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The Importance of the Diverse Drivers and Types of Environmental Innovation for Firm Performance

Justin Doran and Geraldine Ryan
Department of Economics
University College Cork
Ireland

ABSTRACT

Today, firms are faced with a number of environmental challenges such as global warming, pollution control and declining natural resources. While there is increasing pressure to deliver environmentally friendly products and services, little is known about what drives the many different types of environmental innovation, or, how such pursuits' impact firm performance. Using a sample of 2,148 firms, this paper examines the factors which drive nine different types of eco-innovation in Ireland, and assesses how such innovations impact firm performance. We find that while demand-side, supply-side, and regulatory drivers' impact on the likelihood of a firm engaging in eco-innovation, the relative magnitude of these impacts vary across the types of eco-innovation considered. Moreover, we find that only two of the nine types of eco-innovation positively impact firm performance. The results point to regulation and customer pressure as viable mechanisms through which firms can be encouraged to eco-innovate.

Keywords: environmental innovation (eco-innovation), eco-innovation drivers, firm performance, environmental regulation, environmental policy, Ireland

Introduction

Numerous studies in economics, organizational theory, strategic management, and marketing argue that innovation is a key driver of economic growth. Many argue that it is a mechanism by which firms can draw upon their core competencies and transform these into performance outcomes which are critical for success (Chen *et al.*, 2006; Chiou *et al.*, 2011). While innovation is broadly seen as an essential component of competitiveness, embedded in the organisational structures, processes, products, and services within a firm, recent studies argue that the type of innovation matters (Gerstlberger *et al.*, 2013; Gunday *et al.*, 2011; Jin *et al.*, 2004; Kesidou and Demirel, 2012). In this paper, we focus on eco-innovation, and we ask whether it can provide firms with a means of creating a sustainable competitive advantage in today's turbulent environment. In particular, using a sample of 2,181 firms, we examine the economic drivers of nine types of product and process eco-innovation in Ireland and we analyse how each of these innovation types impact firm performance.

Within the literature there are many definitions of eco-innovation. Horbach (2008), for example, argues it describes new or modified processes, techniques, systems or products that reduce or prevent environmental damage. Kammerer (2009), on the other hand, contends that it includes all innovations that have a beneficial effect on the natural environment regardless of whether this was the main objective of the innovation. Hemmelskamp (1997) notes that the utilisation of a narrow definition of innovation can result in confining studies to a simple analysis of new product technologies which are introduced by firms. He argues that a wider range of innovations can be important in determining the success of eco-innovation and notes that an innovation can involve a new product or service being delivered, a change in the production process of the firm, a change in the organisational structure of the firm or a change in how the product is marketed. Within all of these types of innovation there is scope for improved environmental protection. Consequently, we utilise Hemmelskamp's (1997) broad definition of innovation when considering the different types of eco-innovation undertaken by Irish firms (these forms include technological and non-technological items such as reduced material use, reduced energy use and reduced pollution).

As consumer awareness increases, government regulations tighten and sustainable development becomes a financially astute matter, managing eco-innovation is becoming an increasingly important issue for firms and policy makers (Guoyou *et al.*, 2013; Ormazabal *et al.*, 2013). Eco-innovation is a powerful tool which can be used by new firms to undermine established firms and by established firms who need to maintain their competitive position in dynamic markets. Policy makers can use environmental regulation and policies to simulate eco-innovation and thereby reduce pollution and the general degradation of natural resources, incentivise research and development, and remove information asymmetries between key players in the market. For the full potential of eco-innovation to unfold we need to know what drives it. Drivers are generally understood as specific and evident agents or factors leading to increased or reduced pressure on the environment (Bleischwitz *et al.*, 2009). Using the literature we identify three key sets of eco-innovation drivers - demand-side drivers, supply-side drivers and regulatory drivers (Frondel *et al.*, 2007; Guoyou *et al.*, 2013; Horbach, 2008; Kesidou and Demirel, 2012) and we investigate how these influence the different types of eco-innovation undertaken in Ireland.

After examining the eco-innovation drivers we turn to the matter of firm performance and we test whether the nine types of eco-innovation positively or negatively influence firm performance. There is a general dearth of evidence examining the relationship between eco-innovation and firm performance (Cainelli *et al.*, 2011) and to our knowledge this is the first paper to examine how different types of eco-innovation impact on firm performance. Previous authors examining this issue tend to focus on the more specific relationship between eco-regulation and firm performance (see for example Rennings and Rammer, 2011) and within that literature there are mixed views on whether eco-regulation has a positive or negative impact on firm performance. One view suggests that the private costs induced through strict environmental regulation compromise competitiveness and productivity (Palmer *et al.*, 1995), while the other view argues that environmental regulation can trigger innovation that may, partially or more than fully, offset the costs of complying with such regulations (Porter and Van der Linde, 1995). We add to this literature by examining whether different types of eco-innovation have positive or negative effects on firm performance. This is a particularly important question as currently 72% of innovating firms in Ireland engage in some type of eco-innovation (see data from the Community Innovation Survey discussed below).

Briefly, our ideas are developed as follows: in the next section we use the literature to identify if a firm can gain a competitive advantage by eco-innovating, the factors that are likely to drive eco-innovation, and whether eco-innovation impacts firm performance. Following this we introduce our key data source - the Community Innovation Survey for Ireland 2006-2008 - and we specify our two regression equations; a modified innovation production function (which allows us to examine what drives eco-innovation), and a knowledge augmented production function (which allows us to assess the impact of eco-innovation on firm performance). We then present our empirical results and finally we conclude our study and set-out some implications for future research.

Literature Review

Gaining a Competitive Advantage

For a firm to prosper and grow it must do more than keep up with its competitors. It must gain a competitive advantage over them whenever possible. In Porter's (1996) traditional strategy model, companies gained competitive advantage by lowering costs or by differentiating their product. However, outsourcing, access to capital and low-cost raw materials have eroded these traditional sources of advantage and modern firms need to refine their business strategy. Esty and Winston (2009) claim that environmental strategy can offer firms the opportunity to differentiate themselves and hence to increase their competitive advantage. They contend that the environment presents firms with an opportunity to bring fresh thinking to old ideas. Moreover careful use of the environmental perspective can help to reduce costs, increase revenue, grow market size and share whilst simultaneously reducing the environmental impacts of the firm (Ambec *et al.*, 2013; del Río *et al.*, 2013; Marchi *et al.*, 2013).

The literature on eco-innovation uses a variety of theoretical underpinnings for its arguments including resource based theory and stakeholder theory. Resource based theory emphasizes the role of resources and capabilities in forming the basis for gaining a competitive advantage (Thurner and Proskuryakova, 2013). Hart and Dowell (2011) define a resource as something that a firm possesses whereas a capability is something a firm is able to perform. Resources include physical assets, financial assets, employee skills and organisational know-how. Owning resources that are valuable, rare, inimitable, and non-substitutable enables a firm to gain a competitive advantage (Dangelico and Pontrandolfo, 2013; del Río *et al.*, 2013). Firms organise their resources so as to achieve the desired output. While some resources are outside the firm, they can be captured by the firm using networks, personal relationships, gifts, and philanthropy (Lin *et al.*, 2014). Capabilities, on the other hand, are the bundles of skills and assets needed to organise resources (Pålsson and Kovács, 2014).

Stakeholder theory suggests that in order to survive and grow firms must satisfy stakeholders' demands (Kassinis and Vafeas, 2006). Stakeholder analysis is a holistic approach that is used for gaining an understanding of a system by identifying the key stakeholders in the system and assessing their interest in that system. Henriques and Sadorsky

(1999) identify four types of environmental stakeholders: regulatory stakeholders (governments, trade associations, informal networks, and competitors), organizational stakeholders (customers, suppliers and employees), community stakeholders (community groups, environmental organisations and other lobbyists), and the media. Stakeholders influence the practices of a firm through direct pressure and/or by conveying information. Lin *et al.* (2014), Rennings and Rammer (2011), and Horbach (2008), amongst others, show that stakeholder pressure from regulators, consumers, suppliers and competitors drive eco-innovation. Sarkis *et al.* (2010) concurs with this view and adds to it by suggesting that stakeholder theory and resource based theory complement each other as a company's internal motives (from resource based theory) and its external drivers (from stakeholder theory) together explain its intension to eco-innovate.

While the mechanisms for creating competitive advantage are complex, history teaches us that one way to do so is by successfully innovating (Patterson *et al.*, 2009; Utterback, 1996). Significant advances in science, information, telecommunications and design technology over the last few decades have benefited many firms and individuals. New innovations have changed the way we live, learn and communicate. Powerful computer systems have increased the speed with which goods, services and information are designed, produced, and distributed (Misko and Nechvoglod, 2011). Technology developments have changed how we produce, present and exchange information (Paas and Creech, 2008), and scientific developments have led to new and improved materials, drugs, medications and medical equipment (Austin, 2007). There is little doubt that an organisation's ability to innovate is key to its success (Shipton *et al.*, 2006).

By integrating environmental innovation into its' strategy the literature finds that a firm can increase its sales, attract new markets, enhance its competitive advantage, improve its financial performance, enrich its corporate impact, differentiate its product(s) and improve the environment (Arundel and Kemp, 2009; Brouwers and Jacke, 2010; Chiou *et al.*, 2011; Dangelico and Pontrandolfo, 2013; del Río *et al.*, 2013; Guoyou *et al.*, 2013; Hall and Wagner, 2012; Porter and Van der Linde, 1995; Vachon and Klassen, 2008). Whilst environmental innovation involves many areas of knowledge and many different industrial sectors, our aim is to explore potential mechanisms driving different types of environmental product and process innovation at the firm-level.

Product innovation is the most evident form of innovation from a market-facing point of view. This type of innovation is critical in changing markets where creating new products is key for firm success, survival and renewal (Eisenhardt and Tabrizi, 1995). An product eco-innovation is the introduction of a new or significantly improved product or service which reduces any negative impact on the environment during any stage of a product's life cycle (Cheng and Shiu, 2012). Chiou *et al.* (2011) argue that firms are more likely to grow if they can develop products and services which consumers are anxious to buy. In this way product eco-innovation is a source of competitive advantage for a firm. Process eco-innovation, on the other hand, involves the development or adaption of the manufacturing process so as to reduce environment externalities (Rennings, 2000). Process eco-innovation focuses on reaping efficiency gains by means of cost reductions and increased production volumes, reduced development times for products, and improved product quality and reliability. Frishammar *et al.* (2012) argue that a firm that invests in new process technology will be superior in introducing new products to the market, will sustain lower development risks, and will be protected from would-be imitators.

While there is growing pressure to deliver products and services which are environmentally friendly, regulators and policy makers are faced with two market failures; (1) most environmental problems are negative externalities and (2) innovation is a positive externality providing value to the innovating firm (e.g. in the form of lower costs) and to the general community (e.g. in the form of R&D benefits and less pollution). As a result firms often harm the environment too much and innovate too little (Johnstone and Kalamova, 2010). Consequently, while researchers examining the broad field of innovation comment on the importance of demand side and supply side drivers, those focusing on eco-innovation stress the additional importance of regulation, environmental policy, and institutional and political drivers (Hemmelskamp, 1999; Horbach, 2008; Horbach and Rennings, 2007; Rehfeld *et al.*, 2007). We briefly examine each of these drivers below.

Eco-innovation Drivers

Demand-Side Drivers

Consumer demand for environmentally friendly products, public procurement requirements and exports all play a part in the market for eco-innovation. Horte and Halila (2008) argue that consumer perception, interest group pressures and social corporate responsibility is enough to induce firms to develop, adapt and use more environmentally friendly products, process and management systems. In a survey of Swedish car owners Jansson (2011) finds that norms, attitudes, and consumer novelty-seeking towards eco-innovation influence adoption rates. Gerstlberger *et al.* (2013) note that customers have started to pressure firms to improve their environmental performance, whilst Wesseling *et al.* (2013) argue that environmentally aware consumers are likely to avoid products or services in an attempt to punish a firm for its unacceptable behaviour.

Kesidou and Demirel (2012) note that while active stakeholders and the increasing demand for corporate social responsibility play an important role in generating eco-innovative products and processes, they do not impact on the level of eco-innovation. In particular, they find using UK data, that in response to stakeholder pressure firms only invest in enough eco-innovation so as to be able to present a 'green image'. del Río *et al.* (2013), using Spanish data, also find that demand side drivers are not very effective. This contrasts with studies by Rehfeld *et al.* (2007) and Veugelers (2012) for Germany and Flanders respectively, who find that find a statistically significant demand effect.

Empirical evidence shows that the pressure to eco-innovate is strongest in product markets which are close to final consumers. In these markets firms can easily communicate the added value of the innovation to the customer, and most importantly, they can readily assess willingness to pay. Many empirical papers find that consumers are willing to pay for eco-innovation if they can identify the added value. For example, Guagnano (2001) reports that eighty-six percent of customer will pay more for household products which are less harmful to the environment. Similarly Manget *et al.* (2009), in a survey of 9,000 consumers across nine countries, found that consumers are willing to pay more for green goods especially those considered as ingestible goods (e.g. food, medicine) and plug-in-products (e.g. appliances, electronics).

Supply-Side Drivers

Kesidou and Demirel (2012) argue that supply-side drivers, such as a firms' technological and organisational capability, are important drivers of eco-innovation. These drivers are nurtured by developing a firm's intramural (internal) innovation capabilities (Triebswetter and Wackerbauer, 2008). The more innovative a company and the more knowledge it has accumulated, the higher its capacity to apply these factors to environmental innovation. Kemp and Foxon (2007) contend that firms which build organisational capabilities in areas such as pollution control, green product sourcing/ design and efficient energy use are most likely to eco-innovate. Triguero *et al.* (2013) find that the availability of environmentally concerned/ trained human resources (managers and employees) enhances environmental process innovations. Whilst firms with a high engagement in both intramural and extramural R&D

activities may be viewed as possessing more potential for innovation, Horbach *et al.* (2012) find that only intramural R&D fosters eco-innovation.

A second key supply side driver is the level of engagement between the innovating firm and its external environment (i.e. with consumers, suppliers, competitors, and with universities). The stronger this link, the greater the firm's access to knowledge about consumer perceptions and demand, suppliers' ability to provide greener raw materials, competitors' experiences, and universities' intellectual capital (Dangelico and Pontrandolfo, 2013). By engaging in research partnerships, firms can tap external knowledge and thus profit from their partners' expertise, while complementing their own internal knowledge with external knowledge. Recent research finds that eco-innovators are more likely to cooperate with each other than general innovators (see for example Cainelli *et al.*, 2011; del Río *et al.*, 2013; Horbach, 2008). Wagner (2007), in his study of German manufacturing firms, found that collaboration with environmentally concerned stakeholders is an important determinant of eco-innovation, whilst Cainelli *et al.* (2012) argue that competition between firms drives eco-innovation in Italy. In Spain, De Marchi (2012) found that firms which cooperate with external partners experience a greater increase in their energy and material efficiency. They argue that working with external partners is especially important for eco-innovation as firms are still inexperienced in developing such innovations and they need to leverage on the expertise of their external partners. Triguero *et al.* (2013), using data for 27 EU countries, found that good access to external information and knowledge is an essential driver of environmental product and process innovation.

Regulation, Environmental Policy, Institutional and Political Drivers

Many authors, including del Río *et al.* (2013), Gerstlberger *et al.* (2013) and Porter and Van der Linde (1995) argue that regulation is an important driver of eco-innovation. Since eco-innovation faces two externalities – an innovation externality and an environmental externality – researchers argue that this type of innovation is more likely to be policy led rather than market driven (see for example del Río *et al.*, 2013; Horbach, 2008; Horbach *et al.*, 2012). Public policy plays an important role by incentivising firms to engage in innovation using 'carrots' (subsidies) or by punishing them for not engaging using 'sticks' (environmental regulations). Governments can mandate firms to reduce their environmental impact (Darnall, 2006) and they can encourage them to implement proactive green process innovation. Failure to meet these regulations leads to penalties, fine, lawsuits, and even loss of operating permits (Kassinis and Vafeas, 2006; Sarkis *et al.*, 2010).

Today, Government policy initiatives and programmes that promote eco-innovation are diverse and include both supply-side and demand-side measures. Demand-side measures are receiving increasing attention, as governments acknowledge that insufficiently developed markets are often the key constraint for eco-innovation. These measures take many forms including green public procurement and the creation of networks, platforms or partnerships that engage different industry and non-industry stakeholders.

Kemp (2000) argues that environmental regulations are valuable as they have both an informative and normative content in that they translate the demand for a greener environment into specific policies and they give strict guidelines to polluters and eco-innovators as to what is required. Indeed they suggest that the most important impact of eco-regulation is that it can change the level and nature of competition between firms. OFWAT (2011) concur with this view and argue that regulators can drive innovation by incentivising firms to think differently while also providing them with information about how to change and adapt their technologies. Clearly stated and straight-forward regulations work best at stimulating eco-innovation whilst unclear or overly detailed regulations act as barriers to innovation (Arundel and Kemp, 2009; Triguero *et al.*, 2013).

Whilst firms engage in eco-innovation to comply with current regulation, to pre-empt future regulation and/or to avoid punishments and higher taxes (Triguero *et al.*, 2013), regulation is most effective when firms have limited information about consumer needs and wants. By offering incentives to innovate, eco-regulation can reduce (or eliminate) the prisoners dilemma faced by firms considering investing in novel forms of eco-innovation where consumer demand is not known (Zhang *et al.*, 2011). On the other hand, when consumer demand is known firms often eco-innovate in the anticipation of stringent environmental regulations (Blum-Kusterer and Hussain, 2001; del Río *et al.*, 2013; Khanna *et al.*, 2009) as this can allow them to lower the future cost of compliance while also gaining a competitive advantage relative to their peers.

Innovation and Firm Performance

Whilst many studies find a positive relationship between innovation and firm performance (Kleinknecht and Mohnen, 2002), there is a dearth of evidence regarding the relationship between eco-innovation and firm performance. Understanding this relationship is important for researchers, policy-makers and owner-managers alike. In this section we examine the likely impact of eco-innovation on firm performance in general, while later we test how nine different types of eco-innovation impact on firm performance in Ireland.

Many authors find a strong positive link between innovation and R&D (see Klette and Kortum (2002) for an overview of this literature). Favre *et al.* (2002) and Arvanitis and Hollenstein (2002), for example, all note that supply factors drive innovation and this innovation results in increased profits. Favre *et al.* (2002) find that R&D intensity causes innovation and this increases firm profits, while Arvanitis and Hollenstein (2002) find that the use of external knowledge increases the productivity of knowledge capital thus resulting in a higher return to patents. In relation to eco-innovation De Marchi (2012), in a study of over 6,000 Spanish firms, finds that cooperation with external partners is even more important for eco-innovators than it is for other innovations and R&D cooperation is more intense for environmental innovators than for other innovators.

Strong linkages also exist between consumer demand and firm performance. Horbach (2008), for example notes that consumer demand for environmentally friendly products, interest group pressures, social corporate responsibility and public procurement requirements are often enough to induce firms to develop, adapt, and use more environmentally friendly products, process and management systems. Jansson (2011) find that some consumers seek out new and exciting products and that these consumers are likely to be attracted to new innovations that are marketed as environmentally friendly. Moreover, Sammer and Wüstenhagen (2006) find that in markets where consumers are willing to pay extra for green goods, firms will brand themselves as eco-friendly and use this branding as a quality-signal to consumers.

Rather than innovating in every direction at once, firms make choices based on their current competitive position and the world around them. One important element of the outside world is regulation and this can influence the pace and direction of firm innovation (Hemmelskamp, 1997; Rennings and Rammer, 2011). As mentioned above, there are two conflicting views relating to the impact of environment regulation on firm performance. The conventional economic approach assumes that there is a trade-off between environmental regulation and productivity. According to this view regulation is a means whereby environmental costs are partly or wholly internalised. Therefore, firms undertaking additional expenditures in order to abate pollution and reduce environmental damage will tend to have higher costs than those which do not. As a result eco-regulation will reduce a firms' competitiveness and in turn its profitability.

The reverse hypothesis argues that environmental regulation can drive eco-innovation and that this eco-innovation has a positive effect on firm performance. This view has received a lot of support in the last few years and is often portrayed as a ‘win-win’ scenario for firms (Porter and Van der Linde, 1995; World Bank, 1992). Central to this ‘win-win’ view is the belief that environmental regulation promotes innovation at firm level. This in turn may lead to changes in production which may reduce production costs or may lead to a change in customer awareness, tastes and preferences which may lead to increased demand. Moreover, the firm which introduces the innovation may enjoy a first-mover advantage and/or may increase its competitiveness by obtaining a niche market based on its eco-friendly status (Demirel and Kesidou, 2011).

Now that we have examined the key factors that drive eco-innovation and the impact of same on firm performance we turn to our data set and we use it to answer our two key questions, firstly what drives eco-innovation, and secondly, how does this eco-innovation impact on firm-performance.

Data Sources and Methodology

In this paper we use data collected as part of the most recent Irish Community Innovation Survey. This survey gathered data on new and significantly improved products (good or services), processes, organisational and marketing innovations introduced in Ireland during the period 2006 to 2008 inclusive. This survey is conducted every three years and is carried out in accordance with European Commission Regulation (EC) No 1450/2004. Firms included in the sample are selected from the full list of enterprises on the Central Statistics Office Business Register. Firms included must employ more than ten people and must be located in the following NACE 2 sectors: Mining and quarrying (B 05-09), Manufacturing (C 10-33), Electricity, gas, steam and air conditioning supply (D 35), Water supply; sewerage, waste management and remediation activities (E 36-39), Wholesale trade, except of motor vehicles and motorcycles (G 46), Transportation and Storage (H 49-53), Information and communication (J 58, 61, 62, 63), Financial and insurance activities (K 64-66) and Architectural and engineering activates; technical testing and analysis (M 71). The 2006-2008 sample consisted of 4,650 firms and had a 48% response rate, giving a total of 2,128 responses. This response rate is high relative to other Irish studies (Roper, 2001).

The 2006-2008 survey included some specific questions on eco-innovation and it is this information which is of particular interest to us in this paper. All firms were asked whether they introduced any of the following nine types of innovation: An eco-innovation which (1) Reduced material use per unit of output, (2) Reduced energy use per unit of output, (3) Reduced CO_2 'footprint' (total CO_2 production), (4) Replaced materials with less polluting or hazardous substitutes, (5) Reduced soil, water, noise, or air pollution, (6) Recycled waste, water, or materials, (7) Reduced energy use, (8) Reduced air, water, soil or noise pollution, (9) Improved recycling of product after use.[i]

As part of the survey firms were asked to give details of their expenditure on R&D in 2008 (they were not asked for these expenditures over the three year period) and they were asked to give details on their external linkages with consumers, suppliers, competitors, and universities. We use these variables to measure supply induced eco-innovation. The last question in the survey asked about the demand and regulation drivers of innovation. In particular, firms were asked if they eco-innovated in response to any of the following: (1) Existing environmental regulations or taxes on pollution, (2) Environmental regulations or taxes that you expected to be introduced in the future, (3) Availability of government grants, subsidies or other financial incentives for environmental innovation, (4) Current or expected market demand from your customers for environmental innovations, (5) Voluntary codes or agreements for environmental good practice within your sector. We classify the first three factors as the regulatory drivers of eco-innovation and the last two factors as demand drivers of eco-innovation.

Our last variable of interest is a measure of firm performance. Turnover per worker is incorporated into the Irish CIS from the Central Business Register. Therefore we use turnover per employee as a measure of firm performance. Ideally we would also like to include some measure of eco-innovation costs but unfortunately such data was not collected as part of the survey.

The CIS survey includes some additional information on the size of the firm, the sector within which it is located and whether the firm is Irish owned. Previous research has shown that these factors can impact on the innovation propensity of firms (Freel, 2003; Love and Roper, 1999; Pavitt, 1984) and therefore control for them in our analysis.

To answer our first research question - what factors drive the nine types of eco-innovation - we use an innovation production function. This function relates innovation inputs and conditioning factors to a firms' innovation output (Doran and O'Leary, 2011; Hall *et al.*, 2009; Roper *et al.*, 2008). Equation (1) specifies the innovation production function estimated by this paper.

$$IO_{ih} = \alpha_0 + \alpha_j R\&P_{ji} + \alpha_k KS_{ki} + \alpha_l R\&D_{li} + \alpha_m X_{mi} + \varepsilon_{1i} \qquad (1)$$

Where IO_{ih} is a binary variable indicating whether firm *i* engaged in eco-innovation activity *h* (where *h* refers to the nine eco-innovation types identified above), α_0 is the intercept coefficient, $R\&P_{ji}$ is a series of *j* variables which indicate whether firm *i* experienced regulation or perception factor *j*, α_j is the associated slope coefficient, KS_{ki} is a series of *k* variables indicating whether firm *i* engaged in knowledge sourcing activity *k*, α_k is the associated coefficient, $R\&D_{li}$ are a series of variables indicating the expenditure of firm *i* on intramural and extramural R&D, α_l is the associated coefficient, X_{mi} are a series of *m* variables which control for firm specific factors, α_m are the associated coefficients and ε_{1i} is the error term. The firm specific variables *X* are (i) a binary variable indicating whether the firm is Irish owned or not, (ii) the number of employees in the firm and (iii) the sector in which the firm operates.

As the dependent variable in equation (1) is a binary indicator of innovation output this suggests the utilisation of a probit or logit model as most applicable. However, given that the *h* different forms of eco-innovation considered are likely to be driven by common, unobservable factors there is a possibility that the error terms will be correlated across equations. Essentially, this implies that the decision by a firm to engage in one form of eco-innovation may be related to that same firm's decision to engage in another form of eco-innovation. If this is the case the estimation of a series of binary probit models for each different type of innovation output will be inefficient, as it will not take into account the correlation amongst the error terms. In order to overcome this deficiency, a multivariate probit model is utilised to estimate equation (1). A multivariate probit model is similar in conception to a seemingly unrelated regression except that the dependent variables in the case of the multivariate probit model are binary. The multivariate probit model utilises information from the variance/covariance matrix of the estimated model to capture interdependencies between the series of probit equations and to provide efficient estimates of the coefficients and standard errors of the model (Greene, 2008). For this reason, the multivariate probit model is preferred over a series of probit models.

To answer our second research question - how do the nine types of eco-innovation impact on firm performance - we use a knowledge augmented production function (Griliches, 1979; Klomp and Van Leeuwen, 2006; Love and Mansury, 2007). The production function specified is displayed as follows:

$$\Pr od_i = \beta_0 + \beta_1 IO^*_{ih} + \beta_j Z_{ji} + \varepsilon_{2i} \quad (2)$$

Where $Prod_i$ indicates firm *i*'s turnover per employee, IO^*_{ih} is a series of variables which contain the predicted values of eco-innovation form *h* derived from equation (1) for firm *i*, Z_{ji} is a series of firm specific variables, ε_{2i} is the error term and the *β*s are the associated coefficients. The firm specific variables *Z* are (i) the number of employees in the firm, (ii) the sector in which the firm operates and (iii) the capital expenditure of the firm per employee on the acquisition of capital for the production of new products or services during the reference period. This last variable acts as a proxy for the capital stock of the firm.[ii]

All continuous variables are expressed in natural logarithms. As the dependent variable in this case is continuous, ordinary least squared estimation techniques are used to estimate the model. However, before estimation is it important to acknowledge that the innovation output values in equation (2) are actually endogenous (Crépon *et al.*, 1998). Therefore, estimation of equation (2) without correcting for this endogenity will result in biased estimates of the coefficients of the model. In order to correct for the potential endogeneity of these variables a two-step instrumental procedure is adopted (Griffith *et al.*, 2006). Initially, equation (1) is estimated. Predicted probabilities are then derived from each of these estimations. These predicted probabilities are then utilised as instruments in equation (2), correcting for the potential endogeneity problem (Milgrom and Roberts, 1990).

Empirical Results

In this section we begin by summarising some key information relating to the types and drivers of eco- innovation and then we estimate the innovation production function and knowledge augmented production function.

Descriptive Statistics

2,181 firms completed the 2006-2008 Community Innovation Survey. Of these 1,281 firms (58.78%) engaged in some form of innovation. Of these innovating firms, 72% (919 firms) engaged in some form of eco-innovation. This suggests that innovating Irish firms are interested in green issues.

Of the six types of process eco-innovation identified in the CIS survey, *Recycled waste, water, or materials* is the most common form with 33.7% of firms engaging in this form of eco-innovation (see Table 1). The next most popular are *Reduced energy use per unit of output* (22.2%) and *Reduced* CO_2 *'footprint'* (21.6%). Of the three types of product innovation *Improved recycling of product after use* is the most popular with 22% of firms engaging in this type of innovation, whilst *Reduced energy use by the end user* (20%) is the second most popular. The least popular type of process innovation is *Reduced material use per unit of output* with only 18.6% of firms engaging in this type of innovation whilst the least popular form of product innovation is *Reduced air, water, soil or noise pollution by the end user* (14.5%).

Turning next to the eco-innovation drivers, in terms of regulatory drivers *Existing regulation* is the most frequently cited driver with nearly 17% of firms identifying it as the reason they introduced an eco-innovation during the 2006-08 period (see Table 1). Almost 13% of firms eco-innovated in the expectation of future regulation, while only 6% eco-innovated in response to a government grant. The demand factors are slightly more popular with over 16% of firms claiming to have eco-innovated in response to consumer perceptions and almost 18% claiming to have eco-innovated on a voluntary basis.

We include two supply side drivers, namely knowledge linkages and R&D expenditure. In line with Roper *et al.* (2008), we classify four types of knowledge linkages; forward linkages (to customers), backward linkages (to suppliers and consultants), horizontal linkages (to competitors) and public linkages (to universities and public research institutes). Backward linkages to suppliers and consultants are most common while only 3% of firms cooperate with competitors for innovation activities (see Table 1). We also include two forms of R&D expenditures; intramural and extramural R&D. Intramural R&D is defined as creative work undertaken within the enterprise to increase the stock of knowledge for developing new and improved products and processes while extramural R&D is defined as the same activities as intramural R&D, but performed by enterprises outside the business. The mean expenditure per employee by firms on intramural R&D is €2,054 and the mean expenditure of firms per employee on extramural R&D is €460, with standard errors of €10,253 and €5,064 respectively.

[Insert Table 1 around here]

Innovation Production Function

Table 2 displays the results of the multivariate probit estimate of equation (1). The key variables of interest in this paper are the nine eco-innovation variables. The six process innovations refer to the benefits from the production of the good or service within the firm and are labelled as follows: *Eco1* represents reduced material use per unit of output, *Eco2* represents reduced energy use per unit of output, *Eco3* represents reduced CO_2 footprint, *Eco4* represents replaced materials with less polluting or hazardous substitutes, *Eco5* represents reduced soil, water, noise, or air pollution and *Eco6* represents recycled waste, water, or materials. The three product innovations refer to the environmental benefits from the after sales use of the good or service by the end user and they are labelled as follows: *Eco7* represents reduced energy use, *Eco8* represents reduced air, water, soil or noise pollution and *Eco9* represents improved recycling of product after use.

Looking first at the regulatory drivers of eco-innovation we note that exiting regulation is a positive and significant driver of all nine forms of eco-innovation. This result is generally supported in the literature (see for example del Río *et al.*, 2013; Horbach *et al.*, 2012; Triguero *et al.*, 2013). In line with Kammerer (2009) and Triguero *et al.* (2013), we find that expected regulation is not a consistent driver of eco-innovation. We find that it is only important for *Eco4* (replaced materials with less polluting or hazardous substitutes), *Eco5* (reduced soil, water, noise, or air pollution), and *Eco8* (Reduced air, water, soil or noise pollution). Our last regulation driver is government grants and here we note that with two exceptions – *Eco1* (reduced material use per unit of output) and *Eco6* (Recycled waste, water, or materials) - government grants strongly influence a firm's decision to eco-innovate. Our results are similar to del Río *et al.* (2013) and Veugelers (2012) who find that government grants are important eco-innovation drivers.

There is a weak relationship between the supply side factors and a firm's likelihood of engaging in eco-innovation. This is particularly the case for the knowledge linkages variable where forward linkages and horizontal linkages only impact on some forms of product innovation, public linkages have no impact at all, while backward linkages have the strongest effect, impacting three forms of process innovation and one form of product innovation. In particular, forward linkages have a positive impact on the likelihood of *Eco9* (improved recycling of product after use by end user), while horizontal linkages have a positive impact on the likelihood of *Eco8* (reduced air, water, soil or noise pollution by end user). Backward linkages, on the other hand, increase a firms likelihood of engaging in *Eco1* (reduced material use per unit of output), *Eco2* (reduced energy use per unit of output), *Eco3* (reduced CO_2 'footprint'), and *Eco7* (reduced energy use by end user). Given that these forms of eco-innovation involve changing inputs or reducing energy use this finding may not be surprising as undertaking these forms of changes may necessitate working closely with suppliers. Our results contrast somewhat with those of Cainelli *et al.* (2012), De Marchi (2012), Kammerer (2009) and Triguero *et al.* (2013) who find that linkages with the external environment is an essential driver for all types of eco-innovation.

While the literature is generally supportive of the idea that knowledge generation drives general innovation (see De Marchi, 2012; Horbach *et al.*, 2012; Klette and Kortum, 2002), we find some mixed results with intramural R&D driving four types of process eco-innovation, namely *Eco1* (reduced material use per unit of output), *Eco2* (reduced energy use per unit of output), *Eco3 (*reduced CO_2 'footprint') and *Eco6* (recycled waste, water, or materials), while extramural R&D drives three types of process eco-innovation and one type of product eco-innovation. These are *Eco4* (replaced materials with less polluting or hazardous substitutes), *Eco5* (reduced soil, water, noise, or air pollution), *Eco6* (recycled waste, water, or materials) and *Eco8* (reduced air, water, soil or noise pollution by end user). Only in the case of *Eco6* (recycled waste, water, or materials) does both intra- and extra-mural R&D drive eco-innovation, while neither type drives *Eco9* (improved recycling of product after use).

Unsurprisingly, the demand side factors (consumer perceptions and voluntary agreements) are both positive and significant for all nine forms of eco-innovation. If we focus on the strength of the variables we can see that customer perceptions is the strongest driver of *Eco7(*reduced energy use), *Eco1* (reduced material use per unit of output), *Eco8* (reduced air, water, soil or noise pollution), *Eco9 (*improved recycling of product after use) and *Eco4* (replaced materials with less polluting or hazardous substitutes). It is noteworthy that all three types of product innovation rank in the top four. Voluntary agreements, on the other hand, have a larger impact on process innovation and are the strongest driver of *Eco6* (recycled waste, water, or materials), *Eco3* (reduced CO_2 'footprint'), *Eco9* (improved recycling of product after use), *Eco2* (reduced energy use per unit of output), and *Eco5* (reduced soil, water, noise, or air pollution). Our results concur with those of Kesidou and Demirel (2012) who examined UK data, Rehfeld *et al.* (2007) who examined German data and Veugelers (2012) who examined data for Flanders, but they contrast with del Río *et al.* (2013) who finds little support for these factors in Spain.

In relation to the control factors, larger firms are more likely to engage in seven out of the nine forms of eco-innovation, with only *Eco7 (*reduced energy use) and *Eco9* (improved recycling of product after use) being unaffected by economies of scale effects. Triguero *et al.* (2013) report a similar size relationship for eco-innovation in general in their study of 27 European Countries, where they argue that size is proxying for the barriers to eco-innovation faced by small firms. We find that Irish and foreign owned firms are equally likely to introduce eight forms of eco-innovation. The sole exception is *Eco9* (improved recycling of product after use), where Irish owned firms are more likely to undertake this form of eco-innovation relative to foreign owned firms.

Knowledge-Augmented Production Function

Following from the drivers of eco-innovation, Table 3 presents the results of the ordinary least squares estimation of the importance of the different forms of eco-innovation for firm performance, where firm performance is measured as the turnover per worker of the firm. Of the nine forms of eco-innovation considered only two process innovations have a significantly positive effect on firm performance. Firms which reduce their CO_2 'footprint' (*Eco3*) and firms which recycle waste, water, or materials (*Eco6*) are able to increase their turnover per worker. On the other hand, firms which improve the recyclability of the product after use (*Eco9*) experience significantly lower their level of turnover per worker.

[Insert Table 3 around here]

These varying results provide inconclusive evidence for the Porter and Van der Linde (1995) hypothesis. The hypothesis proposes that eco-innovation, specifically eco-innovation driven by regulation, can provide a win-win situation for firms and society whereby both firms and society can benefit from increased profits and environmental benefits respectively. While reducing the CO_2 'footprint' of the firm and recycling waste, water, or materials within the firm result in the hypothesised benefit to the firm, and presumably to the environment, the negative profitability effect as a result of *improved recycling of product after use* deviates from the Porter and Van der Linde (1995) hypothesis in favour of the traditional view that eco-innovation is costly and has a negative impact on a firms performance and competitive position. This suggests that the validity of the Porter and Van der Linde (1995) hypothesis varies depending on the specific sub-type of eco-innovation considered.

Conclusions and Public Policy/ Business Strategy Recommendations

Today, firms all over the world are faced with a number of environmental challenges such as global warming, declining natural resources, pollution control and a growing demand for environmentally friendly goods. Increasingly restrictive environmental regulations, consumer concern about firms' environmental behaviour, along with significant technological developments have spurred top management teams into integrating environmental innovation into their business strategies. As firms strive for market position and competitive advantage they must look for profitable ways to get ahead, and stay ahead of their rivals. One way of doing this is to eco-innovate (Ambec *et al.*, 2013; del Río *et al.*, 2013; Esty and Winston, 2009; Guoyou *et al.*, 2013; Marchi *et al.*, 2013; Ormazabal *et al.*, 2013). A firms strategic decision to eco-innovate is likely to be influenced by internal and external factors. This paper analyses the impact of demand-side, supply-side and regulatory drivers on the likelihood of firms performing nine different forms of eco-innovation and the subsequent impact of these eco-innovations on the performance of these firms. This paper contributes to existing literature on eco-innovation by considering an extremely disaggregated level of eco-innovation, facilitating an analysis of whether the drivers of eco-innovation vary across differing forms of eco-innovation and subsequently whether these different types of eco-innovation increase, decrease, or have no influence on firm performance. The analysis is conducted on the Irish Community Innovation Survey (CIS) 2006-08.

While the results indicate that the impact of demand-side, supply-side and regulatory drivers vary across the different types of eco-innovation, it is consistently observed that existing regulation, customer expectations and voluntary agreements have a positive effect on the likelihood of firms' introducing each of the nine types of eco-innovation. However, the impact of eco-innovation on firm performance is more ambiguous. While two forms of process eco-innovation (*reduced CO_2 'footprint'* and increased *recycling of waste, water, or materials*) are found to have a positive and significant impact on firms productivity, one form of product eco-innovation (*improved recycling of product after use*) is found to reduce firms' productivity and six forms of eco-innovation are found to have no significant impact on productivity at all.

While the Porter and Van der Linde (1995) hypothesis clearly states that regulation driven eco-innovation should positively influence firm performance our results question whether this hypothesis encompasses all forms of eco-innovation. It appears, in the Irish case, that certain forms of eco-innovation can result in a win-win situation, with both firms and society benefiting from the eco-innovation while others actually result in a beneficial environmental situation but at the expense of firms' productivity. Other types of eco-innovation, while benefiting the environment are found to have a benign impact on firms, nether increasing productivity nor decreasing it.

Our findings have implications for both policy makers and managers. Given that we cannot rely on improved firm performance to cover the cost of eco-innovation there is an important role for public policy. Traditional environmental policy is effective in Ireland; existing regulations (stick incentives) are significant in driving all nine types of innovation examined in this paper, whilst government grants (carrot incentives) are a significant trigger of all three types of product eco-innovation and four of the six types of process eco-innovation. In addition the strength of the demand-side factors, suggest that the public sector can drive eco-innovation through public procurement and other supportive government agreements. In contrast to the literature (see for example Cainelli *et al.*, 2012; Kammerer, 2009; Triguero *et al.*, 2013; Wesseling *et al.*, 2013) we find that public linkages with universities, research centres and agencies have no impact on eco-innovation in Ireland. Given the recognition of their importance in other regions policymakers should promote the creation of these networks in Ireland as when investment costs are high, collaboration between innovators can serve to reduce costs and promote the creation of industry standards.

While the literature shows that through the integration of the environmental dimension into a firm's strategy and activities several benefits can be generated in terms of market performance, corporate image performance, manufacturing performance, and financial performance (see review in Cainelli *et al.*, 2011; Dangelico and Pontrandolfo, 2013), our results show that from a business strategy perspective the type of eco-innovation being pursued is very important. Managers should pay attention to the type of eco-innovation they are engaging in and then should adapt their environmental strategy accordingly. Our results show that firms can only increase their turnover from eco-innovation in two ways: either by reducing their CO_2 footprint or by increasing their recycling of waste, water or materials. Moreover, these eco-innovations are triggered by different drivers. Looking at the strength of the drivers, in order of importance, we see that *reduced CO_2 footprint* is influenced by voluntary agreements, customer perceptions, government grants, existing regulations, backward linkages and intramural R&D, whilst the variables driving *recycled waste, water, or materials* are voluntary agreements, existing regulation, customer perceptions, extramural R&D and intramural R&D. These variations suggest that attempts to incentivise eco-innovation may need to be tailored to the specific type of environmental outcome desired.

Our results suggest that, at least in the short term (our data only has turnover data for 2008) firms neither gain or lose by implementing the remaining four types of process eco-innovation (*reduced material use per unit of output, reduced energy use per unit of output, replaced materials with less polluting or hazardous substitutes, reduced soil, water, noise, or air pollution*). Therefore, it is difficult to recommend that firms get involved in eco-innovation, but if they do decide to get involved, they should take into account their internal capabilities and skills (R&D, internal information from the company) and complement these with external knowledge flows through cooperation activities. In particular, for process eco-innovation, while all four types are driven by existing regulations, customer perceptions, and voluntary agreements, *reduced material use per unit of output* and *reduced energy use per unit of output* are also driven by backward linkages and intramural R&D, whilst *replaced materials with less polluting or hazardous substitutes* and *reduced soil, water, noise, or air pollution* are driven by expected regulation, government grants and extramural R&D. Therefore those interested in the former two types of process eco-innovation should invest their resources in developing links with suppliers and upgrading their employees skills, those interested in the latter two types should seek out government grants, outsource their R&D and should try to pre-empt changes in regulation.

Rather than increase turnover, product eco-innovation either has no impact (*reduced energy use*, and *reduced air, water, soil or noise pollution*) or significantly reduces turnover (*improved recycling of product after use*), at least in the short run. While consumer perception, voluntary agreements, existing regulation, government grants, are the strongest drivers of these types of innovation firms must weigh-up the costs and benefits of these types of innovation. If stakeholders want to foster these types of innovation then further incentives for firms may be required (either in the form of more regulations or subsidies etc.).

Overall, our results point to the possibility that environmental regulation and customer pressure can generate environmental benefits which may benefit firms, or at least not impact upon them. However, caution must also be observed as forcing firms to eco-innovate may result in a losing position for firms. This indicates that there is a need for policy makers to weigh up the environmental benefits which may accrue from regulation against the possible losses which may result at the firm level.

To summarise, from a firm's perspective it appears that certain types of eco-innovation can generate a positive return for both the firm and, presumably, the environment. Firms can also tailor their innovation inputs to maximise the likelihood of succeeding in these forms of innovation (as discussed in the preceding paragraphs). However, it also appears that at times firms may be 'forced' to eco-innovate, due to government regulations or consumer pressures, in areas which may not generate a tangible return to productivity but which may require incurring additional cost. If this is the situation facing the firm, eco-innovation may not be a choice and the strategic decision required by the firm becomes eco-innovating in a way that minimises the additional costs incurred. Again, as discussed previously this could entail tailoring the innovation inputs utilised to best satisfy the eco-innovation required (for instances in some cases intramural R&D may be more effective than extramural R&D or *vice versa*).

Table 1: Eco-Innovation Type and Eco-Innovation Drivers Proportions

	Mean (Standard Deviation)
Eco-innovation Types	
Environmental benefits from the production of goods or services within your enterprise	
Eco1: Reduced material use per unit of output	18.62%
Eco2: Reduced energy use per unit of output	22.19%
Eco3: Reduced CO_2 'footprint' (total CO_2 production)	21.64%
Eco4: Replaced materials with less polluting or hazardous substitutes	19.12%
Eco5: Reduced soil, water, noise, or air pollution	17.29%
Eco6: Recycled waste, water, or materials	33.70%
Environmental benefits from the after sales use of a good or service by the end user	
Eco7: Reduced energy use	20.17%
Eco8: Reduced air, water, soil or noise pollution	14.53%
Eco9: Improved recycling of product after use	22.01%
Eco-Innovation Drivers	
Regulation	
Existing Regulation (1/0)	16.87%
Expected Regulation (1/0)	12.61%
Government Grants (1/0)	5.96%
Demand Side	
Customer Perceptions (1/0)	16.23%
Voluntary Agreements (1/0)	17.88%
Supply-Side	
Forward Linkages (1/0)	7.48%
Backward Linkages (1/0)	9.87%
Horizontal Linkages (1/0)	3.06%
Public Linkages (1/0)	6.44%
Intramural R&D (€)	€2,054 (€10,253)
Extramural R&D (€)	€460 (€5,064)
Firm Specific Factors	
Employment	89 (246)
Irish Owned (1/0)	76
Capital (€)	€3,606 (€36,718)
Performance Indicator	
Turnover per Employee	€696,000 (€6,309,000)
Sector	
High-Tech Manufacturing (0/1)	30.03
All Other Manufacturing (0/1)	9.54
Wholesale, Transport, Storage and Communication (0/1)	35.12
Financial Intermediation (0/1)	10.82
Computer, Architecture and Engineering Services (0/1)	14.49

Notes: Data source is the Irish Community Innovation Survey 2006-08, Sectoral definitions are based on NACE Rev2.

Table 2: Multivariate Probit Estimation of Equation (1)

	Eco 1	*Eco 2*	*Eco 3*	*Eco 4*	*Eco 5*	*Eco 6*	*Eco 7*	*Eco 8*	*Eco 9*
Constant	-2.0606	-1.9614	-1.7232	-1.8202	-1.7755	-0.9399	-1.5925	-2.0094	-1.4232
	(0.1811)	(0.1704)	(0.1707)	(0.1801)	(0.1801)	(0.1556)	(0.1688)	(0.1749)	(0.1637)
Regulation Drivers									
Existing Regulation	0.5191***	0.4997***	0.4307***	0.5558***	0.5286***	0.6433***	0.4604***	0.3954***	0.4384***
	(0.1012)	(0.0958)	(0.0944)	(0.0967)	(0.0959)	(0.1006)	(0.0950)	(0.0929)	(0.0940)
Expected Regulation	0.2058	0.1310	0.1957	0.4204***	0.3799***	0.1138	0.1179	0.3128***	0.1808
	(0.1139)	(0.1103)	(0.1089)	(0.1098)	(0.1074)	(0.1173)	(0.1065)	(0.1035)	(0.1062)
Government Grants	0.1297	0.4257***	0.4346***	0.3194***	0.4395***	0.1070	0.2701**	0.2489**	0.2515**
	(0.1351)	(0.1353)	(0.1325)	(0.1310)	(0.1277)	(0.1399)	(0.1240)	(0.1190)	(0.1254)
Demand-Side Drivers									
Customer Perceptions	0.7867***	0.5495***	0.6643***	0.6795***	0.5331***	0.3807***	0.7917***	0.6863***	0.6670***
	(0.0962)	(0.0929)	(0.0927)	(0.0926)	(0.0920)	(0.0960)	(0.0902)	(0.0884)	(0.0889)
Voluntary Agreements	0.5450***	0.7209***	0.8340***	0.5765***	0.6487***	1.0574***	0.6064***	0.6512***	0.7651***
	(0.0936)	(0.0891)	(0.0879)	(0.0904)	(0.0899)	(0.0928)	(0.0868)	(0.0865)	(0.0852)
Supply-Side Drivers									
Forward Linkages	0.1136	-0.0316	-0.0160	0.1994	0.0130	0.0763	-0.0986	-0.0354	0.2627***
	(0.1686)	(0.1642)	(0.1627)	(0.1633)	(0.1648)	(0.1583)	(0.1541)	(0.1570)	(0.1516)
Backward Linkages	0.3471**	0.3615***	0.2690***	0.0576	0.0823	0.1339	0.2964**	0.0715	0.0629
	(0.1501)	(0.1453)	(0.1470)	(0.1503)	(0.1485)	(0.1439)	(0.1374)	(0.1402)	(0.1379)
Horizontal Linkages	0.1143	-0.0303	0.0431	0.2740	0.1317	-0.2406	0.2379	0.3708**	-0.0593
	(0.2108)	(0.2050)	(0.2097)	(0.2079)	(0.2114)	(0.1973)	(0.1912)	(0.1934)	(0.1891)
Public Linkages	0.0589	0.0477	-0.1394	0.1183	0.0888	0.0660	-0.0245	-0.0428	0.0943
	(0.1570)	(0.1504)	(0.1516)	(0.1540)	(0.1556)	(0.1555)	(0.1452)	(0.1479)	(0.1461)

Table 2: Multivariate Probit Estimation of Equation (1) (con.)

	Eco 1	Eco 2	Eco 3	Eco 4	Eco 5	Eco 6	Eco 7	Eco 8	Eco 9
Supply-Side Drivers Cont.									
Intramural R&D	0.0461***	0.0305***	0.0378***	0.0071	0.0140	0.0345***	0.0190	-0.0007	0.0077
	(0.0118)	(0.0114)	(0.0115)	(0.0118)	(0.0119)	(0.0109)	(0.0112)	(0.0116)	(0.0112)
Extramural R&D	0.0156	0.0274	0.0295	0.0648***	0.0459***	0.0369**	0.0155	0.0442***	0.0165
	(0.0170)	(0.0166)	(0.0164)	(0.0166)	(0.0165)	(0.0166)	(0.0159)	(0.0157)	(0.0158)
Sector[3]									
All Other Manufacturing (0/1)	0.1730	0.0293	-0.1306	0.2273	0.0039	-0.2239**	0.1123	0.1145	0.1154
	(0.1211)	(0.1164)	(0.1190)	(0.1193)	(0.1183)	(0.1140)	(0.1147)	(0.1153)	(0.1123)
Wholesale, Transport, Storage and Communication (0/1)	-0.2177**	-0.2347***	-0.1308	-0.1031	-0.2388***	-0.2101***	-0.0242	-0.0545	0.0923
	(0.0953)	(0.0883)	(0.0890)	(0.0907)	(0.0900)	(0.0786)	(0.0866)	(0.0889)	(0.0817)
Financial Intermediation (0/1)	-0.2079	-0.4288***	-0.2253	-0.4675***	-0.8013***	-0.5249***	-0.3242**	-0.5765***	-0.3846***
	(0.1422)	(0.1404)	(0.1367)	(0.1524)	(0.1635)	(0.1195)	(0.1360)	(0.1584)	(0.1307)
Computer, Architecture and Engineering Services (0/1)	-0.3314***	-0.2226**	-0.1371	-0.3550***	-0.6509***	-0.3233***	-0.0052	-0.1256	-0.2431***
	(0.1237)	(0.1112)	(0.1116)	(0.1180)	(0.1266)	(0.0991)	(0.1078)	(0.1115)	(0.1068)
Firm Specific Factors									
Employment	0.1281***	0.1949***	0.1458***	0.0606	0.0854***	0.0739***	0.0326	0.0762**	-0.0150
	(0.0344)	(0.0329)	(0.0329)	(0.0343)	(0.0346)	(0.0308)	(0.0322)	(0.0333)	(0.0315)
Irish Owned	0.0876	-0.0602	-0.2896	0.1431	0.0537	-0.1165	0.0893	0.1480	0.2197***
	(0.0914)	(0.0844)	(0.0843)	(0.0912)	(0.0910)	(0.0790)	(0.0858)	(0.0880)	(0.0844)
Obs									2,127
Chi2									1,766.13
Prob > Chi2									0.0000
Log-Likelihood									-5,371.81

Note 1: *** indicates significant at 1% level and ** indicates significant at the 5% level
2: Standard errors are given in parentheses
3: High-technology is the reference category
4: Each Eco heading corresponds to a type of eco-innovation in Table 1. (1) Reduced material use per unit of output, (2) Reduced energy use per unit of output, (3) Reduced CO_2 'footprint' (total CO_2 production) by your enterprise, (4) Replaced materials with less polluting or hazardous substitutes, (5) Reduced soil, water, noise, or air pollution, (6) Recycled waste, water, or materials, (7) Reduced energy use, (8) Reduced air, water, soil or noise pollution, (9) Improved recycling of product after use.

Table 3: Ordinary Least Squares Estimation of Equation (2)

	Coeff	s.e.
Constant	4.66497	(0.1908)
Innovation Activity		
Eco1: Reduced material use per unit of output	0.3775	(1.0473)
Eco2: Reduced energy use per unit of output	-1.3799	(1.5529)
Eco3: Reduced CO ’footprint’	3.1816***	(1.0570)
Eco4: Replaced materials with less polluting or hazardous substitutes	0.7502	(1.2646)
Eco5: Reduced soil, water, noise, or air pollution	-2.0039	(1.4095)
Eco6: Recycled waste, water, or materials	1.1210**	(0.6250)
Eco7: Reduced energy use	0.4582	(1.6371)
Eco8: Reduced air, water, soil or noise pollution	1.1465	(1.5621)
Eco9: Improved recycling of product after use	-3.3360***	(1.0886)
Sector[3]		
All Other Manufacturing (0/1)	0.2459**	(0.1168)
Wholesale, Transport, Storage and Communication (0/1)	0.5777***	(0.0967)
Financial Intermediation (0/1)	0.4352***	(0.1300)
Computer, Architecture and Engineering Services (0/1)	-0.4132***	(0.1232)
Firm Specific Factors		
Employment	0.0321	(0.0486)
Capital	0.0088	(0.0087)
Obs		2,127
F		15.84
Prob > F		0.0000
R2		0.1012

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

2: Variables expressed in natural logarithms.

3: High-technology manufacturing is the reference category.

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[i] Note this was the first time such questions were included in the Irish survey so it is not possible for us to conduct a longitudinal study. In addition these questions are not included in the 2009-2011 survey which is currently underway.

[ii] The use of this flow variable as a proxy for capital is consistent with Doran and O'Leary Doran J, O'Leary E. 2011. External Interaction, Innovation and Productivity: An Application of the Innovation Value Chain for Ireland. *Spatial Economic Analysis* **6**(2): 199 - 222. **DOI**: 10.1080/17421772.2011.557777..