This is an author's original manuscript of an article whose final and definitive form, the Version of Record, has been published in the International Journal of Business Innovation and Research - Vol 9(6) [Copyright InderScience] available online at http://www.inderscienceonline.com/doi/abs/10.1504/IJBIR.2015.072489

# A Two-Stage Examination of Business Innovation Decision-Making: Evidence from Ireland

**Jane Bourke* and Declan Jordan**
**School of Economics, University College Cork**
**Western Road, Cork, Ireland**
**Email: jane.bourke@ucc.ie**
**Email: d.jordan@ucc.ie**

***Corresponding author**

**Abstract:** This paper sheds light on how businesses make decisions regarding product and process innovation by comparing the power of one-stage and two-stage models to explain business-level innovation decision-making. The first, a one-stage model, represents the business as making a one-off choice between four discrete alternatives. These are not to innovate, to product innovate only, to process innovate only or to both product and process innovate. The second model, a two-stage model, represents the business as making an initial decision on whether or not to innovate. This approach facilitates analysis of business innovation as simultaneous and sequential processes and identification of the model which best explains innovation decision-making. The paper uses original business-level survey data from over 400 small and medium-sized enterprises in Ireland. The results suggest that a two-stage model of the innovation decision has a statistically significant advantage in predicting the innovation output, indicating that there is a need to incorporate the incidence and type of innovation into future empirical studies utilising a knowledge production function. The results suggest that the use of a two-stage model provides a better understanding of the impact of different knowledge sources on different types of innovation. However, the paper also discusses whether the two-stage model is a useful way of understanding how businesses make decisions on innovation in practice.

**Keywords:** Customer and Supplier Interaction, Innovation Management, Decision-Making, Sources of Innovation

**Biographical Notes:** Dr. Jane Bourke is a Lecturer in Economics at University College Cork and holds a PhD from Warwick Business School. Jane's research interests are in the areas of innovation & technological change, adoption and diffusion of innovations, and health economics.

Dr Declan Jordan is a Lecturer in Economics at University College Cork and holds a PhD from the National University of Ireland. His research interests include innovation, regional development and competitiveness, business performance and strategy and innovation and enterprise policy. He has substantial management and corporate experience before joining the School of Economics in UCC.

## 1 Introduction

It is now generally accepted in management and economic literature that the ability of an individual business to innovate is critical for its growth and survival and this has arisen from and led to a growing interest in the literature on the process of business innovation. This paper sheds light on business-level innovation decision-making, using data from two original surveys of Irish businesses.

Earlier studies on innovation looked to the characteristics of the business, such as size, age or human capital, to explain innovation performance, (for example Acs and Audretsch, 1988 and Mansfield, 1981) while more recent studies have focused less on the business itself, and more on its position within a network or system of interactions and relationships (Huber, 2012, Howells and Bessant, 2012, Balland, 2012 and see Moulaert and Sekia, 2003 for a review of frameworks of networks for innovation). Within this literature the emphasis has been on identifying and estimating the effects on innovation outputs of sources of innovation, such as Research and Development (R&D) and interaction for innovation, while controlling for factors like firm size, industry and firm age (for example Love and Roper, 2009, Woerter and Roper, 2010, Jordan and O'Leary, 2011, Doran et al, 2012a and 2012b).

This paper estimates the effects of various internal and external factors on business' decision to engage in innovation. This investigation takes quite a novel approach in examining the influences of such factors, firstly, on the likelihood of incidence of innovation, and secondly, on the likelihood of type of innovation. It uses a two-stage econometric model to test first the importance of internal R&D and external interaction on the likelihood of firm-level innovation and on the types of innovation undertaken – product innovation, process innovation or both.

The contribution of this paper is two-fold. First, we identify the factors which influence business-level innovation in Ireland using survey data. Second, the application of a two-stage model of business innovation has conceptual and empirical dimensions, and this paper further supports the need to examine the likelihood of the incidence, as well as the type, of innovation in future research.

The paper is structured as follows. Section 2 outlines the conceptual framework of the study and considers the importance of the study in the context of policy supports for business level innovation. The methodology is presented is in Section 3, in particular setting out the two-stage model. This is followed in Section 4 by a description of the data and in Section 5 an estimation of the determinants of the decision to innovate and whether to product and/or process innovate. Finally, Section 6 concludes with comments on the statistical advantages of the two-stage model and considers some issues arising for business managers for decisions on innovation.

## 2 Conceptual Framework

It is now generally accepted that innovation is of critical importance for business productivity and growth. Recently, in an Irish context Roper, Du and Love (2008) find that innovation output positively affects business performance, measured by turnover and employment growth. Doran and O'Leary (2011) also report more productive firms being more innovative and vice versa.

In the context of Ireland's economic situation following the 'Celtic Tiger' period, there is a growing need for greater understanding of the process of innovation in Irish businesses to underpin potential future prosperity. Irish policy endeavours to encourage business-level innovation. As long ago as 2000, Forfás, the state policy advisory board for enterprise in

Ireland, identified the importance of technology linkages and innovation systems for stimulating innovation in Irish businesses (Forfás, 2000). To that end, 'technology intelligence' networks and strategic collaborative partnerships between industry and third-level/state institutions have been established. Furthermore, within the *Strategy for Science, Technology and Innovation 2006-13*, the Irish government committed €1.9 billion to fund research activity in third–level institutions and supports for research in private and public research centres (Department of Enterprise, Trade and Employment, 2006). An Irish government document prepared since the onset of the current economic downturn, *Building Ireland's Smart Economy*, commits substantial investment to education, skills training and R&D, to encourage innovation and generate renewed prosperity and growth (Department of the Taoiseach, 2008).

Before considering how innovation occurs in business, it is necessary to clarify what innovation means. Schumpeter famously defines innovation as consisting of five categories:

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

This definition suggests an important distinction. The first is the difference between product and process innovation. Product innovation relates to Schumpeter's first category, that is a new good or new quality of good. The remaining four refer to process innovation. This distinction is now common in the international literature and facilitated by the use of survey data (see for example Roper 2001, Gordon and McCann, 2005, Cordis, 2007 and

Doran et al, 2012a). However, the distinction is not clear-cut, as product innovation may lead to process innovation and vice versa (Gordon and McCann, 2005) and Doran (2012) finds that there is a substantial degree of complementarity among different forms of innovation.

The innovation literature provides a wealth of research outlining the factors which influence innovation. While there is wide support for a positive relationship between R&D effort and innovation output, there is emerging debate regarding the importance of increased frequency of face-to-face interaction for innovation (Weterings and Boschma, 2009). Lundvall (1988) and Kline and Rosenberg (1986) suggest that interactive learning is crucial for innovation by facilitating the acquisition of tacit knowledge (Lundvall, 1995 and Nonaka, Toyama and Konno, 2001). Oerlemans, et al (1998) suggest that increased levels of face to face interaction may be crucial for the development of trusting relationships and the transfer of tacit knowledge. However, Weterings and Boschma (2009) suggest that a high degree of face-to-face interaction may in fact represent the lack of a trusting relationship which may be detrimental for innovation efforts. Winter (2012) identifies potential benefits and drawbacks to networking for innovation, asserting that some aspects of networking may help customers overcome uncertainties towards new product adoption and some aspects may "create additional anxieties that harm product performance" (2012:1).

Kuittinen et al (2013) in a study of R&D collaboration among Finnish firms point to a critical role for knowledge sharing in driving innovative performance. Mei and Nie (2008) find evidence that networking has positive direct and indirect effects on business innovation, the latter through complementarities with technological and marketing capabilities. Thus it is important to pose the question to whether the frequency of interaction among different external agents matters for innovation. There have been a number of studies on networking for innovation by Irish businesses, most recently Jordan and O'Leary (2011), Doran et al (2012a) and (2012b). Several earlier studies focus particularly on the role of knowledge spillovers from multinational businesses to local businesses (Ruane and Ugur, 2002; Hewitt-Dundas et al, 2002) and Roper (2001) estimated the relative importance of external interaction as a driver of product and process innovation in Irish businesses.

Returning to the distinction between product and process innovation, it is important to note that studies which attempt to identify how internal and external factors may influence both product and process innovation in a different manner or to a differing extent typically focus on innovating firms only and exclude a simple, yet crucial, part of the innovation process: whether the firm innovates or not (Cabagonals and Le Bas, 2002 and Arundel et al, 2013). Therefore, there is limited research into the innovation decision-making process in its entirety, i.e. the likelihood of the incidence of innovation and the subsequent type of innovation. The purpose of this paper is an attempt to establish whether innovation decision-making should be examined as a one-step, i.e. the likelihood of product innovation, process innovation or both occurring in a business, or a two-step process, i.e. firstly, the likelihood of the incidence of business- level innovation occurring and secondly, the likelihood of the type of innovation – product innovation, process innovation or both. Du, Love and Roper (2007) note the lack of research into the innovation decision-making process, and suggest that a better understanding of these distinct aspects of the innovation process are required.

In line with Du, Love and Roper (2007), we test the performance of two alternative models of the innovation process. In other words, we test the assumption that the innovation process consists of a decision to product and/or process innovate (a one-step approach) by providing an alternative two step approach which identifies the first stage as being the likelihood of the incidence of innovation followed by a second stage for innovators consisting of product and/or process innovation. The hypothesis tested is that innovation decision-making is best explained by modelling it as a two-stage process.

This paper considers the range of potential interaction agents, including suppliers, customers, competitors, academic-based researchers and innovation-supporting agencies and the extent to which interaction with each is a source of knowledge for innovation. This paper, using original Irish survey data, contributes to the limited empirical evidence on innovation decision-making. Specifically, it contributes to the academic literature by exploring these issues for Ireland and to policy-setting by providing evidence to identify appropriate interventions to support business innovation activity.

## 3 Method

The standard approach in the literature to modelling innovation is to use an innovation production function (see for example Acs and Audretsch, 1988, McCann and Simonen, 2005, Love and Roper, 2009 and Doran and O'Leary, 2011). This models innovation output as a function of the R&D effort of the business and external sources of knowledge through interaction. In addition the model controls for characteristics of the business that might affect its innovation output, such as size, age and sector. Following this tradition, the innovation production function takes the form:

$$IO_i = \alpha_0 + \alpha_1 Z_i + \alpha_2 R\&D_i + \alpha_3 EI_i + \mu_i$$

where $IO_i$ is an indicator of innovation output in business i.

$Z_i$ is a range of business-specific factors that may affect business i's capacity to innovate.

$R\&D_i$ is an indicator of R&D effort in business i.

$EI_i$ is an indicator of the extent of interaction for innovation in business i with customers, suppliers, competitors, HEIs and support agencies.

$\mu_i$ is the error term.

Du *et al* (2007) propose two alternative models of innovation decision-making. The first, a one-stage model, represents the business as making a one-off choice between four discrete alternatives. These are not to innovate, to product innovate only, to process innovate only or to both product and process innovate. The second model, a two-stage model, represents the business as making an initial decision on whether or not to innovate. If the decision is made to innovate, then the business must decide whether to innovate on product, process or both. These models are shown in Figure 1.

[Figure 1 here]

In our empirical examination of firm level innovation, we follow the Du *et al*. (2007) approach. We adopt the innovation production function approach and test whether a one-stage or two-stage model of the innovation process best predicts innovative activity.

Empirically, the influence of firm characteristics on firm level innovation has been tested and established by numerous scholars (Acs and Audretsch, 1988, Roper, 2001 and McCann and Simonen, 2005); and, a priori, we expect the characteristics of the firms in our sample to be in line with the literature. Similar to previous studies of firm innovation (Love and Roper, 1999, Kuittinen *et al*., 2013), we expect R&D to positively influence innovative activity. Given the knowledge acquisition and learning aspects to regular interaction with major stakeholders (Lundvall, 1995, Oerlemans, Meeus and Boekema, 1998, Nonaka, Toyama and Komo, 2001, Mei and Nie, 2008), we expect our firms to also exhibit the positive effects of such interaction.

In our examination of the innovation decision-making, we also adopt the one- and two-stage model approach. To date, no researchers have empirically tested and compared the one-and two-stage models as proposed by Du *et al* (2007). Our empirical analysis will allow us to determine which model best explains innovation decision-making. This approach also allows us to examine the innovation decision-making by firms as both a simultaneous and sequential process.

**4 Data and Descriptive Statistics**

This paper estimates the one- and two-stage models presented above using original data from two self-administered surveys. The first surveyed 184 Irish high-technology businesses. This survey was conducted towards the end of 2004. The second surveyed 223 Irish SMEs in the South-West and South-East Irish regional authority areas. This gives a total of 407 businesses, as the surveys were mutually exclusive. This survey was conducted in late 2006. Both surveys used an identical survey instrument. Descriptive statistics are presented later in this section. A full description of the survey design, implementation and response rates for the former survey are contained in Jordan (2011) and for the latter survey in Jordan and O'Leary (2008).

*4.1 South-West and South-East Regional Data*

This paper uses survey data collected by the South-West and South-East Regional Authorities as part of the 'DRIVE for Growth' Project (DRIVE 2008). The Authorities cover the NUTS 3 areas of the South-West, consisting of Cork and Kerry, and the South-East, made up of Carlow, Waterford, Kilkenny, Wexford and south Tipperary. These contiguous regions, with a combined population of just over 1 million, contain two cities; Cork, with a population of 250 thousand (Atkins 2008) and Waterford, with over 120 thousand (South East Regional Authority 2006). Disposable income per capita in the South-West and South-East was 96% and 93% respectively of the national average in 2006 (Central Statistics Office 2006). A total of 86% of the businesses surveyed were indigenous Irish businesses.

A self-administered survey was circulated to 1,619 enterprises employing 250 persons or less in all sectors, excluding agriculture, forestry and fisheries and public services, during the winter of 2006/2007. The definition of SMEs as having less than 250 employees is standard in the literature and is consistent with the European Commission (2005) definition of SMEs, though the absence of financial information on respondent enterprises prevents categorisation based on turnover or balance sheet size. A total of 223 enterprises responded, representing a response rate of 14%.

The median age of enterprises is 15 years with a standard deviation of 28 years. The mean number of employees is 37 (standard deviation of 53) and the average number of employees with third level education is 36% (standard deviation of 35%).

As the survey focuses on only a sub-set of Ireland it is important to provide a discussion on the reliability of the survey. To address this a number of key variables from the survey are compared to corresponding data from the Irish Innovation Panel (IIP) (Roper and Hewitt-Dundas 2006), which has been used extensively to document and analyse the innovation performance of Irish firms (Love and Roper 1999; Roper 2001; Roper and Anderson 2000; Roper et al. 2008; Roper and Hewitt-Dundas 2003).

IIP data for businesses in the South-East and South-West NUTS3 regions of Ireland employing less than 250 employees are used for comparison. The reference periods for both surveys are the three years from 2004 to 2006. Comparisons between the two data sets are based on the mean and variance of innovation performance and the number of employees.

Tables 4 and 5 display the results of t-tests for comparison of means and variance ratio tests for innovators (either product or process), product innovators only, process innovators only and firm size. This approach is generally consistent with Weterings and Boschma (2009), who also use statistical comparison tests to assess the representativeness of their sample. It can be observed in Table 1 that the mean values for three of the four values are not statistically different from the values of the IIP. The sole significant difference is in the propensity of enterprises to introduce process innovations. This discrepancy may be explained by slight differences in the construct of the question posed to enterprises in the two surveys. In the South-West and South-East survey respondents were asked to indicate the frequency with which they introduced process innovation while in the IIP respondents were asked to indicate the incidence of process innovation. In Table 2 it can be noted that there is no significant difference in the variance associated with any variable.

[insert Table 1 and 2 around here]

The similarity in these key variables in both surveys suggests the survey is a reliable indicator of the innovation performance of Irish SMEs in the South-East and South-West of Ireland.

*4.2 High-Technology Sectors Survey*

The self-administered survey of 184 Irish high-technology businesses was conducted towards the end of 2004. Given the obvious differences in the development of both indigenous and foreign-owned businesses it is important to note the different characteristics of these respondents. The 98 indigenous respondents had an average of 49 employees in

2003, 54% of whom had a third level degree. The 86 foreign-owned respondents had an average of 182 employees, 29% of whom had third level education. The average age of indigenous businesses was 14 years compared to 23 for foreign-owned. ICT respondents were significantly smaller businesses and a greater proportion of their workforce had third level education. These differences in age, employment and proportion with third level qualifications are statistically significant at the 95% level.

The representativeness of the sample is assessed based on average employment. Table 4.8 shows the average employment in the population and the survey sample, as well as the 95% confidence interval of the survey mean and the survey sample 5% trimmed mean. These are presented by sector.

It can be seen from Table 4.8 that in each sector average employment is higher in the sample than it is in the population, indicating that the sample is under-representative of smaller businesses. However, the population mean employment is within the 95% confidence interval for the survey mean for each sector.

Adopting a 5% trimmed mean, average employment in the sample is close to the population levels, particularly for the ICT and Electronic Devices and Engineering sectors. This suggests that there may be a small number of very large businesses pulling the average employment levels upwards.

### *4.3 Measuring Innovation and its Determinants*

In line with studies such as MacPherson (1998), Roper (2001), and the EU's Community Innovation Survey (Cordis, 2007), product innovation is defined as the introduction of new or improved goods/services which may be new to the market or new to the businesses in the reference period. Process innovation, which is less observable from outside a business, 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 and Gordon and McCann, 2005).

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

Descriptive statistics are reported in Table 1. The average firm age is just under 20 years. The average number of employees is 74. Almost two thirds of businesses perform R&D, and one third has a dedicated R&D department. Almost 30 per cent of firms are foreign owned. External regular interaction is represented by a series of dummy variables, with regular interaction defined as at least once a year. 82 per cent and 86 per cent of firms regularly interact with their suppliers and customers respectively. 37 per cent of firms report regular interaction with their competitors. 36 per cent and 42 per cent of firms regularly interact with academics and agencies.

[Table 1 Here]

In relation to innovation output, 81% of businesses are innovation active which means that they introduced at least one product and/or process innovation. Of the sample, 16.7% of businesses introduced only product innovation, 10.8% introduced only process innovation and 53.8% introduced both.

## 5 Results

The one-stage innovation process is empirically modelled in the form of multinomial Probit; and the two-stage innovation process is empirically modelled in the form of a Probit and multinomial Probit model. Tables 2 and 3 report Probit estimations of the one- and two-part models respectively.

[Tables 2 and 3 here]

The results are discussed later in this section, however initially the following should be noted. The results for both models are consistent, with significant variables always having the same sign, nearly always the same level of significance and often very similar coefficients. Table 4 presents a comparison of the prediction statistics from both the one- and two-part model. Similar to Du *et al* (2007), we find that two-stage model has a statistically significant advantage in prediction in three of the four categories (non-innovator; process only; and product and process) and overall. In line with Du *et al* (2007), we find that the two-part model outperforms the one-part model as a means of modelling the innovation decision. Therefore, there is clear support for examining the innovation decision-making process in terms of the incidence of innovation and the type of innovation.

[Table 4 here]

In both models, regular supplier interaction and regular customer interaction have no effect on the decision to innovate or not, nor do they have any effect on product only or process only innovation. However, both forms of interaction have a positive effect on process and product innovation. Du *et al* (2007) also report that backward and forward linkages have a positive effect on product and process innovation. This suggests that knowledge acquisition and learning through interaction with firms ensures that suppliers and customers have a better understanding of the product; in turn ensuring that firms are in a better position to develop new products and processes (Winter, 2012). However, Du *et al* (2007) find that these linkages affect the decision to innovate or not. They also find that interaction with suppliers and customers discourage product only innovation and process only innovation respectively. In contrast to Du *et al* (2007), we find that interaction with competitors does not affect the innovation decision either at a one- or a two-stage level.

We find no evidence that interaction with academics impacts any of the four innovation decisions, and we find that interaction with agencies has a negative effect on the decision to be an innovator or not. In fact, previous research has found that links with academics and universities has no impact on innovation activity in Ireland (Du *et al*, 2007) or negatively impacts innovation activity in Ireland (Jordan and O'Leary, 2008; Roper and Arvanitis, 2008). These results may arise from innovations developed in collaboration with universities or agencies taking longer to come to fruition than those developed with commercial partners (Roper and Arvanitis, 2008) or more advanced innovations (Todtling *et al*, 2009). It may also arise from the nature of the measurement of interaction between businesses and universities, as the nature of the interaction required for different aspects of business innovation may be more nuanced than the traditional linear model approach suggests (Sparrow, Mooney and Lancaster, 2006).

In both models, R&D has a negative effect on product only innovation and a positive effect on product & process innovation. Interestingly, a dedicated R&D department has no impact on the decision to innovate or not, nor does it have any impact on the type of innovation decision. These results suggest that R&D is a source of knowledge for all innovation and there appears to be no benefit from having a formalized R&D effort. Du *et al* (2007) report similar R&D results, although they also report a positive coefficient for product only innovation and a negative coefficient for non-innovator. Du *et al* (2007) report similar results with respect to plants with R&D departments, although they find that having an R&D department reduced the likelihood of being a process only innovator. Du *et al* (2007) found that having an R&D department increased the likelihood of being a product and process innovator. Previously, Kuittinen *et al*., 2013 identified the critical role for knowledge sharing in driving innovative performance.

Statistically significant results with respect to firm vintage are reported for the non-innovator and process only innovator in both models. As firm age increases, firms are more likely to be non-innovators. Similarly, the older the firm, it is less likely to be a process only innovator. Du *et al* (2007) did not report statistically significant results for non-innovators and process only innovators; however they did report that older plants are more likely to be product only innovators. Previously, Roper, Du and Love (2006) reported plant vintage negatively affecting the probability of a plant being a process innovator and innovation success. Firm size does not affect the decision to innovate or not. A very small statistically significant positive coefficient is reported for process only innovation with respect to firm size. Roper, Du and Love (2006) reports a positive, linear impact relationship between firm size and the probability of undertaking process innovation. However, our finding differs from Du *et al* (2007) who find plant size does affect whether plants decide to innovate or not, but does not affect the type of innovation decision.

As previously stated, we also find that the two-part model outperforms the one-part model as a means of modelling the innovation decision. Therefore, in the first testing of Du *et al.*'s (2007), our empirical results clearly support examining the innovation decision-making process in terms of the incidence of innovation and the type of innovation. However, unlike Du *et al* (2007), this paper argues that these two models should not be seen to depict decision-making processes *per se* but more so as a way of determining which model is the best method of identifying the factors which influence business innovation. As the two-stage model is a better predictor of business innovation, it is imperative that future researchers adopt a similar approach in order to fully understand businesses' innovation activity, identify the internal and external factors that are likely to influence innovation, as well as, the different types of innovation, and inform the policy agenda. In the next section, we discuss possible policy interventions and supports for firm level innovation given our empirical support for the two-stage model.

## 6 Conclusions

Our results are consistent with those of Du *et al* (2007) indicating that a two-stage model of the innovation decision has a statistically significant advantage in predicting the innovation output in three of the four categories and overall. Du *et al* (2007) conjectured that the increased reliability of the two-stage model may be specific to their data; however, our results further support Du *et al'*s (2007) assertion that future economic studies on the determinants and effects of innovation should consider the two-stage model. In addition, we argue that the two-stage innovation decision model does not necessarily mean that businesses are making distinct decisions regarding whether or not to innovate and the type of innovation to engage in, but rather suggests the need to incorporate the incidence and type of innovation into future empirical studies of this part of the 'knowledge production function'.

It is clear that the use of a two-stage model provides better understanding of the impact of different knowledge sources on different types of innovation. For example, it is seen in Table 2 that older businesses are less likely to be process only innovators, while larger businesses are more likely to be process only innovators. This has implications for the types of supports geared towards these businesses to help them improve innovation performance. It also conditions what we may expect from these types of businesses in terms of their innovation output.

Furthermore, we can see that interaction with customers increases the probability of innovating in both products and processes. This suggests that talking to customers can provide insights for new product development but will also help businesses to process innovate. Similarly, interaction with suppliers does not only help businesses to improve processes but can also be a source of knowledge for new products and services. Our findings in relation to the absence of a positive effect on business innovation from interaction with HEIs is not particularly surprising given recent studies on business level innovation in Ireland (Jordan and O'Leary, 2008, Hewitt-Dundas and Roper, 2008, Du et al, 2007). It is consistent with Piperopoulos and Scase (2009:497) who note that businesses that develop strategic partnerships are more likely to innovate than "those that adopt a more 'traditional' go-it-alone approach". Also, Doran and O'Leary (2011) in an examination of how Irish businesses source knowledge for innovation highlight a dichotomy with businesses either sourcing knowledge from market agents (suppliers and customers) or non-market agents (universities and government research institutes). The authors conclude that this may reflect the current science-push policy agenda in Ireland.

There is little doubt that Irish innovation policy endeavours to encourage business-level innovation, corroborated by a substantial increase in the level of funding for R&D in recent years. However, our findings, strengthened by the application of the two-stage model, should be considered with respect to the supports provided for innovation by the Irish government and their agencies. For instance, Enterprise Ireland's Innovation Voucher scheme is aimed at indigenous businesses of less than 50 employees. Vouchers (not to exceed a value of €5,000) can be redeemed by businesses for research undertaken by approved third level institutes (Enterprise Ireland, 2011). However, given our findings in relation to the positive effect of R&D on business innovation and the negative influence of academic interaction on business innovation, perhaps the scope of this scheme could be broadened to allow for financial support for in-house R&D. Perhaps, consideration also needs to be given to providing businesses with support for interacting with market agents as our findings clearly identify the positive influence of such interaction in relation to product and process innovation.

This study is not without limitations. The data set used is cross-sectional and so prevents analysis of changes in the determinants of innovation decision across time. Therefore, it would be worthwhile in future analyses to utilise a panel data framework which would shed light on the extent to which product and process innovation decisions may be time dependent or sequential. Also, it would be beneficial to conduct this analysis on a larger data set which would allow greater analysis of differences across categories of business characteristics such as sectors, age and/or size. Care must also be taken in generalising these results to other locations and periods. Roper et al. (2010) argue that country heterogeneity can impact on the interdependence of innovation activities so that the use of qualitative, including case study, analysis may be needed before the generalizability of results from an econometric analysis such as this can be ascertained.

Notwithstanding these concerns, the interpretation of the results of this estimation requires careful consideration. While the statistical advantages of the two-stage model is clear, it is not suggested that businesses may choose between types of innovation. The complexity of the innovation process means that businesses are unlikely to decide between product innovation and process innovation. However, businesses may decide on the resources they dedicate to innovative activity, including R&D effort and whether or how frequently to interact with other businesses and/or academic-based researchers. It is clear from this study however that business managers must consider the impact on each type of innovation activity of the resources dedicated to internal and external knowledge generation and recognise the inter-dependency between each type of innovation.

The strength of the two-stage model may be to shed light on the likely innovation output, that is whether a business will successfully innovate and whether that innovation is likely to be product, process or both, having decided to invest in sourcing knowledge for innovation. This means we may not expect businesses to decide to introduce product innovation and then seek to interact with customers or engage in R&D. Rather, businesses may decide to interact with customers for innovation or engage in R&D, and the model presented here sheds light on the probable innovation outcome.

## References


Acs, Z.J. and Audretsch, D.B. (1988) “Innovation in Large and Small Businesses”, *American Economic Review*, 78, pp. 678-690.

Arundel, A., Robertson, P. and Torugsa, N. (2013) “The Development and Adoption of Product and Process Innovations in European Firms” *R&D Management Conference 2013: Skills for Future Innovation - Implications for R&D Management*, June, Manchester [Available online at http://ecite.utas.edu.au/86320 - accessed 9 December 2013]

Balland, P.-A. (2011) “Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry” *Regional Studies*, 46(6), pp. 741-756.

Cabagnols, A., and Le Bas, C. (2002) “Differences in the determinants of product and process innovations: the French case” in Kleinknecht, A. and Mohnen, P. (eds.) *Innovation and Firm Performance* Palgrave, New York pp. 112-149.

Cordis, (2007), *Community Innovation Survey*, [Available online at http://cordis.europa.eu/innovation-smes/src/cis.htm – Accessed July 12, 2011].

Department of Enterprise, Trade, and Employment (2006). *Strategy for Science, Technology and Innovation to 2013,* Government Publications, Dublin.

Department of the Taoiseach. (2008). *Building Ireland's Smart Economy: A framework for sustainable economic renewal* [Available online at http://www.taoiseach.gov.ie/attached_files/BuildingIrelandsSmartEconomy.pdf accessed July 4, 2013].

Doran, J. (2012) "Are differing forms of innovation complements or substitutes?" *European Journal of Innovation Management*, 15(3), pp.351 - 371

Doran, J., Jordan D. and O'Leary, E. (2012a) “The Effects of the Frequency of Spatially Proximate and Distant Interaction on Innovation by Irish SMEs” *Entrepreneurship and Regional Development.* 24, pp. 705-727.

Doran, J., Jordan, D. and O'Leary, E. (2012b) “The Effects of National and International Interaction on Innovation: Evidence from the Irish CIS: 2004-06” *Industry and Innovation.* 19(5), pp. 371-390.

Doran, J. and O’Leary, E. (2011). “External Interaction, Innovation and Productivity: An Application of the Innovation Value Chain to Ireland”, *Spatial Economic Analysis*, 6, pp. 199-222.

Du, J., Love, J.H. and Roper, S. (2007) “The innovation decision: An economic analysis”, *Technovation*, 27, pp. 766-773.

Forfás (2000) *Enterprise 2010.* Available online at http://www.forfas.ie/publication /search.jsp?ft=/publications/2000/Title,941,en.php - accessed July 4, 2013

Freel, M. (2003) “Sectoral Patterns of Small Firm Innovation, Networking and Proximity”, *Research Policy* 32, pp. 751-770.

Hewitt-Dundas, N., Andreosso-O’Callaghan, B., Crone, M. and Roper, S. (2005) “Knowledge Transfers from Multinational Plants in Ireland: A Cross-Border Comparison of Supply Chain Linkages”, *European Urban and Regional Studies*, 12, pp.23-43.

Jordan, D. (2011) *Innovation, Interaction and Space: Interaction and Proximity for High-Tech Business Innovation*, Lambert Academic Publishing, London.

Jordan D. and O’Leary, E. (2008) “Is Irish Innovation Policy Working? Evidence from Irish High-Technology Businesses”, *Journal of the Statistical and Social Inquiry Society of Ireland*, 37, pp. 1-44.

Jordan, D. and O'Leary, E. (2011) “The Role of External Interaction for Innovation in Irish High-technology Businesses” *International Journal of Entrepreneurship and Innovation*, 12 (4), pp. 248-256.

Gordon, I. and McCann, P. (2005) “Innovation, Agglomeration and Regional Development” *Journal of Economic Geography*, 5, pp. 523-543.

Howells, J. and Bessant, J. (2012) “Introduction: Innovation and economic geography: a review and analysis” *Journal of Economic Geography*, 12(5), pp. 929-942.

Huber, F. (2012) “Do clusters really matter for innovation practices in Information Technology? Questioning the significance of technological knowledge spillovers” *Journal of Economic Geography*, 12(1), pp. 107-126.

Kline, J. and Rosenberg, N. (1986). “An Overview of Innovation”, in Landau, R. and Rosenberg, N. (eds) *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, National Academy Press, Washington.

Kuittinen, H., Puumalainen, J., Jantunen, A., Kyläheiko, K. and Pätäri, S. (2013) “Coping with uncertainty - exploration, exploitation, and collaboration in R&D”, *International Journal of Business Innovation and Research*, 7 (3), pp.340 – 361.

Love J. and Roper S. (2001) “Location and Network Effects on Innovation Success: Evidence for UK, German and Irish Manufacturing Plants”, *Research Policy,* 30, pp. 643-661.

Love, J. H. and Roper, S. (2009). "Organizing the innovation process: complementarities in innovation networking" *Industry and Innovation* 16, pp. 273-290.

Lundvall, B. E. (1988) “Innovation as an interactive process: From user-producer interaction to the national system of innovation” in Lundvall, B.E. (ed) *Technical Change and Economic Theory*, London, Pinter Publishers.

Lundvall, B. (1995) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London, Pinter.

MacPherson, A.D. (1998) “Academic-industry Linkages and Small Firm Innovation: Evidence from the Scientific Instruments Sector”, *Entrepreneurship and Regional Development*, 10, pp. 261-275.

McCann P. and Simonen J. (2005) “Innovation, Knowledge Spillovers and Local Labour Markets”, *Papers in Regional Science*, 84, pp. 465-485.

Mei, S. and Nie, M. (2008) “Firm's capabilities and innovation: a case study of Wuhan optoelectronic cluster” *International Journal of Business Innovation and Research*, 2(1), pp. 57-70.

Moulaert, F. and Sekia, F. (2003) “Territorial Innovation Models: A Critical Survey” *Regional Studies*, 37, pp. 289-302.

Nonaka, I., Toyama, R. and Konno, N. (2001) “SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation” in Nonaka, I., and Teece, D. (eds) *Managing Industrial Knowledge: Creation, Transfer and Utilisation*, Thousand Oaks, Ca, Sage.

Oerlemans, L., M. Meeus and F. Boekema (1998). "Do Networks Matter for Innovation? The Usefulness of the Economic Network Approach in Analysing Innovation", *Journal of Economic and Social Geography*, 89, pp. 298-309.

Piperopoulos, P. and Scase, R. (2009) Competitiveness of small and medium sized enterprises: towards a two dimensional model of innovation and business clusters *International Journal of Business Innovation and Research*, 3(5), pp. 479-499.

Roper, S., and Arvantis, S. (2009) “From Knowledge to Added Value: A comparative, panel-data analysis of the Innovation Value Chain in Irish and Swiss Manufacturing Firms”, *Warwick Business School’s Small and Medium Sized Enterprise Centre Working Papers*, WP-109. [Available online at http://www2.warwick.ac.uk/fac/soc/wbs/research/csme/research/working_papers/wp107.pdf - Accessed July 4, 2013]

Roper, S., Du, J. & Love, J. (2008) Modelling the innovation value chain, *Research Policy*, 37, pp. 961-977.

Ruane, F. and Ugur, A. (2005) “Foreign Direct Investment and Productivity Spillovers in the Irish Manufacturing Industry: Evidence from Firm Level Panel Data”, *International Journal of the Economics of Business*, 11, pp. 53-66.

Schumpeter, J., (1934) *The Theory of Economic Development*, Harvard University Press, Cambridge, U.S.

Sparrow, J., Mooney, M. and Lancaster, N. (2006) “Perceptions of a UK university as a knowledge-intensive business service enhancing organisational and regional service innovation” *International Journal of Business Innovation and Research*, 1 (1/2), pp. 191-203.

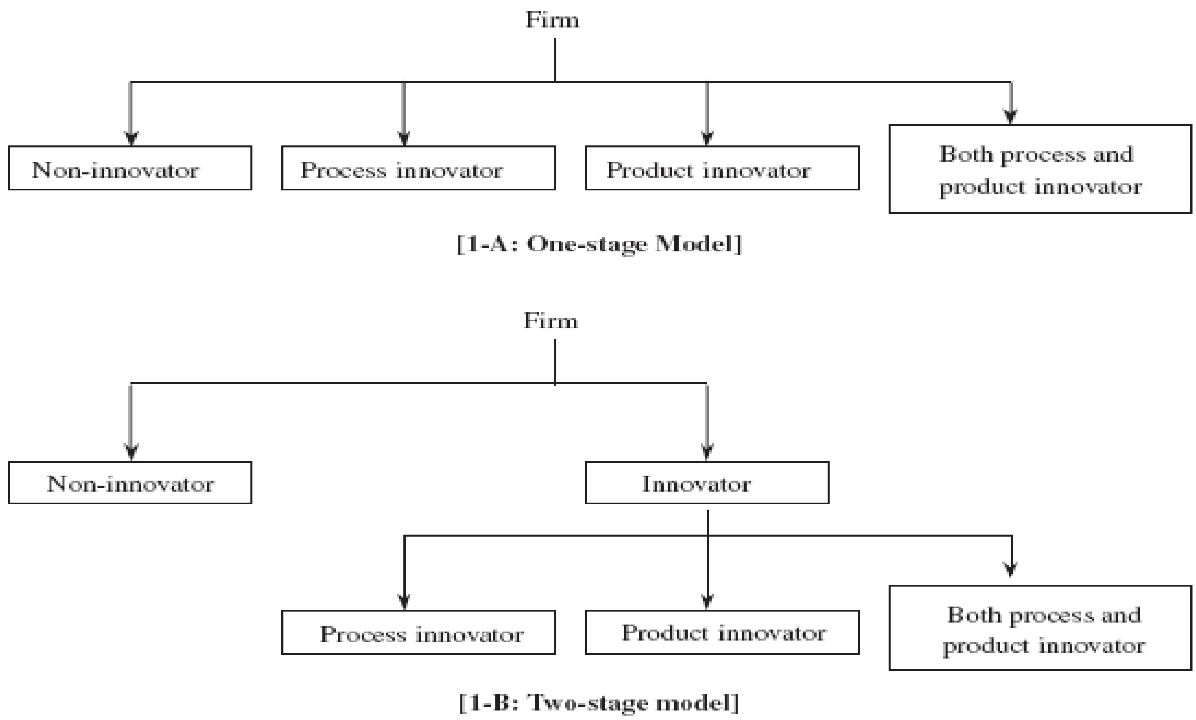
Tödtling, F., Lehner, P. and Kaufman, A. (2009) “Do different types of innovation rely on specific kinds of knowledge interactions?”, *Technovation* 29, pp. 59-71.

Weterings, A. and R. Boschma (2009) "Does spatial proximity to customers matter for innovative performance?: Evidence from the Dutch software sector", *Research Policy*, 38, pp. 746-755.

Winter, S. (2012) “Network effects and new product success: strengthening product advantage, overcoming customer uncertainty?” *International Journal of Business Innovation and Research*, 6(1), pp. 1-27.

Woerter, M. and Roper, S. (2010). "Openness and innovation—home and export demand effects on manufacturing innovation: panel data evidence for Ireland and Switzerland" *Research Policy* 39, pp. 155-164.

**Fig. 1: Firms' decision tree of innovation activity**




Source: Du *et al* (2007:767)

Table 1: Two-Sample Mean Comparison t-test of South-West and South-East Survey and the IIP

| 4a Two-sample t - Innovator | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Innovator - IIP | 0.7183 | 0.0309 | 0.4509 |
| Innovator - DRIVE | 0.7453 | 0.0425 | 0.4378 |
| Combined | 0.7273 | 0.0250 | 0.4461 |
| Difference | -0.0270 | 0.0526 | |
| Ho: diff = 0 | | | t = -0.5132 |
| | | | Pr(\|T\| > \|t\|) = 0.6083 |

| 4b Two-sample t test - Product | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Product - IIP | 0.6038 | 0.0477 | 0.4914 |
| Product - DRIVE | 0.5561 | 0.0340 | 0.4980 |
| Combined | 0.5719 | 0.0277 | 0.4956 |
| Difference | 0.0477 | 0.0586 | |
| Ho: diff = 0 | | | t = 0.8136 |
| | | | Pr(\|T\| > \|t\|) = 0.4168 |

| 4c Two-sample t test - Process | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Process - IIP | 0.4953 | 0.0486 | 0.5023 |
| Process - DRIVE | 0.6197 | 0.0333 | 0.4866 |
| Combined | 0.5781 | 0.0277 | 0.4946 |
| Difference | -0.1244 | 0.0589 | |
| Ho: diff = 0 | | | t = -2.1117 |
| | | | Pr(\|T\| > \|t\|) = 0.0359 |

| 4d Two-sample t test - Employees | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Innovator - IIP | 62.90476 | 6.014292 | 61.62815 |
| Innovator - DRIVE | 58.58879 | 5.462056 | 56.49995 |
| Combined | 60.72642 | 4.051776 | 58.99474 |
| Difference | 4.315977 | 8.124393 | |
| Ho: diff = 0 | | | t = 0.5312 |
| | | | Pr(\|T\| > \|t\|) = 0.5958 |

Table 2: Two-Sample Variance Ratio Test of South-West and South-East Survey and the IIP

| 5a Variance ratio test - Innovator | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Innovator - IIP | 0.71831 | 0.030894 | 0.450883 |
| Innovator - DRIVE | 0.745283 | 0.04252 | 0.437772 |
| Combined | 0.727273 | 0.024975 | 0.446062 |
| Ho: ratio = 1 | | | f = 0.9427 |
| | | | Pr(F < f) = 0.7422 |

| 5b Variance ratio test - Product | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Product - IIP | 0.5561 | 0.0340 | 0.4980 |
| Product - DRIVE | 0.6038 | 0.0477 | 0.4914 |
| Combined | 0.5719 | 0.0277 | 0.4956 |
| Ho: ratio = 1 | | | f = 0.9738 |
| | | | Pr(F < f) = 0.8902 |

| 5c Variance ratio test - Process | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Process - IIP | 0.6197 | 0.0333 | 0.4866 |
| Process - DRIVE | 0.4953 | 0.0486 | 0.5023 |
| Combined | 0.5781 | 0.0277 | 0.4946 |
| Ho: ratio = 1 | | | f = 1.0657 |
| | | | Pr(F > f) = 0.6909 |

| 5d Variance ratio test – Employees | | | |
|---|---|---|---|
| Variable | Mean | Std. Err. | Std. Dev. |
| Innovator - IIP | 62.90476 | 6.014292 | 61.62815 |
| Innovator - DRIVE | 58.58879 | 5.462056 | 56.49995 |
| Combined | 60.72642 | 4.051776 | 58.99474 |
| Ho: ratio = 1 | | | f = 1.1898 |
| | | | Pr(F < f) = 0.3743 |

**Table 3 – Descriptive Statistics**

| Variable Description | Mean | St. Dev. |
|---|---|---|
| Age of Firm (years) | 19.73 | 22.59 |
| Employment (numbers) | 74.35 | 147.74 |
| R&D (0/1) | 0.6596 | 0.4744 |
| R&D Dept (0/1) | 0.3280 | 0.4701 |
| Regular Supplier Interaction (0/1) | 0.8206 | 0.3841 |
| Regular Customer Interaction (0/1) | 0.8599 | 0.3475 |
| Regular Competitor Interaction (0/1) | 0.3660 | 0.4823 |
| Regular Academic Interaction (0/1) | 0.3562 | 0.4794 |
| Regular Agency Interaction (0/1) | 0.4201 | 0.4941 |
| High-Tech Sector (0/1) | 0.6108 | 0.3892 |
| Foreign Ownership (0/1) | 0.2973 | 0.4576 |

**Table 2: Marginal Effects of Multinomial Probit for Innovation Decision (One-Part Model)**

| Variables | Non-Innovator | | Process Only | | Product Only | | Process & Product | |
|---|---|---|---|---|---|---|---|---|
| | *dy/dx* | SE | *dy/dx* | SE | *dy/dx* | SE | *dy/dx* | SE |
| Age of Firm | -0.0016 | 0.0007** | -0.0023 | 0.0011** | 0.0005 | 0.0011 | 0.0002 | 0.0014 |
| Employment | 0.0002 | 0.0003 | 0.0002 | 0.0001** | -0.0002 | 0.0002 | 0.0001 | 0.0002 |
| R&D | 0.0413 | 0.0473 | -0.0650 | 0.0457 | -0.1390 | 0.0598** | 0.2454 | 0.0666*** |
| R&D Dept | -0.0100 | 0.0472 | 0.0011 | 0.0467 | 0.0353 | 0.0538 | -0.0464 | 0.0691 |
| Education | 0.0006 | 0.0006 | -0.0008 | 0.0005 | 0.0008 | 0.0007 | 0.0006 | 0.0009 |
| Foreign Ownership | -0.0242 | 0.0465 | 0.0093 | 0.0431 | -0.0454 | 0.0492 | 0.0120 | 0.0687 |
| Reg Supplier Int. | 0.0926 | 0.0595 | -0.0020 | 0.0518 | -0.0877 | 0.0686 | 0.1823 | 0.0828** |
| Reg Customer Int. | 0.1421 | 0.0760 | -0.0617 | 0.0710 | -0.0592 | 0.0773 | 0.2631 | 0.0971*** |
| Reg Competitor Int. | -0.0091 | 0.0396 | 0.0007 | 0.0399 | 0.0120 | 0.0467 | -0.0283 | 0.0595 |
| Reg Academic Int. | -0.0459 | 0.0447 | 0.0015 | 0.0408 | -0.0552 | 0.0441 | 0.0078 | 0.0618 |
| Reg Agency Int | 0.1274 | 0.0384*** | 0.0022 | 0.0411 | -0.0069 | 0.0450 | 0.1321 | 0.0594** |
| High Tech Sector | 0.2012 | 0.05488*** | -0.0456 | 0.04305 | 0.0496 | 0.0423 | 0.1972 | 0.0603*** |

*Note* 1: Significant level: ***$p$<0.01, **$p$<0.05.

**Table 3: Marginal Effects of Probit and Multinomial Probit for Innovation Decision (Two-Part Model)**

| Variables | Probit of Innovator | | Multinomial Probit Model | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Process Only | | Product Only | | Process & Product | |
| | *dy/dx* | SE | *dy/dx* | SE | *dy/dx* | SE | *dy/dx* | SE |
| Age of Firm | 0.0014 | 0.0007** | -0.0027 | 0.0013** | 0.0011 | 0.0015 | 0.0016 | 0.0018 |
| Employment | -0.0002 | 0.0002 | 0.0002 | 0.0001** | -0.0002 | 0.0002 | 0.0002 | 0.0002 |
| R&D | -0.0335 | 0.0415 | -0.0780 | 0.0514 | -0.1841 | 0.0674*** | 0.2620 | 0.0709*** |
| R&D Dept | 0.0102 | 0.0452 | 0.0033 | 0.05632 | 0.0525 | 0.0619 | -0.0558 | 0.0723 |
| Education | -0.0006 | 0.0006 | 0.0011 | 0.0006 | 0.0006 | 0.0007 | 0.0005 | 0.0009 |
| Foreign Ownership | 0.0226 | 0.0438 | 0.0219 | 0.0484 | -0.0587 | 0.0526 | 0.0368 | 0.0663 |
| Reg Supplier Int. | -0.0721 | 0.0558 | -0.0369 | 0.0631 | -0.1515 | 0.0803 | 0.1883 | 0.0880** |
| Reg Customer Int. | -0.1212 | 0.0725 | -0.1027 | 0.0922 | -0.1413 | 0.1020 | 0.2440 | 0.1168** |
| Reg Competitor Int. | 0.0058 | 0.0375 | 0.0036 | 0.0420 | 0.0213 | 0.0486 | -0.0177 | 0.0582 |
| Reg Academic Int. | 0.0391 | 0.0435 | 0.0114 | 0.0443 | -0.0476 | 0.0473 | 0.0361 | 0.0593 |
| Reg Agency Int | -0.1223 | 0.0365*** | -0.0215 | 0.0438 | -0.0402 | 0.0475 | 0.0598 | 0.0576 |
| High Tech Sector | -0.1915 | 0.0470*** | -0.0881 | 0.0533* | 0.0279 | 0.0513 | 0.0602 | 0.0661 |

*Note* 1: Significant level: ***$p$<0.01, **$p$<0.05, * $p$<0.1.

**Table 4: Prediction Statistics**

| | Actual Probability | One-Stage Model | | | | Two-Stage Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Predicted Probability | % | Correctly Predicted Probability | % | Predicted Probability | % | Correctly Predicted Probability | % | z-stat |
| Non-Innovator | 66 | 58 | 88 | 25 | 38 | 93 | 141 | 83 | 126 | -6.176 |
| Process Only | 42 | 1 | 2 | 1 | 2 | 4 | 10 | 2 | 5 | -0.749 |
| Product Only | 62 | 12 | 19 | 2 | 3 | 19 | 30 | 8 | 13 | -2.234 |
| Product & Process | 205 | 304 | 148 | 189 | 92 | 286 | 140 | 199 | 97 | -3.710 |
| | | | | | | | | | | |
| | 309 | | | | | 309 | 100 | 209 | 68 | |
| | 375 | 375 | 100 | 217 | 58 | 402 | 107 | 292 | 78 | -5.478 |

*Note* 1: The selection threshold for the Probit model predicting non-innovation is set to 0.25