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Authors	Doran, Justin;McCarthy, Nóirín;O'Connor, Marie
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UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

The Importance of Internal Knowledge Generation and External Knowledge Sourcing for SME Innovation and Performance: Evidence from Ireland

Keywords: Innovation Value Chain, External Interaction, R&D, SME Innovation

JEL: O3, L25

Abstract

This paper analyses the knowledge sourcing, transformation and exploitation stages of the innovation value chain for a sample of Irish SMEs using Community Innovation Survey data. It explores the role of internal (R&D) and external knowledge on SMEs' innovation and performance. The open innovation paradigm, which stresses the importance of external linkages, is used to examine the impact of different external knowledge sources on SMEs' innovation. The consideration of external linkages in the innovation performance of SMEs is crucial as these firms may be constrained in their ability to perform R&D due to their size. The analysis expands the traditional CDM methodology beyond the consideration of research and development as the sole source of knowledge for innovation by also considering a range of potential external knowledge sources. The findings indicate that SMEs generate knowledge internally through the performance of R&D while also exploiting linkages to external agents. However, the impact of external sources of knowledge is not uniform. The results suggest that backward linkages have a positive impact on SME product innovation but negatively affect SME process innovation while public knowledge sources are positively related to the probability of product innovation occurring. This may have important policy implications. Finally, process innovation is also found to be a key determinant of SME productivity while product innovation has no impact on SME performance.

1. Introduction

SMEs are a vital driver of national employment and economic growth (Hoffman at al., (1998); Keizer et al., (2002); Hall et al., (2009)) accomplished through their dynamic innovation performance, which allows them to continually improve their enterprise performance (Hall et al., 2009). However, the innovation activities of SMEs can differ substantially from that of larger enterprises (Keizer et al., 2002, Freel, 2003, Raymond and St-Pierre, 2010a). SMEs may be more likely to experience potential internal resource limitations as a result of their size which may constrain certain elements of their knowledge sourcing and exploitation activities namely the performance of in-house research and development (R&D) (Cohen and Klepper, 1996, Hewitt-Dundas, 2006). This is known as the "liability of smallness" which makes innovation more difficult relative to larger firms (Parida et al., 2012). As a result, smaller companies require more external linkages for innovative activities (Tsai, 2009). Consequently, it is important to consider alternative knowledge sources for SME innovation such as linkages with external partners (Freel, 2000b, Lundvall, 1988). These may include linkages to customers, suppliers, competitors, consultants, universities and public research institutes (Freel, 2000b, Roper et al., 2008a). In this paper we specifically analyse the role of external interaction and R&D in determining the likelihood of innovation activity in a sample of Irish firms using data from the Irish Community Innovation Survey 2010-2012.

Given the reliance of SMEs on external knowledge sources the concept of open innovation is extremely relevant to understanding their innovation value chain. "Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas … as they look to advance their technology." (Chesbrough, 2006: 1). In light of the potential barriers faced by SMEs in generating knowledge for innovation purposes, open innovation may be critical to their innovation output and performance. Chesbrough and Crowther (2006)

distinguish two types of open innovation: inbound and outbound. Inbound refers to the use of external knowledge to further the firm's innovation performance. Outbound open innovation occurs where the firm exploits its internally generated knowledge externally through, for example, licensing or the sale of intellectual property. This paper focuses on the former: inbound open innovation. Collaborating with external organisations is viewed as positive for firm innovation because the organisations provide knowledge that the firm lacks (Un et al., 2010). This research examines whether this is indeed the case for SMEs.

The open innovation paradigm is used in conjunction with the innovation value chain. The innovation value chain presents innovation as a three stage process consisting of knowledge sourcing, knowledge transformation and knowledge exploitation (Roper et al., 2008). Knowledge sourcing can incorporate both internal (R&D) and external knowledge sourcing. This paper seeks to establish how SMEs source knowledge for innovation purposes. The second stage, knowledge transformation, analyses how knowledge sourced by the enterprise is translated into innovation outputs (Roper et al., 2008). The final stage, knowledge exploitation, focuses on the subsequent impact of these innovation outputs on firm performance. Open innovation is useful in analysing the first two stages of the innovation value chain: knowledge sourcing and transformation. It can be used to establish to what extent SMEs source knowledge from external agents. Where external sources of knowledge are used, the impact of each can be explored with respect to the SME's innovation output. This approach is adopted here.

This paper analyses the innovation value chain of a sample of approximately 3,000 small to medium sized enterprises (SMEs) using the Irish Community Innovation Survey 2010-12 (hereafter referred to as the CIS). The SMEs included are drawn from the manufacturing and services sectors. In order to account for the unique innovation value chain of SMEs this paper

modifies the traditional CDM model, developed by Crépon et al. (1998), to incorporate these elements of SME innovation activity. In doing so this paper builds on existing studies (Freel, 2000b, 2003; Roper et al., 2008a; Hall et al., 2009) by providing a comprehensive examination of the complete innovation value chain for Irish SMEs.

The majority of existing studies focus on open innovation in large, multinational companies; there are few that explore it in the context of SMEs (Lee et al., 2010, Spithoven et al., 2013, Popa et al., 2017, Van de Vrande et al., 2009). Where such studies exist they tend to neglect SMEs operating outside high-technology industries (Vanhaverbeke et al., 2012) and tend to adopt a qualitative, case-study approach (Wikhamn et al., 2016). This research seeks to address these gaps. The contributions of this paper to the empirical evidence on SME innovation are fourfold: (i) it incorporates a range of potential external linkages into firms' knowledge sourcing activity, (ii) it investigates the importance of these external linkages for innovation output, (iii) it analyses the effects of this innovation output on enterprise performance and (iv) it focuses on a large sample of SMEs in manufacturing and services not just those operating in high-tech industries. By adopting a similar conceptual view to that of Freel (2003) this paper builds on the work of Hall et al. (2009) by considering external linkages in addition to R&D as important knowledge sources for SME innovation.

The rest of the paper is structured as follows. Section 2 provides an overview of the relevant literature on open innovation, the innovation value chain and the important considerations surrounding SME innovation. Testable hypotheses are developed based on existing research. This is followed in Section 3 by a description of the methodology employed. In Section 4 the data used are outlined. Section 5 presents and discusses the empirical results. Finally, Section 6 concludes and presents the limitations of this paper and avenues for future research.

2. Open Innovation and The Innovation Value Chain of SMEs

The open innovation (OI) paradigm represents a significant shift away from the traditional, closed innovation model. The latter emphasises the fact that firms generate their own ideas and undertake all activities related to bringing that idea to market themselves. There is no collaboration; the firm acts in isolation. The open model, however, advocates the use of external (as well as internal) sources of knowledge and paths to markets to discover and exploit innovative opportunities (Chesbrough, 2003). Central to the concept of open innovation is the assumption that firms cannot conduct all R&D activities by themselves (Gassmann, 2006). Open innovation activities comprise both inbound and outbound OI. Inbound OI encompasses the use of external sources of knowledge to build upon the firm's existing knowledge and resource base. Outbound OI is the external exploitation of knowledge generated internally by the firm through licensing or the sale of intellectual property rights (Greco et al., 2015). Laursen and Salter (2006) identify two components of inbound OI: search breadth and search depth. Search breadth is the number of different search channels that a firm draws upon. Search depth is the intensity by which firms draw from different search channels. This paper explores the former.

The innovation value chain itself is concerned with the process whereby firms source knowledge, transform this knowledge into innovation output and finally exploit innovation output for performance gains (Hansen and Birkinshaw, 2007). Its chief advantage is to highlight the structure and complexity of the innovation process. This increasingly popular perspective has echoes in the work of Kline and Rosenberg (1986) who argue that:

> "*Innovation is complex, uncertain, somewhat disorderly and subject to changes of many sorts. Innovation is also difficult to measure and demands close coordination of adequate technical knowledge and excellent market judgement in order to satisfy economic, technological and other types of constraints – all simultaneously. The process of innovation must be viewed as a series of changes in a complete system"* (1986: 275).

Studies such as Klomp and Van Leeuwen (2001: 2006), Janz, Lööf and Peters (2003), and Lööf and Heshmati (2006) develop models and theoretical frameworks to capture the innovation process of firms. However, as noted by Hall et al (2009), SMEs exhibit different features that may necessitate the development and use of specific conceptual frameworks which take into account the unique features of SME innovation behaviour. For example, Freel (2000b) highlights the increased importance of external linkages for SMEs as a means of supplementing and complementing their limited internal resources. These distinguishing features of SMEs innovation requirements demands a re-visitation to the conceptual developments surrounding firms' knowledge sourcing, transformation and exploitation in their innovation value chain. The open innovation paradigm facilitates this.

The first stage in this process concerns firms' sourcing of knowledge for innovation. It is well known that knowledge sourcing can be both internal and external to the firm (Cohen and Klepper, 1996, Lundvall, 1995). External knowledge sourcing may be especially important for SMEs (Hall et al., 2009, Freel, 2000c) due in part to the resource limitations experienced by these enterprises owing to their small size (Cohen and Klepper, 1996). The sourcing of external knowledge for innovation is a critical process of a firm's inbound open innovation activities (Chesbrough et al., 2006, Dahlander and Gann, 2010). Inbound open innovation is a firm's

search strategy exploring external sources of knowledge that can be used to complement, strengthen or accelerate a firm's in-house R&D activities (Spithoven et al., 2013). This echoes the views put forward by Keizer et al (2002) and Raymond and St-Pierre (2010b) who note that internal R&D performance by SMEs can facilitate the accumulation of knowledge within the enterprise, thereby improving its innovation potential. Existing research on inbound open innovation define openness as the number of external sources of knowledge that each firm draws upon in its innovation activities (Laursen and Salter, 2006). External knowledge sourcing may span a number of external innovation partners (Brunswicker and Vanhaverbeke, 2015) including enterprises within the firm's group, competitors and consultants (collectively known as horizontal linkages) suppliers (backwards linkages), customers (forward linkages), and public sources such as universities and research institutes.

Firms may collaborate with firms within the same enterprise group. According to Mention (2011), firms can enlarge their knowledge base and access additional resources in this way. Furthermore, this may prove to be an easier means of accessing knowledge as firms within the same group may be cognitively proximate (Nooteboom et al., 2007). Horizontal linkages with competitors may also be a source of external knowledge. The concept of coopetition, introduced by Brandenburger and Nalebuff (1996), encompasses firms that are simultaneously engaged in cooperation and competition. Competitors may be an important source of external information because they may share the same knowledge base thus making it easier to collaborate with them (Wikhamn et al., 2016). However, according to Lee et al. (2010), SMEs may be reluctant to disclose detailed information to potential competitors. As a result, SMEs may be less likely to seek information from competitors if they believe they will have to reciprocate and share what they perceive to be valuable or sensitive information. Consultants may also be a source of external knowledge for SMEs. According to Love and Mansury (2007),

consultants can positively impact a firm's ability to innovate especially with respect to radical innovation. They say that consultants are more likely to have a major input and be highly relevant when the firm is contemplating a radical innovation.

SMEs may also establish backwards linkages with suppliers who can act as a potential source of external knowledge. Suppliers may have greater expertise and more knowledge regarding parts and components which could be critical to a firm's new product development (Tsai, 2009). The use of external knowledge generated by suppliers may benefit the firm's innovation activity because their approach to innovation is likely to be more practical and efficient than forward linkages with customers (Greco et al., 2015). They argue that customers may be driven by their own desires without sufficient thought about whether they will contribute to the organisation's growth and sustainability. However, Van de Vrande et al. (2009) believe that firms may benefit from their customers' ideas and knowledge through proactive market research, developing similar products to the firm's current offering, or by producing new products based on customer designs. Furthermore, sourcing knowledge from customers may reduce the likelihood of poor design in the early stages of development (Tsai, 2009). Von Hippel (1986) identifies a particular subset of customers known as lead users who, he believes, can be used to drive a firm's innovation activities. These users are regarded not just as passive adopters of innovations but rather as developers of these innovations (Von Hippel, 2005). Their current needs will become commonplace in the market in the future (Von Hippel, 1986).

Finally, public knowledge sources such as universities and research institutes may be a source of external knowledge for SMEs seeking to innovate. According to Tsai (2009) government encouragement (and arguably direct policy interventions) has resulted in an increased level of

firm collaboration with universities and research institutions for innovation purposes. Specifically, Greco et al. (2015) say that firms interact with these external sources for the explicit purpose of improving their products or processes. However, collaboration between universities and enterprises faces significant challenges primarily due to differences in culture and incentive systems (Wynarczyk et al., 2013). Furthermore, Roper and Hewitt-Dundas (2013) say that the focus of research centres is not adequate for the needs of SMEs. As a result, there may be a tendency towards creating linkages with larger firms (Roper and Hewitt-Dundas, 2013) which may lead to a lower incidence of collaboration between SMEs and these public knowledge sources.

While the above highlights the potential external innovation partners available, SMEs do not have the capacity to search extensively among them (Hossain and Kauranen, 2016). Larger firms have fewer resources constraints than SMEs which facilitates a wider search for potential external partners (Spithoven et al., 2013, Van de Vrande et al., 2009). As a result, the number of external innovation partners used by SMEs to source knowledge for innovation purposes may be small. Indeed, Ebersberger et al. (2012) show that SMEs exhibit a lower propensity to engage with any type of collaborative partner compared to large enterprises. Of the potential external collaborators available to SMEs, existing empirical research is inconsistent with respect to the most widely used source(s) of external knowledge.

Existing studies find that SMEs rate internal sources of knowledge as the most widely used for innovation purposes (Lee et al., 2010, Mention, 2011). However, where SMEs engage with external knowledge sources, they tend to collaborate with customers more frequently than other external sources of knowledge (Love and Mansury, 2007, Van de Vrande et al., 2009, Theyel, 2013). This is supported by Brunswicker and Vanhaverbeke (2015) who find that direct

customers are the most widely used external knowledge source reported by SMEs followed by network partners and suppliers. Lee et al. (2010) find that SMEs utilise customers (including users) and competitors most frequently. However, Laursen and Salter (2006) report that suppliers are the most frequently used source of external knowledge though followed closely by customers and users. Universities, and research centres in particular, tend to be less frequently used (Brunswicker and Vanhaverbeke, 2015, Ebersberger et al., 2012, Laursen and Salter, 2006). However, van Hemert et al. (2013) find that contact with a university and competitors are the most frequently used source of knowledge by SMEs in their Italian study. Micro, small and medium size enterprises are less likely to be involved in collaborative R&D with research centres; there is a bias towards larger firms (Roper and Hewitt-Dundas, 2013).

The final issue to consider with respect to knowledge sourcing is the question of whether internal R&D and external knowledge sources are complements or substitutes. It may be expected that they are complements; external knowledge sources should be used to strengthen a firm's internal R&D capabilities. It does not have to be an 'either or' scenario but rather they can be used as complementary aspects of a firm's innovation strategy. However, existing research indicates that this is not always the case. Laursen and Salter (2006) find evidence of a substitution effect between internal R&D and external knowledge search activities. This is contrary to Cassiman and Veugelers (2006) who find that the two are complementary activities. Wikhamn et al. (2016) find that SMEs that collaborate with external stakeholders also maintain a high level of innovation capabilities in-house suggesting a complementary relationship exists. However, Vega-Jurado et al. (2009) fail to find support for the complementary hypothesis between internal knowledge transformation and external knowledge sourcing.

Following on from the discussion above, the following hypotheses are proposed:

H_1: A complementary relationship exists between SMEs internal and external knowledge sourcing activities.

H_2: Smaller businesses are more likely to utilise backward linkages.

The next stage in the innovation value chain involves transforming knowledge into innovation output. At this stage, knowledge sourced by the enterprise is translated into innovation outputs (Roper et al., 2008). Innovation output can take the form of either product, process, marketing or organizational innovation (OECD, 2005). This paper considers only the first two types of innovation.[1] Product innovation involves the introduction of new or improved goods/services, which may be either new to the market or new to the business while process innovation is the introduction of a new or significantly improved method of production or supply. While some papers use R&D as a proxy for firms' innovation decision (Griffith et al., 2006) this paper considers R&D as an input in the innovation process as well as external knowledge sources. Thus, the impact of both R&D as well as external knowledge sources on a firm's innovation performance, specifically the introduction of a product or process innovation, is explored.

Existing studies analyse how firms generate innovative output (Love and Roper, 2001, Love and Mansury, 2007, Roper et al., 2008b). The general consensus is that both R&D and external interaction have a positive effect on the likelihood of innovation. Existing studies highlight the positive relationship that exists between R&D and innovation output (Freel, 2000c, Freel, 2003, Hall et al., 2009, Keizer et al., 2002, Love and Mansury, 2007, Raymond and St-Pierre, 2010a, Romijn and Albaladejo, 2002). Ebersberger et al. (2012) state that investments in R&D are still important for innovative performance; they stress the fact that open innovation is not a

[1] In the CIS questionnaire only product and process innovation are linked to R&D activity and external linkages. Therefore, only these two types of innovation can be studied in this paper.

substitute for internal knowledge building and capabilities. Studies have shown that the firm's internal resources, including R&D, are the main determinants of their innovation performance while the creation of external networks only has a limited impact (Freel, 2003). However, several studies question the positive relationship between internal knowledge generation (R&D) and innovation output. Leiponen (2005) reports that R&D intensity is not significantly related to the probability of introducing service innovations while Elche-Hotelano (2011) find that internal R&D is negatively related to above average innovative activity.

Engaging in external knowledge sourcing is a positive move for SMEs as it improves the success of launching an innovation (Brunswicker and Vanhaverbeke, 2015). Indeed, it appears that firms that engage in open innovation tend to be more innovative (Laursen and Salter, 2006, Parida et al., 2012, Wikhamn et al., 2016). The decision to introduce new products is positively related to the presence of horizontal, backward and forward linkages, to varying degrees (Love and Mansury, 2007, Roper et al., 2008b). However, the empirical evidence highlights the inconsistent findings with respect to the type of external partner used and the impact on innovation performance. Given the limited body of existing research on SMEs, empirical evidence related to all firm types is presented here.

The primary focus with respect to the impact of horizontal linkages tends to be on competitors with little attention paid to the role of consultants and within-group collaboration. There are mixed findings with respect to the impact of competitors on firms' innovation performance among existing studies. While some studies highlight a positive relationship between collaboration with competitors and innovation (Bigliardi and Dormio, 2009; Leiponen, 2005; Parida et al., 2012; Un et al., 2010; Vega-Jurado et al., 2009) others report a negative relationship in general (Inauen and Schenker-Wicki (2011) or in relation to the degree of

innovation novelty (Mention, 2011). Further studies fail to find any significant relationship between horizontal linkages with competitors and innovation performance (Ebersberger et al., 2012).

The empirical evidence with respect to forward linkages with customers tend to present a more conclusive result. The vast majority of existing research finds that collaboration with customers positively effects firms' innovation performance (Ebersberger et al., 2012; Inauen and Schenker-Wicki, 2011; Leiponen, 2005; Mention, 2011; Parida et al., 2012; Vega-Jurado et al., 2009; Wikhamn et al., 2016). However, there are a number of studies that fail to support this positive relationship with some reporting that customer collaborations are insignificant when explaining firm innovation performance (Bigliardi and Dormio, 2009; Un et al., 2010) with others reporting a negative relationship exists (Elche-Hotelano, 2011).

The importance of backwards linkages for innovation purposes is evident in existing empirical work. Collaborations with suppliers positively impacts firms' innovation performance (Ebersberger et al., 2012, Freel, 2003; Inauen and Schenker-Wicki, 2011; Mazzola et al., 2012; Mention, 2011; Parida et al., 2012; Reichstein and Salter, 2006; Un et al., 2010). Elche-Hotelano (2011) are one of the few studies that report a negative relationship between supplier collaborations and both product and process innovations.

Finally, the results related to the importance of public knowledge sources for firm innovation performance is mixed. Un et al. (2010) find that R&D collaborations with universities positively impacts firms' product innovation. This is supported by several studies (Inauen and Schenker-Wicki, 2011; Mention , 2011; van Hemert et al., 2013; Vega-Jurado et al., 2009) who find that cooperation with universities and research institutes positively affects innovation.

However, several studies report a negative relationship between public knowledge sources and firm innovation performance (Jordan and O'Leary, 2008) or an insignificant relationship (Ebersberger et al., 2012; Zeng et al., 2010) between them.

Thus, it appears that the impact of external partners on knowledge transformation is not equal. However, much of the literature points to a positive relationship between a firm's innovation output and collaboration with suppliers and customers. The evidence on engagement with horizontal linkages and public knowledge sources is not as clear cut though the latter tends to be mostly positive.

Following this, the following hypotheses are proposed:

H_3: There is a positive relationship between R&D and innovation activity.

H_4: Horizontal linkages negatively affect SME innovation performance.

H_5: Backward linkages positively affect SME innovation performance.

H_6: Forward linkages positively affect SME innovation performance.

H_7: Collaboration with public knowledge sources positively affects SME innovation performance.

The final stage in the innovation value chain is knowledge exploitation. Of interest here is the impact of innovation output on the business in terms of, for example, improved business productivity or profitability. According to Artz et al. (2010), when innovative new products are introduced to the market they will face little competition and thus generate high profits resulting in increased firm performance. This implies a positive relationship between innovation output and firm performance. Indeed, the majority of the empirical evidence supports this assertion (Artz et al., 2010; Cho and Pucik, 2005; Hall et al., 2009; Klomp and

Van Leeuwen 2001: 2006; Janz, Lööf and Peters, 2003; Love and Mansury, 2007; Roper et al., (2008a)). Their results, with a few minor exceptions[2], have shown the importance of innovation for productivity. For example, Klomp and Van Leeuwen (2006) find that innovation success has a positive effect on productivity and Roper et al. (2008a) find that innovation output positively affects firms' sales and employment growth. Hall et al. (2009) find that both product and process innovation have a positive effect on firm productivity. Based on this, the following hypotheses are proposed:

H_8: There is a positive relationship between product innovation and firm performance.

H_9: There is a positive relationship between process innovation and firm performance.

In addition to internal and external sources of knowledge, other factors may influence a firm's ability to source, transform and exploit knowledge. These include the absorptive capacity of the workforce (Cohen and Levinthal, 1990) as well as the size and sector of the business (Pavitt, 1984, Cohen and Klepper, 1996, Jordan and O'Leary, 2008, Weterings and Boschma, 2009). Absorptive capacity refers to a firm's ability to use its own prior related knowledge to recognise, assimilate, and use external knowledge for its own commercial ends (Cohen and Levinthal, 1990). Firms with high levels of absorptive capacity are better able to create and exploit linkages with other firms (Caloghirou et al., 2004).[3]

[2] For example Roper, Du and Love (2008) find that product innovation success has a negative effect on productivity which the authors ascribe to a disruption effect.

[3] While these are all potential determinants of firm level innovation we are restricted when analysing innovation in the Irish context as the Irish CIS has limited or no information on many of these factors. For example, no indicator of third level education is present. Also age is not present. We note this as a limitation of our data in the conclusion section.

3. Methodology

This paper expands the methodology utilised by Hall et al (2009) by adopting a modified version of the CDM model (Crépon et al., 1998). This is a four equation system which incorporates equations for the knowledge sourcing, transformation and exploitation stages of the innovation value chain (Lööf and Heshmati, 2006). The main contribution of this paper is to expand the knowledge sourcing stage of the innovation value chain to consider external interaction as well as R&D performance. The expansion of the knowledge sourcing section for innovation is crucial when considering SMEs as these firms may not have the necessary capabilities to conduct R&D and, therefore, may be more likely to engage with external agents to acquire knowledge (Cohen and Klepper, 1996, Freel, 2003).

The first equation is the innovation decision. In analysing the innovation value chain it is necessary at times to concentrate on the behaviour of innovating firms only (Crépon et al., 1998). Since these are not randomly drawn from the population, selection bias may arise. The CDM-model corrects for this by including a selection equation, the innovation decision, and estimating an inverse Mill's ratio for inclusion in all subsequent regressions which focus on innovators only (Heckman, 1979, Janz et al., 2003, Lööf and Heshmati, 2006).

Equation (1) therefore analyses the firm's decision to engage in innovative activity. The inclusion of the decision equation also allows for an analysis of factors which may impact on a firm's decision to engage in innovation. Equation (1) is estimated using a probit model.

$$y_{0i} = \begin{cases} 1 \text{ if } y_{0i}^{*} = x_{0i}\alpha_0 + \varepsilon_{0i} > 0 \\ 0 \text{ if } y_{0i}^{*} = x_{0i}\alpha_0 + \varepsilon_{0i} \leq 0 \end{cases} \qquad (1)$$

Where y_{0i}^{*} is a latent innovation decision variable measuring the decision of a firm to innovate and y_{0i} is the corresponding observed binary variable being 1 for innovating firms and 0 for non-innovating firms. Innovating firms are defined as those which have introduced new products or processes during the reference period, 2010-2012. The rationale for using a binary innovation indicator for the innovation decision as oppose to an indicator of R&D performance arises as SMEs may be constrained in terms of their performance of R&D activity due to cost and size (Cohen and Klepper, 1996). Therefore, the use of R&D as an indicator of SME innovation may understate the extent to which firms innovate. Also x_{0i} is a vector of explanatory variables, α_0 is the associated coefficient vector and ε_{0i} is the error term.

The explanatory variables used to explain a firm's decision to engage in product innovation are:

$$x_{oi} = (F_i, Z_i)$$

Where F_i is a vector of factors which may affect a firm's probability of innovating. The Irish CIS contains data on a range of factors which firms can report as having no impact or a low, medium or high impact on their decision to innovate. These factors are categorised into four categories for the purposes of this paper; cost, knowledge, market and other factors. Z_i is a vector of control variables representing firm size and the sector in which the firm operates. Previous research suggests that larger firms are more likely to innovate and that there is considerable heterogeneity amongst innovation levels in different sectors (Love and Mansury, (2007); Oerlemans, Marius and Boekema, (1998) and Roper et al., (2008a). This is required as a first step prior to estimating equation (2), and (3) which focus only on innovative firms.

As noted previously SMEs, unlike larger firms, have limited resources with which to devote to innovation activities (Freel, 2000b, 2003; Hall et al., 2009). This suggests that external linkages may be especially important for the innovation performance of these firms. Therefore, this paper considers not just R&D, but also a range of external agents as potential sources of knowledge for innovation. These external sources of knowledge are classified as backwards linkages to suppliers, forward linkages to customers, horizontal linkages to competitors and consultants and public linkages to university and public and private research institutions. It builds on the analysis in Crépon, Duguest and Mairesse (1998), Janz, Lööf and Peters (2003) and Hall et al (2009) who solely analyse the determinants of R&D. It follows the approach of Roper, Du and Love (2008a) and allows for a detailed analysis of the interdependence of various knowledge sources. Equation (2) is estimated using a series of probit models.

$$KS_{ji} = KS_{ki}\beta_0 + x_{1i}\beta_1 + \varepsilon_{1i} \quad \text{if } y_{0i} = 1 \qquad (2)$$

Where KS_{ji} represents firm i's knowledge sourcing activity *j* during the reference period. KS_{ki} represents firm i's knowledge sourcing activity *k* where $j \neq k$, x_{1i} is a vector of explanatory variables, β_{1i} is the associated coefficient vector and ε_{1i} is the error term. When sourcing knowledge H_1 suggests that a complementary relationship exists between SME's internal and external knowledge sourcing activities. Therefore, if $\beta_0 > 0$ this implies that firms which engage in one type of knowledge sourcing (e.g. R&D) are more likely to engage in other types of knowledge sourcing (e.g. backwards linkages). This provides a direct test of H_1.

The explanatory variables used to explain a firm's knowledge sourcing are:

$$x_{1i} = (M_i, Z_i)$$

Where M_i is the inverse Mills' ratio derived from equation (1) and Z_i is as before. Included in the matrix of explanatory variables is a continuous indicator of firm size. This variable allows us to test H_2, which is that smaller businesses are more likely to utilise backwards linkages. If this coefficient is negative in the backwards linkages estimations this suggests that smaller businesses are more likely to use backward linkages relative to larger businesses.

Equation (3) presents the transformation stage of the innovation value chain, where sourced knowledge is transformed into innovation output:

$$IO_i = KS^*_{ki}\lambda_0 + x_{1i}\lambda_1 + \varepsilon_{2i} \qquad (3)$$

where IO_i is innovation output, KS^*_{ki} is the predicted value of firms' knowledge sourcing activity *k* derived from equation (2) and all other variables are defined as above. Binary indicators of product and process innovation are utilised. This is consistent with the approach adopted by Hall et al. (2009) Roper et al. (2008a) and Freel (2003). It is expected that knowledge sourcing should influence innovation output. Should $\lambda_0 > 0$ then this implies a positive relationship while should $\lambda_0 < 0$ this implies a negative relationship. This allows for a test of our hypotheses 3 through 7 (Lundvall, 1988, Oerlemans et al., 1998, Gertler, 2003, Roper et al., 2008a). We summarize these hypotheses and the expected coefficient sign below:

H_3: R&D and innovation performance. $\lambda_0 > 0$

H_4: Horizontal linkages innovation performance. $\lambda_0 < 0$

H_5: Backward linkages innovation performance. $\lambda_0 > 0$

H_6: Forward linkages innovation performance. $\lambda_0 > 0$

H_7: Public linkages innovation performance. $\lambda_0 > 0$

The use of the predicted values, KS_{ki}^{*}, of knowledge sourcing derived from equation (2) is consistent with Griffith et al (2006). The rationale for the utilization of predicted values is to correct for the issue of the endogeneity of knowledge sourcing in equation (3). Papers by Klomp and Van Leeuwen (2001, 2006) have shown that the failure to control for endogeneity in the estimation of the CDM model can result in biased estimates of the coefficients.

Equation (4) then investigates the effect of innovation output on productivity.

$$P_i = IO_i^{*}\chi_0 + x_{1i}\chi_{1i} + \varepsilon_{3i} \qquad (4)$$

Where P_i is a measure of productivity, IO_i^{*} is the predicted value of innovation output derived from the corresponding estimation of equation (3) and all variables are defined as before. Also included under x_{1i} in equation (4) is a proxy for capital per worker. Productivity is measured as the natural log of turnover per worker in 2012. The use of turnover per worker is consistent with Griffith et al (2006), Hall et al (2009) and Johensson and Lööf (2009). The level of turnover per worker in 2012 measures productivity and reflects the firm's current and past learning and experience (Freel, 2000a). To test whether our hypotheses H8 and H9 hold we analyse the coefficient χ_0. Should $\chi_0>0$ then these hypotheses hold as a positive relationship is observed between innovation activity and performance. Hansen and Birkinshaw (2007) suggest that firms which can exploit and develop new products and services or new processes should experience increased productivity performance. This is similar to Kline and

Rosenberg's (1986) assertion that successful innovations are ones which satisfy a market need, thus benefiting the business.

Appendix 1 presents an illustration of the CDM methodology. To summarize the method it begins by firms deciding to engage in innovation activity (innovation decision). Once a firm decides to engage in innovation activity the firm progresses to sourcing knowledge either internally, externally, or through some combination of the two (knowledge sourcing). This knowledge is then utilised to generate innovation output which in the case of our framework is either product or process innovation (innovation output). Finally the firm exploits this innovation output for productive gains (innovation exploitation).

4. Data

The data utilised by this paper is the Irish CIS 2010-12 which contains detailed information relating to the knowledge sourcing and transformation stages of the innovation value chain of Irish firms. In total, for the purposes of our analysis, there are 3,245 valid responses. Table 1 displays the breakdown of this response by firm size.

It can be observed that 69.29% of firms have between 10 and 49 workers, 24.71% of firms have between 50 and 249 workers and 7% of firms have over 250 workers. As this paper is only concerned with SMEs this final category is omitted, resulting in a total sample size of 3,018.

[insert Table 1 around here]

Table 1 also displays the descriptive statistics of the most important variables used from the CIS. The CIS distinguishes between product and process innovation. Product innovation is defined as the introduction of a new or significantly improved good or service to the market. The innovation may be either new to the enterprise or new to the market. Process innovation is defined as the use of new or significantly improved methods for the production or supply of goods or services. Again, the innovation is new to the firms' enterprise but not necessarily new to the market. This is consistent with the OECD's (2005) and Schumpeter's (1934) definitions of product and process innovation. A total of 29% of SMEs introduced new product innovation during the reference period, while 33% process innovated. Overall, 43% of the firms are defined as innovators having introduced at least one new product or process innovation.

The CIS also captures a wide range of knowledge sourcing activity for innovation. Interaction with external knowledge sources is defined as active co-operation with other enterprises or non-commercial institutes on innovation activities. Specifically respondents are asked "During the three years 2010 to 2012, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions? Please indicate the type of co-operation partner". A total of seven external partners are listed by the survey and these are condensed into four categories used by Roper et al (2008): backwards (suppliers), forwards (customers), horizontal (competitors and consultants) and public (universities and government and private research institutes). This yields a series of binary variables indicating whether a firm cooperates with any of these knowledge sources for the purposes of innovation.

Internal knowledge generation through the performance of intramural R&D is also considered. This is defined in the Irish CIS as creative work undertaken within the enterprise on an

occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes.

The average firm size is 41 employees, with a standard deviation of 44. This variable is included in all regression estimations as, even within the definition of an SME, there may be a scale effect for innovation. Finally, to proxy for the capital flow of a firm, the expenditure per employee on the acquisition of advanced machinery, equipment and computer hardware or software to produce significantly new or improved goods or processes is used. The mean expenditure on capital is €68,030 per employee with a standard deviation of €630,340. The Irish CIS is targeted at the full range of manufacturing and services sectors. While not discussed in Table 1 (or subsequent tables), it is standard practice to control for the sector in which the firm operates in all the regressions. We control for whether the firm is in the manufacturing or services sector.

Productivity is measured as turnover per worker. The average turnover per worker is €22,822 with a standard deviation of €109,939. The use of this measure of productivity is consistent with previous studies (Griffith et al., (2006); Hall et al., (2009) Johensson and Lööf, (2009).

The initial focus is on the source of knowledge used. The descriptive statistics show that internal knowledge generation, specifically R&D, is the most frequently used source of knowledge. 26% of SMEs use this source of knowledge.[4] This finding supports existing

[4] It is worth noting that while only 23% of firms report that they perform R&D, 43% are classified as innovators. This suggests that firms which innovate do not necessarily perform R&D and may obtain their knowledge for innovation from other sources, for example, from external knowledge sources. It further suggests that the use of investment in R&D as a proxy for an enterprises' innovation decision would result in an underestimation of SME innovation performance.

empirical evidence which show that SMEs rate internal sources of knowledge as the most widely used for innovation purposes (Lee et al., 2010, Mention, 2011). Backward linkages with suppliers are the most widely used source of external knowledge with 8% of innovators reporting that they collaborate with them. This is followed by forward linkages (7%), horizontal linkages (7%) and public knowledge sourcing (6%). Thus, market based interaction appears to be favoured by firms over interaction with non-market agents which supports existing studies (Lee et al., 2010, Love and Mansury, 2007, Van de Vrande et al., 2009, Theyel, 2013).

5. Empirical Results

Table 2 presents the empirical estimations of equation (1): the innovation decision. The first column displays the results for innovators (those firms which introduced at least one new product or process innovation), the second column presents the results of the estimation for product innovators and the final column presents the results for enterprises which introduced process innovations. It can be observed that there is a strong degree of consistency in the determinants of enterprises' innovation decision. A fuller discussion of the results of this table are presented in Appendix 2 as this table is generated in order to allow for the creation of the inverse Mill's ratio in Table 3 and 4 and it does not specifically relate to our hypotheses.

[insert Table 2 around here]

Table 3 presents the estimation of equation (2): an enterprise's knowledge sourcing decision. This provides our tests for H_1 and H_2. As noted earlier, both internal knowledge generation and external knowledge sourcing are considered. It can be observed that there is evidence to suggest that firms' internal and external knowledge generation activities are interconnected. There is strong, but not complete, evidence to support H_1. SMEs that establish linkages with

their customers (forwards) and public knowledge sources are more likely to engage in R&D activity. It appears that there is a complementary relationship between R&D and knowledge sourced from collaborations with customers and public knowledge sources. This suggests that enterprises do utilise internal and external knowledge to complement or substitute one another. The sole exception to this is that firms which interact with their suppliers (backward linkages) are less likely to engage in R&D activity. Thus, H_1 is mainly supported: there is a complementary relationship between R&D and some, but not all, external knowledge sources.

[insert Table 3 around here]

Among the different forms of external knowledge sources for innovation, a strong complementary relationship is observed. For example, enterprises with forwards, backwards and horizontal linkages are more likely to interact with suppliers via backward linkages. This is consistent with other studies of the knowledge sourcing activities of firms, which generally indicate a complementary relationship between knowledge sources (Roper et al., 2008a). The strong complementarity among external knowledge sources suggests that this form of interaction is undertaken extensively by SMEs. The high degree of interconnectivity also extends to public knowledge sources.

Regarding H_2 which, notes that smaller businesses are more likely to engage with backwards linkages, we find no evidence to support this hypotheses. As the size coefficient is insignificant this implies that firms of all sizes are equally likely to engage in backward linkages. Indeed size appears to have no effect on the likelihood of firms engaging with any external agents. We do however find that larger firms are more likely to engage in R&D. Therefore, we find no support for H_2.

Table 4 presents the estimation of equation (3); the knowledge transformation stage of the innovation value chain. In the estimation of this equation the predicted values of the internal and external knowledge sources are derived and included in order to correct for the potential endogeneity of these variables in the estimation.

[insert Table 4 around here]

We begin by considering H_3 which states that there is a positive relationship between R&D and innovation activity. It can be seen that internal knowledge generation (R&D) positively affects the probability of product innovation occurring but negatively affects the likelihood of process innovation. This suggests that knowledge generated within the firm plays an important role in the generation of new product innovation. This finding supports previous research that highlights a positive relationship between R&D and innovation output (Raymond and St-Pierre, (2010b) Hall et al., (2009); Keizer, (2002). However, it raises questions in the Irish context as to the use of R&D as a stimulant for process innovation. Therefore, we conclude that H_3 holds for product innovation only.

Next we turn to considering H_4 though H_7 which postulate that horizontal linkages have a negative effect on firms' innovation performance, while backwards, forwards, and public linkages have a positive effect on firms' innovation performance. Regarding horizontal linkages we find no evidence that these reduce the likelihood of innovation. Therefore, we reject H_4. SMEs with linkages to suppliers (backwards) are less likely to introduce new product innovations but more likely to introduce process innovations. This provides only partial support for H_5. There is no significant effect of forward linkages on innovation which leads us

to reject H_6. SMEs that interact with public knowledge sources are more likely to introduce new product innovations thus supporting H_7. Collaborations with forward and horizontal linkages does not impact either product or process innovation. Thus, H_4 and H_6 are not supported and H_5 and H_7 are partially supported. This finding of an unequal importance of external linkages for innovation is not unique (Mention, 2011, Un et al., 2010, Vega-Jurado et al., 2009).

Turning to the final stage of the innovation value chain, Table 5 presents the estimations of equation (4). This describes the effects of innovation on enterprise productivity. Again, in order to correct for potential endogeneity within this model, the predicted values for innovation are derived from equation (3) and included.

It can be observed that product innovation has no impact on firm productivity. Thus, H_8 is not supported. However, there is a positive relationship between process innovation and firm performance which supports H_9. Thus, innovation does not have an unequivocal impact on SME performance. This finding of a positive effect of process innovation on productivity is consistent with the international literature on SME performance (Hall et al., (2009); Parisi, (2006). The finding that product innovation does not positively impact firm performance is consistent with some of the evidence presented in Roper et al (2008) who suggest that the benefits accruing for product innovation may take time to be fully realised in productivity figures.

[insert Table 5 around here]

Turning to the control variables, it can be noted that innovation capital per employee does not affect the level of turnover per employee. Similarly, firm size does not impact productivity. Finally, Irish owned firms are more productive relative to foreign owned firms.

6. Conclusions

This paper combines the open innovation paradigm and the innovation value chain to explore the impact of internal and external knowledge on SMEs innovation activities and their subsequent performance. It provides a comprehensive analysis of the innovation activity of a sample of Irish SMEs using the Irish CIS 2010-12. Using a modified version of the CDM model it incorporates internal knowledge generation and external knowledge sources into the knowledge sourcing and transformation stages of the innovation value chain. The expansion of the model to include external linkages is vital when considering SMEs which may be limited in their ability to perform R&D within their own enterprise (Cohen and Klepper, 1996, Freel, 2003, Hewitt-Dundas, 2006).

The results indicate that SMEs' decision to engage in internal knowledge generation and external linkages appear to be related. A complementary relationship exists between R&D and linkages with customers and public knowledge sources. This suggests that SMEs, rather than engaging exclusively in either R&D or external linkages, may adopt a hybrid strategy of leveraging knowledge from both sources for innovation (Veugelers and Cassiman, 1999). This result emphasises the importance of considering both internal and external knowledge sources when modelling the innovation activity of SMEs or when formulating policy discussions.

Furthermore, the results show that the impact of external knowledge sources is not uniform on SMEs' innovation activities. Forward and horizontal linkages have no impact on innovation

while collaboration with suppliers and public sources does affect innovation activity albeit not uniformly. The results show that the open innovation paradigm is a useful framework for analysing innovation activities in SMEs. It also implies a need to build on the limited body of empirical evidence focusing on open innovation in SMEs.

The results also have several practical implications for SME owners and management who may be considering engaging in open innovation. Both internal and external knowledge sources are important in explaining the probability of innovation occurring. External sources of knowledge should not be seen as a replacement for internal R&D but rather as an additional resource for the firm. Where external knowledge sources are used, they do not uniformly affect the probability of product and process innovation occurring. If the aim is to engage in product innovation, collaboration with public knowledge sources should be explored. Backward linkages with suppliers should be explored with respect to process innovation only.

While it would be expected that interaction with agents outside the enterprise should provide an SME with the opportunity to acquire tacit knowledge through interactive learning (Nonaka et al., 2001, Lundvall, 1988, Kline and Rosenberg, 1986), other factors may outweigh this positive effect. This may arise from external linkages introducing increased risk of opportunistic behaviour (Zeng et al., 2010) or because of a lack of cognitive or social proximity between the actors (Boschma, 2005). This warrants further investigation as significant attention is invested in fostering collaboration between firms, including SMEs, and external knowledge sources. Overall, the lack of uniform positive linkages effect suggests the need for more nuanced policy formation as opposed to the broad approach of encouraging all forms of networking (Freel, 2003). It also means that SME owners and managers should be cognisant of the fact that not all external knowledge sources are created equal.

The final element of this paper is an analysis of how innovation output, generated through the sourcing of internal and external knowledge, is exploited for productivity gains. The results indicate that SMEs that engage in process innovation have higher levels of turnover per worker. However, product innovation has no impact on firm performance. The significant effect of process innovation has important policy implication as SMEs are a key provider of regional employment and play an important role in the generation of economic and employment growth (Hoffman et al., 1998). The results presented here provide support for arguments to encourage and nurture the innovation activities of these SMEs so as to promote their development.

This research encountered several limitations. First, the data is cross-sectional in nature which limits the ability to draw causal arguments from the results. Second, it was not possible to include micro-enterprises in this analysis. This is a feature of the Community Innovation Survey (CIS) and thus arises as a result of the data used. Third, the focus on SMEs in Ireland may limit applicability to other countries. However, given the lack of empirical evidence focusing specifically on SMEs, we do not see this as a significant limitation. The results, and limitations, present opportunities for future research. Future research could explore the negative effect of forward and horizontal linkages in more detail to ascertain why SMEs do not benefit from engaging with them for the purpose of innovation. Finally, while not possible here, the exploitation of panel data sets would facilitate the analyses of whether the above findings are consistent across longer time periods.

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Table 1: Descriptive Statistics

	Mean	Standard Deviation
Employment Category		
10-49 (%)	68.29	n.a.
50-249 (%)	24.71	n.a.
250+ (%)	7	n.a.
Innovation		
Product	0.29	n.a.
Process	0.33	n.a.
Innovator	0.43	n.a.
Knowledge Sourcing		
R&D (%)	0.26	n.a.
Backwards	0.08	n.a.
Forwards	0.07	n.a.
Horizontal	0.07	n.a.
Public	0.06	n.a.
Controls		
Log of Employment 2012	3.32	0.84
Innovation Capital per Worker (€)	-1.04	4.46
Productivity		
Turnover per Employee (€)	5.16	1.09

Source: Irish CIS 2010-12

Table 2: Probit Estimation of Equation (1) – Innovation Decision

	Innovation Decision	Product Innovation	Process Innovation
Employment	0.1008***	0.0869***	0.0840***
	(0.0124)	(0.0106)	(0.0112)
Irish Owned	0.0632***	0.0563***	0.0312
	(0.0242)	(0.0217)	(0.0223)
Cost Factors			
Lack of funds within enterprise or groups	0.0899***	0.0196	0.0685**
	(0.0349)	(0.0310)	(0.0318)
Lack of finance from sources outside your enterprise	-0.0870*	-0.0218	-0.0753**
	(0.0344)	(0.0294)	(0.0312)
Innovation costs to high	0.0590*	0.0974***	0.0399
	(0.0352)	(0.0301)	(0.0321)
Knowledge Factors			
Lack of qualified personnel	0.1144***	0.0988***	0.0894***
	(0.0381)	(0.0332)	(0.0348)
Lack of information on technology	-0.0629	-0.0854**	0.0076
	(0.0450)	(0.0376)	(0.0401)
Lack of information on markets	0.1125***	0.1296***	0.0331
	(0.0421)	(0.0360)	(0.0381)
Difficulty in finding cooperation partners for innovation	-0.0271	-0.0249	-0.0004
	(0.0308)	(0.0258)	(0.0278)
Market Factors			
Market dominated by established enterprises	0.0293	0.0327	-0.0036
	(0.0337)	(0.0297)	(0.0311)
Uncertain demand for innovate goods of services	0.1186***	0.1006***	0.0825***
	(0.0340)	(0.0298)	(0.0314)
Need to meet market regulation	0.0518*	0.0293	0.0389
	(0.0311)	(0.0282)	(0.0290)
Excessive perceived economic risk	-0.1286***	-0.1662***	-0.0826***
	(0.0304)	(0.0276)	(0.0283)
Abandoned Innovation	0.3695***	0.3426***	0.2994***
	(0.0335)	(0.0370)	(0.0355)
Services	0.0754***	0.0614***	0.0560***
	(0.0209)	(0.0185)	(0.0193)
No. of obs.	2971	2981	2984
Wald Chi^2	550.9	581.68	376.5
	0.0000	0.0000	0.0000
Pseudo R^2	0.1356	0.163	0.0992
Log-likelihood	-1755.65	-1493.7759	-1708.5574

Note a: Dummy variables indicating the NACE2 sector the firm operates in are included as control variables but are not presented

b: *** indicates significant at 1% level, ** indicates significant at 5% level and * indicates significant at 10% level

c: Marginal effects are presented for ease of interpretation

Table 3: Probit Estimation of Equation (2) – Knowledge Sourcing

Variables	Backwards	Forwards	Horizontal	Public	R&D
External Knowledge Sources					
Backwards	n.a.	0.4060***	0.2903***	0.0861***	-0.1042*
		(0.0434)	(0.0427)	(0.0323)	(0.0564)
Forwards	0.4449***	n.a.	0.1513***	0.1349***	0.1841***
	(0.0461)		(0.0374)	(0.0365)	(0.0520)
Horizontal	0.3289***	0.1518***	n.a.	0.1461***	0.0749
	(0.0477)	(0.0383)		(0.0373)	(0.0555)
Public	0.1097***	0.1368***	0.1455***	n.a.	0.2547***
	(0.0403)	(0.0385)	(0.0381)		(0.0448)
Internal Knowledge Production					
R&D	-0.0341	0.0695***	0.0328*	0.0916***	n.a.
	(0.0226)	(0.0185)	(0.0180)	(0.0167)	
Employment	0.0171	-0.0109	0.0078	0.0019	0.0451**
	(0.0126)	(0.0110)	(0.0104)	(0.0096)	(0.0185)
Irish owned	-0.0142	0.0274	0.0338	-0.0278*	-0.0756**
	(0.0225)	(0.0216)	(0.0212)	(0.0162)	(0.0347)
Inverse Mills Ratio	0.0098	0.0051	0.0079*	0.0046	0.0671***
	(0.0060)	(0.0048)	(0.0045)	(0.0040)	(0.0126)
Services	0.0309	-0.0242	-0.0083	0.0292*	0.1330***
	(0.0216)	(0.0176)	(0.0172)	(0.0164)	(0.0302)
No. of obs.	1277	1277	1277	1277	1277
Wald Chi^2	531.51	499.99	432.89	307	199.51
	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.4482	0.447	0.4056	0.3087	0.113
Log-likelihood	-327.23474	-309.26866	-317.15688	-343.68576	-783.30848

Note a: Dummy variables indicating the NACE2 sector the firm operates in are included as control variables but are not presented

b: *** indicates significant at 1% level, ** indicates significant at 5% level and * indicates significant at 10% level

c: Marginal effects are presented for ease of interpretation

Table 4: Estimation of Equation (3) - Knowledge Transformation

Variables	Product Innovation	Process Innovation
External Knowledge Sources		
Backwards	-0.7514***	0.2433*
	(0.1630)	(0.1455)
Forwards	-0.0127	0.1139
	(0.2071)	(0.1732)
Horizontal	-0.0951	-0.0059
	(0.2403)	(0.1963)
Public	1.6671***	-0.1716
	(0.2849)	(0.2312)
Internal Knowledge Production		
R&D	0.8791***	-0.2623**
	(0.1690)	(0.1339)
Employment	-0.0131	0.0418**
	(0.0191)	(0.0169)
Irish owned	0.1024***	-0.0520
	(0.0316)	(0.0319)
Sector	-0.1476***	0.0433
	(0.0397)	(0.0329)
No. of obs.	1277	1277
Wald Chi^2	173.82	14.77
	0.0000	0.0639
Pseudo R^2	0.1063	0.0106
Log-likelihood	-730.90744	-688.78657

Note a: Dummy variables indicating the NACE2 sector the firm operates in are included as control variables but are not presented

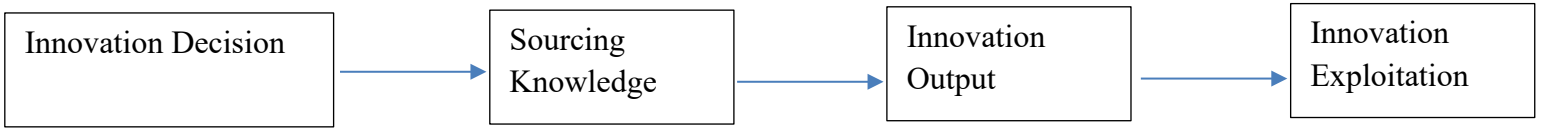
b: *** indicates significant at 1% level, ** indicates significant at 5% level and * indicates significant at 10% level

Table 5: Estimation of Equation (4) – Innovation Exploitation

Productivity	Turnover per Employee
Constant	3.5455***
	(0.5008)
Innovation	
Product Innovation	0.1522
	(0.1720)
Process innovation	1.9228***
	(0.7352)
Innovation Capital Investment per Worker[2]	0.0075
	(0.0045)
Employment[2]	0.0128
	(0.0343)
Irish Owned	0.7084***
	(0.0524)
Sector	-0.3915***
	(0.0414)
No. of obs.	2989
F	58.94
R^2	0.106

Note a: *** indicates significant at 1% level, ** indicates significant at 5% level and * indicates significant at 10% level

Appendix 1: Illustration of CDM Methodology



Appendix 2: Discussion of Table 2

In all cases larger enterprises are more likely to engage in innovation while Irish owned SMEs are more likely to innovate relative to foreign owned SMEs, with the results for process innovation being insignificant. These results are broadly consistent with Freel (2003) who also finds that larger SMEs are more likely to innovate.

For the three groups of innovators considered, a lack of qualified personnel has a positive effect on the likelihood of a firm's decision to innovate. This result appears counter intuitive, given that human capital is deemed important for innovation and therefore a lack of qualified personnel would be expected to have a negative effect on firms' innovation decisions. Two possible explanations exist for this result. Firstly, it may be that firms which do not have sufficient qualified personnel are forced to innovate in order to overcome this handicap. Alternatively, it may be a causality issue; with firms who decide to innovate being more likely to experience this hampering effect and, therefore, more likely to report it.

Similarly, firms which have previously abandoned innovation projects are more likely to decide to engage in innovation. This may represent a learning effect, with firms having gained invaluable experience from their previous innovation efforts resulting in them attempting to leverage this learning through the subsequent implementation of new innovations. However, it may also represent a persistent need to innovate. Firms innovate in order to increase or maintain their productive performance or exploit new opportunities (Crépon et al., 1998, Hansen and Birkinshaw, 2007). Firms which have previously failed to innovate may be under continued pressures to do so and may in effect be left with no alternative other than to attempt further innovation.

Firms which face uncertain demand for innovative goods and services are more likely to engage in innovation, while excessive perceived economic risk has a negative impact on the likelihood of a firm deciding to innovate. Lack of information on markets has a positive and significant effect on the innovation decision in the case of the innovation decision and product innovation.

Other factors appear to affect only one or two types of innovator category. For example, a lack of finances within a firm's enterprise increases the probability of process innovation; perhaps representing an attempt by the firm to streamline its production process. This may indicate that market pull factors are a key determinant for firms' decisions to engage in product innovation.

The impact of these hampering factors, which span a wide range of concepts including competition, knowledge and past experience, is not unique in the literature. Martinez-Ros (2000) finds that firms exposed to competitive pressures are more likely to engage in innovation activity. He also notes that the past experience of firms as well as their market horizons can impact on the likelihood of innovation. This is consistent with Roper, Du and Love's (2008a) findings that regulatory requirements can impact firms' innovation activities.