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Authors	Bourke, Jane;Jordan, Declan
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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.

μ_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.

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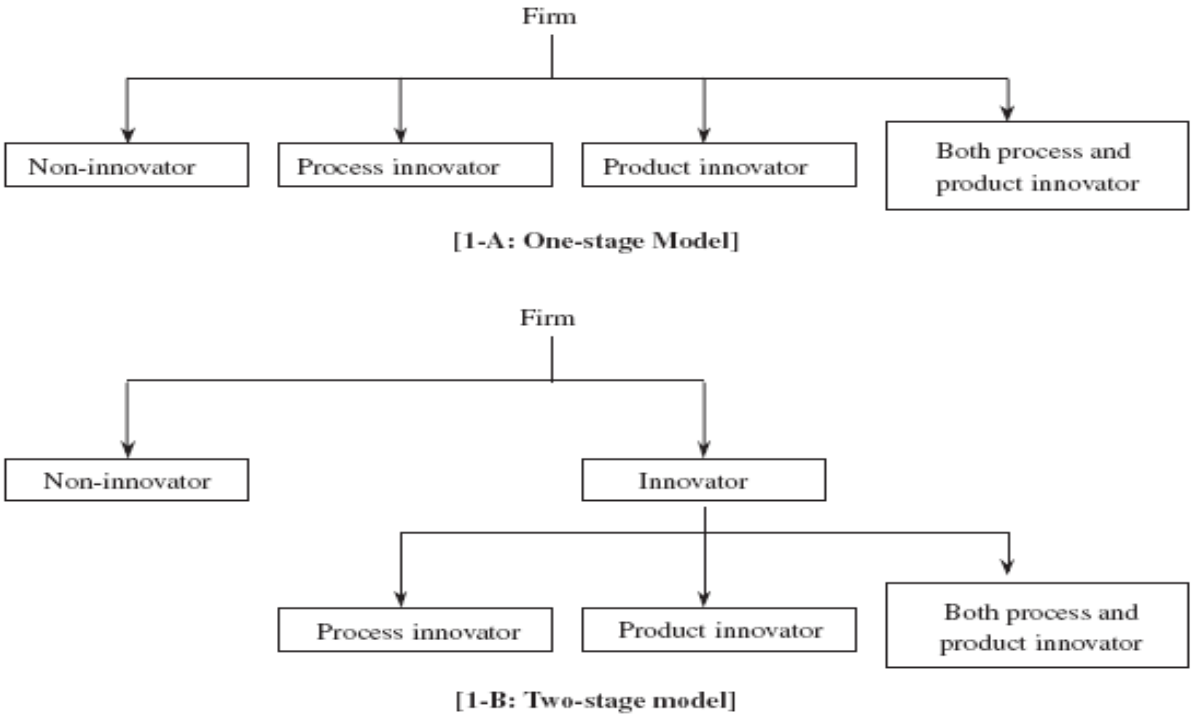
Fig. 1: Firms' decision tree of innovation activity



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