in their estimates and use caution in the discussion of their results. This paper adopts the latter approach due to the inherent difficulty of deriving credible instruments using the CIS dataset. We acknowledge that endogeneity may be present in our analysis and therefore use caution when discussing our results, noting the association between variables but not assuming direct causal relationships. As the key focus of this paper is whether there are differences in the importance of innovation inputs across sectors the potential problem of endogeneity does not detract from the central issue of the paper.

4. Data

The data set utilised by this paper is the Irish Community Innovation Survey (CIS) 2004-2006. This survey was conducted jointly by Forfás (Ireland's national policy advisory body) and the Central Statistics Office in Ireland. A total of 4,150 surveys were issued with 1,974 responses. The survey is directed to companies employing more than 10 persons and engaged in a range of sectors.

The target for the Irish CIS is the complete range of manufacturing sectors with selected service sectors. As this paper focuses on variation in innovation activity across sectors, care must be taken when defining sectoral classifications. When determining these sectoral classifications, three factors must be considered. Firstly, it is necessary to ensure that there are substantial differences in the sectoral classifications as, if they are similar, it would be expected that there would be little variation in sectoral innovation activity. Secondly, the classifications must reflect a logical, coherent selection of firms which operate in a similar manner. Finally, the sectoral classifications must be broad enough to ensure that a sufficient number of firms fall into each category to provide statistically robust estimations of the models specified in the previous section. While it has been standard in some instances to include a vector of NACE2 digit classifications, this was not possible for this paper and therefore broad sectoral classifications are generated based on the OECD classification system as detailed below (European Commission 2003).

Four sectoral classifications are chosen which meet the requirements of the three criteria outlined above. These are (i) *High-Tech Manufacturing*, (ii) *All Other Manufacturing*, (iii) *Wholesale, Transport, Storage and Communication* and (iv) *Financial Intermediation.* Table 1 shows that 27% of the sample are in high-technology sectors with 30% in All Other Manufacturing, 35% in Wholesale, Transport, Storage and Communication and 8% in Financial Intermediation.

As is standard when using the CIS, we use binary indicators of firm level innovation which indicate whether a firm engages in different forms of innovation activity. However, one limitation of CIS data is that firms which indicate that they do not engage in 'innovative activity' are subsequently assumed in the survey not to engage in R&D or external engagement. 'Innovative activity' is defined in the CIS 2004-06 as (i) having produced either a product, process or organisational innovation during the 2004 to 2006 period, (ii) having abandoned an innovation attempt in the 2004 to 2006 period, or (iii) still having an innovative project on-going which will conclude after 2006. It is possible therefore that the CIS under-reports the level of R&D and external engagement. However, this is unlikely to be a significant issue as firms that engage in R&D and external interaction are unlikely to do so without falling into one of the above three categories.

The CIS collects information about knowledge sourcing and innovation output in the reference period 2004 to 2006. Product innovation is defined as the introduction of a new, or significantly improved, good or service during the three years 2004 to 2006 and is distingished between new to firm (NtF) and new to market (NtM) innovation. NtF innovation is defined as the introduction of a new or significantly improved good or service to the firm's market which is already available from competitors. NtM innovation is the introduction of a new good or service to the firm's market, which is not already provided by the firm's competitors.

Process innovation is defined in the CIS as being comprised of three elements; (i) new or significantly improved methods of manufacturing or producing goods or services, (ii) new or significantly improved logistics, delivery or distribution methods for inputs, goods or services or (iii) new or significantly improved supporting activities for processes, such as maintenance systems or operations for purchasing, accounting or computing. Firms which engaged in any of these activities are defined as process innovators. Finally, organisational innovation is defined as (i) new business practices for organising procedures, (ii) new methods of organising work responsibilities and decision-making or (iii) new methods of organising external relations with other firms or public institutions. These definitions of innovation are consistent with the Oslo Manual (OECD 2005) and Schumpeter (1934) definitions of innovation. Table 1 illustrates that 25% of firms introduced NtF innovations, 22% NtM innovations, 31% process innovations and 44% organizational innovations during the reference period.

[insert Table 1 around here]

Compared to other European countries using aggregated CIS statistics, Ireland has among the highest instances of all types of innovation. Belgium, Luxembourg and Finland have the highest proportions of innovative firms while Poland and Slovakia display relatively lower levels of innovative firms as a percentage of those surveyed. Appendix 1 presents a comparison of European countries' innovative output using Eurostat data.

Key innovation input variables considered in this paper are external knowledge sources and R&D. The Irish CIS defines external interaction as active participation with other enterprises or non-commercial institutions on innovation activities. The CIS identifies six potential external partners; (i) suppliers, (ii) customers, (iii) competitors, (iv) consultants, (v) universities, and (vi) public research institutes. Due to the low level of response in the university and public research institute categories this paper amalgamates these two linkages into one category called public interaction. R&D activity is defined as creative work undertaken within an enterprise to increase the stock of knowledge for developing new and improved products and processes. Table 1 shows that 25% of firms engage in R&D activity while the degree to which firms engage with external knowledge sources varies substantially depending on the agent.

Finally, this paper also controls for the size of the firms and whether the firm is Irish owned. The average size of firms surveyed in the Irish CIS is 124 employees with a standard deviation of 525 and marginally less than three quarters are Irish owned.

As with all innovation surveys there is potential for multicollinearity. Therefore, in Appendix 2 we present a correlation matrix of our variables. The highest correlation exists between hampering factors, with a correlation coefficient of 0.7491 observed in one instance. Overall, the degree of correlation between the variables is not sufficiently high to suggest that multicollinearity is a significant problem.

5. Empirical Results

5.1 Results of the Restricted Model

Table 2 displays the multivatiate probit estimation of equation (1), the restricted model. This estimation includes sectoral dummies with high-technology manufacturing (HTM) as the reference category. There is limited evidence to support $\boldsymbol{H_1}$ which suggests that business' propensity to innovate differs across sectors. The exceptions are that firms in *Wholesale, Trasnsport, Storage and Communication* (WTSC) and *Financial Intermediation* (FI) are more likely, relative to firms in *High-Tech Manufacturing* (HTM), to introduce organisation innovation and *All Other Manufacturing* (AOM) is less likely to introduce new to firm product innovation.

The results of the likelihood-ratio test for parameter stability across sectors are also presented in Table 2. The null hypothesis is that there is no variation in the parameter estimates of the four sectors.

[insert Table 2 around here]

The likelihood-ratio statistics indicate that the null hypotheses of parameter stability can be rejected. This implies that the parameter values from the estimation of equation (1) are not consistent across sectoral classifications and that the aggregate estimation may provide misleading insights into the innovation activity of firms across these sectors. Therefore, as dictated by the likelihood ratio test, it is not appropriate to discuss the results in the aggregate sense. Therefore, we progress to estimate our model for each sector. This is consistent with $\boldsymbol{H_1}$ which states that the drivers of innovation output will vary across sectors.

5.2 Results of the Unrestricted Model

The likelihood-ratio test results suggest that the slope coefficients of the model vary across sectors, indicating the need to provide separate estimates for each sector to avoid an incorrectly specified aggregate model. This variation in the drivers of innovation across different sectors is generally consistent with the existing international literature with Pavitt (1984), Oerlemans et al. (1998) and Hall et al. (2009) indicating that the propensity to innovate varies across sectors. The results of these individual sectoral estimations of equation (2) are presented in Tables 3 through 6.

[insert Table 3 around here]

Starting with NtM innovation, it can be noted that, apart from R&D, the drivers of innovation across sectors vary substantially. Firstly, for firms in the HTM sector, the key driver of innovation is internal R&D activity with external interaction having no significant effect on the likelihood of innovation. Likewise firms in the FI sector do not benefit from external interaction. However, for the two remaining sectors, external interaction is found to have a significant effect. Firms in the AOM sector that interact with customers, competitors, and public organisations are more likely to introduce NtM innovations, while firms in the WTSC sector are more likely to introduce NtM innovations if they interact with suppliers or customers, and are less likely to innovate if they interact with consultants. This result suggests the need for targeted interaction by firms (Freel 2003), as opposed to open interaction (Laursen and Salter 2006). Larger firms in the HT, AOM and, WTSC sectors are more likely to innovate, with size being unimportant for FI. Finally, indigenous firms in the WTSC and FI sectors are less likely to innovate relative to non-indigenous firms. Firms in all sectors (except HTM) with higher levels of expenditure on capital per worker are more likely to introduce NtM innovation.

Turning to NtF innovation we again see significant differences across sectors. The performance of R&D is the only factor to have a consistent positive effect on the likelihood of NtF innovation. External interaction is only found to play a limited role in stimulating NtF innovation.This suggests that for the majority of sectors, NtF innovation is primarily driven by internal knowledge generation through R&D. Finally, larger firms in the HTM, AOM and FI sectors have higher likelihoods of innovation while indigenous firms in the WTSC and FI sectors are less likely to introduce NtF innovations. Again we note that more capital expenditure per worker is associated with greater likelihood of NtF innovation in all sectors, except HTM.

There is more commonality in the drivers of process innovation. The performance of R&D, firm size and capital intensity have a consistently positive association with the likelihood of process innovation. External interaction is important across a range of sectors. For HTM and AOM, competitor and public interaction have positive associations, and for WTSC supplier and competitor interaction have positive associations. For these latter sectors, customer interaction has a negative association and for FI customer interaction has a positive association. Irish owned firms in HTM and AOM are less likely to process innovate.

Finally, there are no common factors for organisational innovation across the sectors. For HTM and AOM, interaction with consultants and public interaction is associated with organisation innovation, supplier interaction is associated with organisational innovation in the WTSC sector, and interaction with consultants is associated with process innovation in the FI sector. R&D is positively associated with organisational innovation in the HTM, AOM and FI sectors. Larger firms in AOM, WTSC and FI are more likely to introduce organisational innovation. Irish owned firms in the HTM, AOM and WTSC sector are less likely to introduce organisational innovations and firms with higher levels of capital expenditure per employee in the AOM, WTSC and FI sectors are more likely to introduce organisational innovation.

Across all our estimations we also control for a variety of what are termed in the CIS as 'hampering factors'. These are self-reported factors that are considered likely to negatively impact the likelihood of firms innovating. There is substantial variation in the importance of these hampering factors across all innovation types and sectors.

On balance there is a case for rejecting $\boldsymbol{H_2}$ that the importance of R&D varies across sectors. We see R&D being important across all sectors, suggesting that this is a critical driver of innovation performance. While the magnitude of the coefficient varies, suggesting that it is more effective at generating innovation output in some sectors, it is consistently significant and positive.

Generally $\boldsymbol{H_3}$ cannot be rejected, suggesting that the effectiveness of external interaction varies across sectors. For instance, HTM sectors seem to gain little benefit from engaging with external knowledge sources while WTSC seems to benefit greatly from external interaction.

5.3 Comparing Restricted and Unrestricted Models

The key contribution of this paper is to analyse whether estimations of innovation production functions, in which numerous sectors are included, exhibit parameter stability across sectors. The absence of parameter stability indicates that results derived from aggregate estimations may be misleading. This section compares the results of the estimations of the restricted model, equation (1), against the unrestricted estimation of equation (2). The log-likelihood ratio tests indicate that the aggregate estimation of these forms of innovation are unsuitable due to parameter instability across sectors.

Initially, in Table 2, the aggregate results indicate that interaction with suppliers is positively associated with all forms of innovation while interaction with consultants is negatively associated with NtF and NtM innovation. The aggregate results also indicate that indigenous firms are less likely to innovate. R&D is also found to be unimportant for organisational innovation. However, from Tables 3 through 6, it can be seen that these results are largely driven be the WTSC sector. It is this sector which exhibits the most significant interaction coefficients and negative consultant coefficients. However, due to the fact that it comprises approximately 40% of the sample, it would appear that this sector drives the significance of these interaction coefficients in the overall model. Therefore, conclusions drawn from Table 2 may suggest that interaction is an important driver of innovation; however, a closer examination suggests that this finding applies predominantly to one sector.

A similar conclusion can be drawn for the lack of significance of the R&D variable for organisational innovation in Table 2. We can see in Table 6 that it is only in the case of the WTSC sector that R&D is not associated with organisational innovation. Again, this suggests that the effect of the largest sector may result in incorrect inferences regarding the importance of various factors for innovation. We highlight these two factors but others can be observed throughout the tables.

6. Conclusions and Implications

This paper estimates an innovation production function which analyses the effects of external interaction and internal R&D on firms' innovation performance, using data from the Irish Community Innovation Survey (CIS) 2004-06. While it is common to control for differing propensities to innovate across sectors through the inclusion of sectoral dummy variables in innovation production functions, this implicitly assumes that the importance of innovation inputs do not vary across sectors. In a key contribution, through the estimation of an innovation production function, for four differing types of innovation, and the subsequent testing of these functions for parameter stability across sectors, this paper provides an empirical analysis of whether the importance of innovation inputs vary across sectors. For all forms of innovation, the likelihood ratio test indicates that there is parameter instability across sectors. This suggests that there is a strong degree of heterogeneity in the drivers of innovation across sectors.

These results raise a number of important implications for policy makers. The variability in the driver of innovation across sectors for new to firm and new to market innovation suggests that, by implementing a broad range of innovation support measures or applying a "one size fits all" policy, innovation supports may be less effective than hoped. As noted by Peneder (2010), policy makers should not expect homogeneous firms and sectors, and policies should be customised by sector based upon specific requirements. Our empirical analysis demonstrates these requirements vary substantially across sectors.

The results strongly favour a nuanced approach. For instance, the results derived in this paper suggest that high-technology firms rely on internal R&D to generate new to firm and new to market innovations while manufacturing firms rely on a mixture of internal R&D and business networking. Therefore, policies aimed at high-technology firms should focus on supporting R&D while policies targeted at manufacturing firms could employ a hybrid strategy of supporting R&D while also aiding the firm in establishing business networks.

However, intervention should occur only where it is merited on grounds of clearly specified market problems or systemic failures. There is a large and well established literature which points to market failure arising from under investment by private firms in R&D and this is used to justify policy intervention (Nelson 2002). Our argument is that, based upon the assumption of market failure and underinvestment in R&D effort by firms, public support for innovation is justified but that the exact type of policy intervention must vary dependent upon the sector in which the firm operates, since different sectors may suffer in different ways from such market failures. Martin and Scott (2000) note that sectors differ in the extent to which radical and incremental innovation are undertaken and that the focus of sectors can vary from product to process innovation. The importance and sources of knowledge can also vary across sectors, with some emphasising R&D while others focus on collaborative ventures. Therefore, we propose that policies targeted at fostering innovation such be specific to sectors, and that a broad one size fits all policy approach will not be as effected as more nuanced policies.

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Table 1 – Descriptive Statistics of Key Variables

Variable	Mean	sd
External Interaction		
Supplier (%)	11	n/a
Customer (%)	9	n/a
Competitor (%)	3	n/a
Consultant (%)	6	n/a
Public Interaction (%)	8	
R&D (%)	25	n/a
Control Variables		
Employment	124	525
Irish Owned (%)	74	n/a
Innovation Output		
New to Firm (%)	25	n/a
New to Market	22	n/a
Process (%)	31	n/a
Organisational (%)	44	n/a
Sector		
High-Technology Manufacturing	15	n/a
All Other Manufacturing	35	n/a
Wholesale, Transport, Storage and Communication	40	n/a
Financial Intermediation	10	n/a

Table 2: Multivariate Probit Estimate of Restricted Model

Variable	**Process Innovator**	**Organizational Innovator**	**New to Firm Innovator**	**New to Market Innovator**
Constant	-1.2382*	-0.8755*	-2.0402***	-2.0979***
	(0.5416)	(0.4830)	(0.5655)	(0.5944)
External Interaction				
Supplier	0.2758**	0.4928***	0.2464*	0.4213***
	(0.1411)	(0.1445)	(0.1304)	(0.1312)
Customer	0.0820	-0.2482	0.4187***	0.2249
	(0.1553)	(0.1575)	(0.1416)	(0.1426)
Competitor	0.5469**	0.0761	0.0043	0.1459
	(0.2359)	(0.2203)	(0.1971)	(0.2062)
Consultant	0.2677	0.3550*	-0.3218*	-0.3372*
	(0.1845)	(0.1889)	(0.1645)	(0.1660)
Public Interaction	0.2841*	0.4266**	0.0339	0.1265
	(0.1695)	(0.1707)	(0.1494)	(0.1522)
R&D	0.1555***	0.1248	0.2167***	0.2802***
	(0.0273)	(0.0266)	(0.0263)	(0.0270)
Control Variables				
Employment	0.1683***	0.1148***	0.1160***	0.1686***
	(0.0315)	(0.0294)	(0.0319)	(0.0328)
Irish Owned	-0.1985**	-0.2426***	-0.2385***	-0.3323***
	(0.0851)	(0.0788)	(0.0854)	(0.0887)
Sector[2]				
All Other Manufacturing	-0.0172	-0.0643	-0.1910*	-0.1260
	(0.1119)	(0.1042)	(0.1092)	(0.1110)
Wholesale, Transport, Storage and Communication	0.0240	0.1772*	-0.0227	-0.1300
	(0.1157)	(0.1066)	(0.1159)	(0.1200)
Financial Intermediation	-0.0267	0.3851***	0.0414	-0.1529
	(0.1173)	(0.1096)	(0.1153)	(0.1187)
Hampering Factors				
Lack of funds within your enterprise or group	0.0715	0.0382	-0.0357	0.0364
	(0.0488)	(0.0446)	(0.0493)	(0.0506)
Lack of finance from sources outside your enterprise	-0.1014*	-0.0479	-0.0387	0.1212**
	(0.0522)	(0.0483)	(0.0521)	(0.0532)
Innovation costs too high	0.0320	-0.0188	0.0378	-0.0850*
	(0.0476)	(0.0438)	(0.0483)	(0.0512)
Lack of qualified personnel	0.0842	0.1066**	0.1547***	0.0472
	(0.0531)	(0.0491)	(0.0521)	(0.0546)
Lack of information on technology	-0.0691	-0.0804	-0.1105	-0.0529
	(0.0711)	(0.0652)	(0.0707)	(0.0749)
Lack of information on markets	0.0147	0.1340**	0.1125**	0.0861

	(0.0617)	(0.0568)	(0.0606)	(0.0631)
Difficulty in finding cooperation partners for innovation	-0.0294	-0.0607	-0.1043	0.0000
	(0.0524)	(0.0482)	(0.0526)	(0.0539)
Market dominated by established enterprises	0.0002	0.0240	0.0379	-0.0354
	(0.0450)	(0.0414)	(0.0450)	(0.0473)
Uncertain demand for innovative goods or services	0.0260	0.1010**	0.1725**	0.1747***
	(0.0511)	(0.0475)	(0.0513)	(0.0533)
Need to meet Government regulations	0.1027*	0.0835**	-0.0501	0.0873
	(0.0462)	(0.0424)	(0.0466)	(0.0481)
Excessive perceived economic risks	-0.0616	-0.0397	0.0955*	0.0131
	(0.0575)	(0.0531)	(0.0571)	(0.0599)
No need due to prior innovations	0.0143	0.0761**	0.0128	-0.0611
	(0.0426)	(0.0375)	(0.0482)	(0.0546)
No need because of no demand for innovations	0.0044	-0.0178	-0.1697***	-0.2384**
	(0.0416)	(0.0366)	(0.0493)	(0.0564)
Scale Factors				
Turnover 2004	-0.0201	-0.0126	0.0252	0.0210
	(0.0269)	(0.0238)	(0.0283)	(0.0298)
Capital Investment per Employee	0.1532***	0.0731***	0.0727***	0.0476***
	(0.0100)	(0.0096)	(0.0099)	(0.0103)
Obs				1974
Chi2				1464.40
Prob > Chi2				0.0000
Log-Likelihood				-3451.06
Likelihood ratio test of rho				320.71
P-Value of Likelihood ratio test of rho				0.0000
Likelihood Ratio Test Statistic for parameter stability				431.85
P-Value Likelihood Ratio Test for parameter stability				0.0000

Note 1: ***, ** and * indicate significance at the 99, 95 and 90 percent significance level respectively.
2: Model is estimated using a multivariate probit model and the test of rho suggests that the null hypothesis of no correlation among the error terms can be rejected. This suggests that the application of the multivariate probit model is appropriate.

Table 3: NtM Innovation

Variable	**HTM**	**AOM**	**W,T,S&C**	**FI**
Constant	-0.9726	-1.9741	-4.6744	-0.1111
	(1.6149)	(1.3518)	(1.1849)	(1.1663)
External Interaction				
Supplier	0.2372	0.2045	0.9689***	0.3206
	(0.2881)	(0.2692)	(0.2590)	(0.2999)
Customer	-0.1448	0.5064**	0.6171*	0.179
	(0.3072)	(0.2960)	(0.3768)	(0.2843)
Competitor	0.0756	0.5498*	-0.6179	-0.001
	(0.4474)	(0.4601)	(0.4905)	(0.4529)
Consultant	0.2446	-0.6317	-1.4305***	-0.1247
	(0.3162)	(0.3286)	(0.5211)	(0.3763)
Public Interaction	0.088	0.2143***	0.4932	0.2662
	(0.2815)	(0.2933)	(0.4882)	(0.3573)
R&D	0.2738***	0.2841***	0.2091***	0.3194***
	(0.0697)	(0.0465)	(0.0679)	(0.0583)
Control Variables				
Employment	0.2338***	0.2607***	0.1395**	0.1042
	(0.0847)	(0.0680)	(0.0650)	(0.0710)
Irish Owned	-0.059	-0.0804	-0.5544***	-0.6505***
	(0.2018)	(0.1728)	(0.1860)	(0.2010)
Hampering Factors				
Lack of funds within your enterprise or group	-0.2635**	0.0523	0.2696***	0.0673
	(0.1214)	(0.0913)	(0.1002)	(0.1295)
Lack of finance from sources outside your enterprise	0.2842**	0.1029	-0.1068	0.1678
	(0.1326)	(0.0911)	(0.1188)	(0.1289)
Innovation costs too high	-0.0959	-0.0559	-0.168	-0.0602
	(0.1249)	(0.0917)	(0.1062)	(0.1188)
Lack of qualified personnel	0.1531	-0.1322	0.0158	0.2580***
	(0.1598)	(0.1053)	(0.1128)	(0.1118)
Lack of information on technology	0.0299	0.1222	-0.0882	-0.1712
	(0.2060)	(0.1363)	(0.1526)	(0.1705)
Lack of information on markets	-0.1213	0.034	0.1603	0.0339
	(0.1477)	(0.1126)	(0.1386)	(0.1446)
Difficulty in finding cooperation partners for innovation	-0.0464	0.003	0.1403	-0.2147*
	(0.1423)	(0.0925)	(0.1107)	(0.1337)
Market dominated by established enterprises	-0.1402	-0.0501	0.1232	-0.0029
	(0.1235)	(0.0870)	(0.1001)	(0.1175)
Uncertain demand for innovative goods or services	0.1554	0.2109**	-0.0299	0.4213***
	(0.1336)	(0.0995)	(0.1124)	(0.1206)
Need to meet Government regulations	-0.0155	0.0844	0.1687*	0.1277

	(0.1297)	(0.0940)	(0.0968)	(0.1057)
Excessive perceived economic risks	0.3025**	0.0451	-0.0088	-0.0993
	(0.1525)	(0.1111)	(0.1233)	(0.1357)
No need due to prior innovations	-0.1316	-0.0257	-0.0224	-0.2195
	(0.1490)	(0.1016)	(0.0930)	(0.1543)
No need because of no demand for innovations	-0.1748	-0.3936***	-0.1211	-0.2037
	(0.1645)	(0.1066)	(0.0923)	(0.1554)
Scale Factors				
Turnover 2004	-0.0415	-0.0191	0.1469***	-0.0892
	(0.0849)	(0.0715)	(0.0568)	(0.0597)
Capital Investment per Employee	0.0309	0.0579***	0.0653***	0.0433***
	(0.0235)	(0.0186)	(0.0225)	(0.0235)
Obs	277	591	688	418
Chi2	218.13	524.38	381.85	352.19
Prob > Chi2	0.0000	0.0000	0.0000	0.0000
Log-Likelihood	-547.41	-967.11	-1020.84	-699.77
Likelihood Ratio Test Statistic for parameter stability	56.12	79.01	130.72	100.47
P-Value Likelihood Ratio Test for parameter stability	0.0000	0.0000	0.0000	0.0000

Note 1: ***, ** and * indicate significance at the 99, 95 and 90 percent significance level respectively.
2: Model is estimated using a multivariate probit model and the test of rho suggests that the null hypothesis of no correlation among the error terms can be rejected. This suggests that the application of the multivariate probit model is appropriate.

Table 4: NtF Innovation

Variable	HTM	AOM	W,T,S&C	FI
Constant	-0.8602	-2.0963	-1.9698	-1.0807
	(1.6092)	(1.3128)	(1.0241)	(1.0761)
External Interaction				
Supplier	-0.0039	0.2709	0.3817	0.3025
	(0.2980)	(0.2646)	(0.2612)	(0.2875)
Customer	0.1827	0.2685	1.1632***	0.4709
	(0.3041)	(0.2942)	(0.3743)	(0.2985)
Competitor	0.1588	0.2843	-0.1426	-0.9210**
	(0.4474)	(0.4394)	(0.4405)	(0.4210)
Consultant	-0.2398	-0.1647	-0.7516	-0.4572
	(0.3187)	(0.3147)	(0.4883)	(0.3883)
Public Interaction	0.1436	0.2563**	-0.5413	0.0497
	(0.2784)	(0.2838)	(0.4780)	(0.3531)
R&D	0.2305***	0.2663**	0.1647***	0.1977***
	(0.0702)	(0.0457)	(0.0650)	(0.0559)
Control Variables				
Employment	0.2020**	0.1608**	0.0539	0.1085*
	(0.0870)	(0.0658)	(0.0599)	(0.0678)
Irish Owned	-0.1737	0.187	-0.5857***	-0.5475***
	(0.2019)	(0.1748)	(0.1663)	(0.1835)
Hampering Factors				
Lack of funds within your enterprise or group	-0.0054	-0.0893	-0.0132	-0.0471
	(0.1172)	(0.0922)	(0.1009)	(0.1220)
Lack of finance from sources outside your enterprise	-0.0952	0.0499	-0.0726	-0.1342
	(0.1289)	(0.0907)	(0.1146)	(0.1156)
Innovation costs too high	-0.0653	0.0449	0.094	0.1294
	(0.1245)	(0.0902)	(0.0954)	(0.1049)
Lack of qualified personnel	0.0829	-0.0233	0.1907**	0.3628***
	(0.1639)	(0.1029)	(0.1018)	(0.1017)
Lack of information on technology	0.1793	-0.1525	-0.1399	-0.0851
	(0.2159)	(0.1339)	(0.1377)	(0.1503)
Lack of information on markets	0.0528	0.2226**	0.1451	-0.0697
	(0.1549)	(0.1108)	(0.1262)	(0.1356)
Difficulty in finding cooperation partners for innovation	-0.2426*	-0.0254	-0.0848	-0.2078*
	(0.1422)	(0.0920)	(0.1115)	(0.1224)
Market dominated by established enterprises	0.1305	0.0237	-0.0484	0.1291
	(0.1180)	(0.0855)	(0.0879)	(0.1051)
Uncertain demand for innovative goods or services	0.2841**	0.1923**	0.1904*	0.2400**
	(0.1328)	(0.0972)	(0.1038)	(0.1123)
Need to meet Government regulations	-0.1194	-0.0034	-0.0667	-0.0305

	(0.1294)	(0.0929)	(0.0928)	(0.0967)
Excessive perceived economic risks	0.2138	0.0163	-0.039	0.2825**
	(0.1460)	(0.1093)	(0.1147)	(0.1235)
No need due to prior innovations	0.0992	-0.0265	0.1364*	-0.3366
	(0.1441)	(0.0958)	(0.0746)	(0.1314)
No need because of no demand for innovations	-0.3757	-0.1809*	-0.1467*	-0.0129**
	(0.1695)	(0.0943)	(0.0777)	(0.1196)
Scale Factors				
Turnover 2004	-0.0537	-0.0082	0.044	-0.0263
	(0.0848)	(0.0688)	(0.0494)	(0.0541)
Capital Investment per Employee	0.0354	0.0789***	0.0710***	0.0923***
	(0.0233)	(0.0181)	(0.0206)	(0.0225)
Obs	277	591	688	418
Chi2	218.13	524.38	381.85	352.19
Prob > Chi2	0.0000	0.0000	0.0000	0.0000
Log-Likelihood	-547.41	-967.11	-1020.84	-699.77
Likelihood Ratio Test Statistic for parameter stability	56.12	79.01	130.72	100.47
P-Value Likelihood Ratio Test for parameter stability	0.0000	0.0000	0.0000	0.0000

Note 1: ***, ** and * indicate significance at the 99, 95 and 90 percent significance level respectively.
2: Model is estimated using a multivariate probit model and the test of rho suggests that the null hypothesis of no correlation among the error terms can be rejected. This suggests that the application of the multivariate probit model is appropriate.

Table 5: Process Innovation

Variable	**HTM**	**AOM**	**W,T,S&C**	**FI**
Constant	0.3629	-1.0353	-1.5217	-1.5639
	(1.5963)	(1.2317)	(0.9673)	(0.9811)
External Interaction				
Supplier	-0.1496	-0.026	0.9115***	0.2984
	(0.3644)	(0.2952)	(0.2936)	(0.3041)
Customer	0.2042	0.068	-0.7783**	0.5182**
	(0.3691)	(0.3270)	(0.3857)	(0.3071)
Competitor	1.2540*	1.1035*	0.7343*	0.2479
	(0.7212)	(0.5844)	(0.4560)	(0.4870)
Consultant	0.2241	0.6317*	0.6866	0.0427
	(0.3961)	(0.3635)	(0.5145)	(0.4248)
Public Interaction	0.8216**	0.2318**	0.0963	0.2064
	(0.3449)	(0.3246)	(0.5037)	(0.3647)
R&D	0.2063***	0.1167**	0.0936	0.1603***
	(0.0752)	(0.0485)	(0.0666)	(0.0539)
Control Variables				
Employment	0.1692*	0.2090***	0.1302**	0.1383**
	(0.0918)	(0.0639)	(0.0581)	(0.0660)
Irish Owned	-0.4887**	-0.2984*	-0.0781	-0.1521
	(0.2199)	(0.1681)	(0.1693)	(0.1728)
Hampering Factors				
Lack of funds within your enterprise or group	0.1506	0.019	0.0417	0.1313
	(0.1234)	(0.0902)	(0.0970)	(0.1177)
Lack of finance from sources outside your enterprise	-0.3349**	-0.0164	0.0521	-0.2262*
	(0.1468)	(0.0921)	(0.1094)	(0.1160)
Innovation costs too high	-0.0008	0.0537	-0.0214	0.0427
	(0.1370)	(0.0911)	(0.0935)	(0.1018)
Lack of qualified personnel	0.2314	0.0773	-0.0479	0.2143**
	(0.1912)	(0.1022)	(0.1073)	(0.0982)
Lack of information on technology	-0.7204***	-0.0708	0.1767	-0.0329
	(0.2597)	(0.1415)	(0.1309)	(0.1473)
Lack of information on markets	0.5569***	0.0264	-0.121	-0.1737
	(0.1924)	(0.1142)	(0.1191)	(0.1363)
Difficulty in finding cooperation partners for innovation	0.2187	-0.1078	-0.0809	-0.1675
	(0.1466)	(0.0974)	(0.0990)	(0.1263)
Market dominated by established enterprises	0.0182	0.0711	0.1773*	-0.2448**
	(0.1249)	(0.0881)	(0.0826)	(0.1053)
Uncertain demand for innovative goods or services	-0.3157**	-0.0719	-0.0146	0.4048***
	(0.1444)	(0.1009)	(0.1005)	(0.1156)

Need to meet Government regulations	0.124	0.0938	0.0529	0.2326**
	(0.1280)	(0.0924)	(0.0878)	(0.0991)
Excessive perceived economic risks	0.1187	-0.1161	-0.0651	-0.2579**
	(0.1661)	(0.1108)	(0.1074)	(0.1286)
No need due to prior innovations	-0.0719	-0.0624	0.0622	0.0859
	(0.1396)	(0.0820)	(0.0702)	(0.1004)
No need because of no demand for innovations	0.1091	0.0651	-0.1012	-0.011
	(0.1584)	(0.0755)	(0.0701)	(0.0999)
Scale Factors				
Turnover 2004	-0.0921	-0.0365	-0.0057	-0.0011
	(0.0860)	(0.0640)	(0.0467)	(0.0490)
Capital Investment per Employee	0.1118***	0.2041***	0.1890***	0.1241***
	(0.0247)	(0.0188)	(0.0213)	(0.0223)
Obs	277	591	688	418
Chi2	218.13	524.38	381.85	352.19
Prob > Chi2	0.0000	0.0000	0.0000	0.0000
Log-Likelihood	-547.41	-967.11	-1020.84	-699.77
Likelihood Ratio Test Statistic for parameter stability	56.12	79.01	130.72	100.47
P-Value Likelihood Ratio Test for parameter stability	0.0000	0.0000	0.0000	0.0000

Note 1: ***, ** and * indicate significance at the 99, 95 and 90 percent significance level respectively.
2: Model is estimated using a multivariate probit model and the test of rho suggests that the null hypothesis of no correlation among the error terms can be rejected. This suggests that the application of the multivariate probit model is appropriate.

Table 6: Organisational Innovation

Variable	HTM	AOM	W,T,S&C	FI
Constant	-0.4629	-1.4856	-1.3891	-0.1273
	(1.5452)	(1.0881)	(0.8141)	(0.8746)
External Interaction				
Supplier	0.0088	0.3177	0.9740***	0.268
	(0.3689)	(0.2848)	(0.2919)	(0.3358)
Customer	-0.5165	-0.0673	-0.3119	-0.2381
	(0.3676)	(0.3274)	(0.3822)	(0.3261)
Competitor	-0.0817	0.5558	-0.1541	0.7237
	(0.4985)	(0.5302)	(0.3919)	(0.5860)
Consultant	0.6201*	0.2835*	0.544	1.1497**
	(0.3788)	(0.3558)	(0.5025)	(0.6237)
Public Interaction	0.7058**	0.5946**	-0.1949	0.7000
	(0.3260)	(0.3240)	(0.4752)	(0.4678)
R&D	0.1892***	0.1193***	0.086	0.0939*
	(0.0730)	(0.0465)	(0.0647)	(0.0538)
Control Variables				
Employment	0.0925	0.1157**	0.1014**	0.1160*
	(0.0870)	(0.0585)	(0.0531)	(0.0640)
Irish Owned	-0.6079***	-0.2703*	-0.3334**	-0.0462
	(0.2116)	(0.1560)	(0.1483)	(0.1626)
Hampering Factors				
Lack of funds within your enterprise or group	-0.049	0.0682	0.105	0.0213
	(0.1228)	(0.0787)	(0.0833)	(0.1154)
Lack of finance from sources outside your enterprise	0.2376*	-0.1086	-0.147	0.0364
	(0.1403)	(0.0840)	(0.0959)	(0.1133)
Innovation costs too high	-0.1475	-0.1045	0.0255	0.0753
	(0.1263)	(0.0842)	(0.0779)	(0.1012)
Lack of qualified personnel	0.1623	0.1660*	0.0151	0.1870*
	(0.1698)	(0.0926)	(0.0902)	(0.0982)
Lack of information on technology	-0.5840***	-0.0794	0.0663	-0.1199
	(0.2456)	(0.1244)	(0.1138)	(0.1426)
Lack of information on markets	0.7041***	0.1492	0.0215	-0.051
	(0.2041)	(0.1033)	(0.1061)	(0.1283)
Difficulty in finding cooperation partners for innovation	0.1049	-0.085	-0.084	-0.2949**
	(0.1446)	(0.0888)	(0.0873)	(0.1204)
Market dominated by established enterprises	0.1642	0.0134	0.1092	-0.088
	(0.1231)	(0.0800)	(0.0716)	(0.1002)
Uncertain demand for innovative goods or services	-0.0709	0.135	0.0351	0.3456***
	(0.1358)	(0.0913)	(0.0879)	(0.1091)
Need to meet Government regulations	0.0404	0.1842**	0.0106	0.1406

	(0.1309)	(0.0838)	(0.0764)	(0.0935)
Excessive perceived economic risks	-0.1119	-0.0685	0.0952	-0.2527**
	(0.1564)	(0.0994)	(0.0949)	(0.1249)
No need due to prior innovations	-0.0571	0.1647**	0.0279	0.1369
	(0.1327)	(0.0729)	(0.0585)	(0.0888)
No need because of no demand for innovations	0.0467**	-0.0997	0.0152	0.0065
	(0.1497)	(0.0712)	(0.0569)	(0.0847)
Scale Factors				
Turnover 2004	-0.0183	0.0107	0.0278	-0.0361
	(0.0827)	(0.0558)	(0.0391)	(0.0420)
Capital Investment per Employee	0.0373	0.1107***	0.0722***	0.0552***
	(0.0242)	(0.0171)	(0.0197)	(0.0225)
Obs	277	591	688	418
Chi2	218.13	524.38	381.85	352.19
Prob > Chi2	0.0000	0.0000	0.0000	0.0000
Log-Likelihood	-547.41	-967.11	-1020.84	-699.77
Likelihood Ratio Test Statistic for parameter stability	56.12	79.01	130.72	100.47
P-Value Likelihood Ratio Test for parameter stability	0.0000	0.0000	0.0000	0.0000

Note 1: ***, ** and * indicate significance at the 99, 95 and 90 percent significance level respectively.
2: Model is estimated using a multivariate probit model and the test of rho suggests that the null hypothesis of no correlation among the error terms can be rejected. This suggests that the application of the multivariate probit model is appropriate.

Appendix 1: European Comparison

In this appendix we briefly compare the instances of innovation in Ireland with those of other European countries, using the aggregated CIS figures provided by Eurostat. Note that these are not directly comparable with the results presented in the micro data as adjustments are made to these figures based on grossing factors to control for non-response bias. We present only the data for New to Firm (NtF) and New to Market (NtM) innovation. Ireland is relatively innovative compared to other European countries, within a greater than average proportion of firms indicating performing NtM and NtF innovation.

Proportion of firms which reported NtrF and NtM innovation in CIS 2006

	NtF
Luxembourg	0.2971
Estonia	0.2734
Germany	0.2684
Austria	0.262
Finland	0.2604
Norway	0.2405
Cyprus	0.2394
Sweden	0.23
Belgium	0.2273
Ireland	**0.2224**
Slovenia	0.2035
Denmark	0.1932
Netherlands	0.1889
Greece	0.1841
Average	*0.1801*
Portugal	0.1694
Czech Republic	0.1677
Croatia	0.1665
Turkey	0.164
Romania	0.1473
Malta	0.1363
Spain	0.1359
Italy	0.1339
Slovakia	0.1118
Hungary	0.1018
Bulgaria	0.0986
Poland	0.0972
Lithuania	0.0912
Latvia	0.0295

	NtM
Luxembourg	0.2854
Austria	0.2301
Finland	0.2297
Sweden	0.2285
Belgium	0.2159
Greece	0.2023
Ireland	**0.1926**
Germany	0.1902
Turkey	0.187
Slovenia	0.179
Netherlands	0.1707
Denmark	0.1584
Estonia	0.1581
Average	*0.1440*
Norway	0.1416
Cyprus	0.1364
Czech Republic	0.136
Portugal	0.1229
Italy	0.1022
Croatia	0.0969
Slovakia	0.0936
Malta	0.0875
Bulgaria	0.0834
Lithuania	0.0801
Poland	0.0753
Latvia	0.0723
Hungary	0.0621
Spain	0.0614
Romania	0.0512

Appendix 2: Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
Supplier (1)	1												
Customer (2)	0.61	1											
Competitor (3)	0.38	0.39	1										
Consultant (4)	0.48	0.48	0.34	1									
Public Interaction (5)	0.42	0.40	0.27	0.52	1								
R&D (6)	0.20	0.23	0.08	0.18	0.20	1							
Employment (7)	0.22	0.16	0.05	0.19	0.22	-0.03	1						
Irish Owned (8)	-0.11	-0.11	-0.06	-0.09	-0.13	0.01	-0.39	1					
Lack of funds within your enterprise or group (9)	0.13	0.13	0.08	0.10	0.14	0.26	0.00	0.05	1				
Lack of finance from sources outside yourenterprise (10)	0.11	0.12	0.08	0.11	0.16	0.24	0.01	0.07	0.74	1			
Innovation costs too high (11)	0.12	0.11	0.07	0.10	0.12	0.22	0.06	0.02	0.69	0.68	1		
Lack of qualified personnel (12)	0.12	0.15	0.06	0.15	0.13	0.25	0.09	0.01	0.53	0.51	0.57	1	
Lack of information on technology (13)	0.12	0.12	0.08	0.14	0.13	0.21	0.09	0.00	0.51	0.52	0.57	0.74	1
Lack of information on markets (14)	0.13	0.15	0.06	0.13	0.10	0.27	0.07	0.03	0.55	0.55	0.57	0.65	0.75
Difficulty in finding cooperation partners for innovation (15)	0.13	0.14	0.06	0.14	0.16	0.18	0.05	0.02	0.51	0.55	0.54	0.56	0.63
Market dominated by established enterprises (16)	0.10	0.12	0.06	0.12	0.08	0.18	0.07	-0.01	0.48	0.45	0.52	0.53	0.52
Uncertain demand for innovative goods or services (17)	0.12	0.12	0.05	0.10	0.12	0.26	0.11	-0.02	0.52	0.50	0.55	0.52	0.56
Need to meet Government regulations (18)	0.12	0.11	0.11	0.15	0.14	0.17	0.04	0.03	0.43	0.45	0.53	0.46	0.52
Excessive perceived economic risks (19)	0.11	0.12	0.10	0.14	0.13	0.19	0.07	0.01	0.52	0.52	0.58	0.52	0.57
No need due to prior innovations (20)	-0.04	-0.05	-0.04	-0.02	-0.06	-0.04	0.01	0.01	0.16	0.18	0.19	0.19	0.26
No need because of no demand for innovations (21)	-0.07	-0.07	-0.05	-0.06	-0.09	-0.08	-0.02	0.08	0.14	0.15	0.17	0.16	0.22
Turnover 2004 (22)	0.08	0.07	0.04	0.05	0.05	-0.03	0.18	-0.26	-0.16	-0.14	-0.08	-0.05	-0.02
Capital Investment per Employee (23)	0.33	0.24	0.12	0.19	0.21	0.37	0.24	-0.11	0.24	0.20	0.22	0.24	0.23

Appendix 2: Correlation Matrix (con.)

	14	15	16	17	18	19	20	21	22
Supplier (1)									
Customer (2)									
Competitor (3)									
Consultant (4)									
Public Interaction (5)									
R&D (6)									
Employment (7)									
Irish Owned (8)									
Lack of funds within your enterprise or group (9)									
Lack of finance from sources outside yourenterprise (10)									
Innovation costs too high (11)									
Lack of qualified personnel (12)									
Lack of information on technology (13)									
Lack of information on markets (14)	1								
Difficulty in finding cooperation partners for innovation (15)	0.63	1							
Market dominated by established enterprises (16)	0.54	0.50	1						
Uncertain demand for innovative goods or services (17)	0.60	0.51	0.69	1					
Need to meet Government regulations (18)	0.51	0.48	0.53	0.56	1				
Excessive perceived economic risks (19)	0.57	0.54	0.64	0.72	0.68	1			
No need due to prior innovations (20)	0.19	0.20	0.27	0.27	0.19	0.25	1		
No need because of no demand for innovations (21)	0.18	0.19	0.23	0.27	0.19	0.25	0.59	1	
Turnover 2004 (22)	-0.06	-0.07	-0.04	-0.04	-0.03	-0.02	0.01	-0.03	1
Capital Investment per Employee (23)	0.22	0.16	0.20	0.23	0.20	0.23	-0.04	-0.09	0.09