Regulation and Firm Perception, Eco-Innovation and Firm Performance

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Abstract

Purpose - Recent OECD (2010, 2011) reports argue that eco-innovation is the key to realising growth. The purpose of this paper is to analyse the drivers of eco-innovation and to compare the impact of eco-innovation and non-eco-innovation on firm performance. The paper provides insights into the role government regulation can play in directing and stimulating eco-innovation.

Design/methodology/approach - The approach utilised by this paper is empirical in nature. A modified innovation production function is used to assess the impact of regulation, consumer expectations and voluntary agreements on the performance of eco-innovation while a knowledge augmented production function is used to assess the impact of eco-innovation on firm performance.

Findings - The findings suggest that regulation and customer perception can explain a firm's decision to engage in eco-innovation. Eco-innovation is also found to be more important than non-eco-innovation in determining firm performance.

Research limitations/implications - Due to the limited availability of accounting data this paper uses turnover per worker as the measure of firm performance. As a result it is not possible to assess the impact of eco-innovation on firm costs.

Social implications - The finding that regulation drives eco-innovation and that there is no trade-off between the optimal outcomes of lower levels of pollution for society and higher profit margins for businesses suggests that regulators and policy makers can stimulate growth and create a greener society.

Originality/value - This paper provides an empirical analysis of the Porter and van der Linde's (1995) theory of environmental regulation and firm performance using novel real world data from over 2,000 Irish businesses.

Keywords: Eco-innovation, Environmental regulation, Firm performance, Ireland
Paper type: Research paper

1. Introduction

For many firms innovation is the key to survival (Schumpeter 1934, Baumol 2002). It 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. As governments around the world strive to tackle carbon emissions and climate change, and firms struggle to deal with increasing fuel costs and financial uncertainties more and more emphasis is been placed on innovation, and in particular eco-innovation (Ekins, 2010). Eco-innovation is where firms develop or adapt innovations which diagnose, monitor, reduce or prevent environmental problems (Beise and Rennings 2003; Hemmelskamp 1997). Kemp et al. (2004) argue that eco-innovations may be technical, organisational or marketing innovations. 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. For some firms this involves simply substituting hazardous substances, saving energy, managing their waste or reducing emissions, whilst for others it involves designing and using pollution control, waste management and green energy technologies. In this study we examine the economic drivers of eco-innovation in 2,181 Irish firms and ask whether these innovations impact on firm performance.

Eco-innovation stimulates economic growth and development (Halila and Rundquist 2011). The eco-industry was one of the most dynamic sectors of the EU's economy in the 1990s with an annual growth of up to 5% (European Commission 2006). In 2008 eco-industries in the EU had an estimated turnover of €300 billion and directly employed approximately 3.4 million people (European Commission 2009). Today many claim that this industry has the capability to help the world recover from the current global financial crises (see Schweinfurth 2009; Cainelli et al. 2011). Bleischwitz et al. (2009) argue that the crisis has incentivised firms to move towards more efficient energy use and more sustainable manufacturing/ operating practices. This incentive to eco-innovative has been strengthened by the many recent OECD government stimulus packages which contain an environmental element. Examples of these include car scrapping policies, incentives to create smart energy systems, tax incentives to encourage housing insulation, incentives to foster green ICTs etc (OECD 2009; OECD 2009a).

Ireland's eco-innovation performance is very close to the EU average and Ireland is ranked ninth in the 2010 Eco-innovation Scoreboard (Eco-innovation Observatory 2011). Currently 18,750 employees work in six key sectors[1] of the green economy and this is predicted to increase to 29,000 by 2015 (Forfas 2010). In 2010 alone €660 million was directly committed by the Irish Government to sustainable energy programmes, water services investment and the retrofitting of public housing (High-Level Group on Green Enterprise 2011). It has been noted that heightened environmental awareness and improved regulation have played a large part in this sectors development (Department of Enterprise, Trade and Employment 2008). The Irish Government strongly supports further developments in the eco-innovation sector and has designated it as one of Ireland's target sectors for investment and job creation (High-Level Group on Green Enterprise 2011). Thus, from a policy perspective it is important that we examine the impact of government grants on this sector.

While traditionally many economists and managers thought of eco-innovation as an additional cost burden for the firm this is no longer the case (Ambec et al. 2011). Authors such as Porter and van der Linde (1995) argue that investments in eco-innovation can improve a firms' competitiveness, increase its profits and reduce pollution. They argue that environmental innovations may lead to a 'win-win' situation with both economic and environmental benefits. Horbach (2008) argues that one difficulty faced by society is that often firms do not recognise this 'win-win' opportunity and as a result eco-innovations are less market-driven than other innovations. Consequently many authors argue that correctly designed governmental regulations and institutional arrangements have a positive impact on eco-innovation (see for example Porter and van der Linde 1995; Beise and Rennings 2003; Halila and Rundquist 2011). In this study we test whether government regulations (existing and expected) and/or industry codes of practice have an impact on a firms' decision to eco-innovate in Ireland.

Using data for 2,181 firms collected as part of the Irish Community Innovation Survey 2006-08 this paper asks (1) what are the key economic drivers of eco-innovation in Ireland and (2) how do eco-innovators perform when compared to non-eco-innovators. Briefly, our ideas are developed as follows: Section 2 uses the literature to identify factors that may drive eco-innovation and how these may impact on firm performance; Sections 3 introduces the modified innovation production function and knowledge augmented production function. Section 4 introduces the data and comments on some key summary statistics. Section 5 presents our empirical results and Section 6 concludes our study.

2. Literature Review

Environmental innovations involve many areas of knowledge and many different industrial sectors (Vinnova 2001). In this section using the literature we begin by defining what we mean by eco-innovation. Next we review the demand, supply and regulation-induced drivers of eco-innovation and we examine the Porter and van der Linde (1995) hypothesis. We conclude by reviewing how other firm specific factors such as the size of the firm impacts on eco-innovation behaviour.

2.1 What is Eco-Innovation?

The OECD (1991) define innovation as "an iterative process initiated by the perception of a new market and/or new service opportunity for a technological-based invention which leads to the development, production and marketing tasks striving for the commercial success of the invention" (Garcia and Calantone 2002; 112). Garcia and Calantone (2002) note that this definition implies that the innvoation process is iterative, with different levels of innovativeness. Schumpeter (1934), however, notes the importance of non-technological, as well as technological, innovation for firm performance. As a result of this, the Oslo Manual, developed by the OECD (2005), identifies four distinct types of innovation activity which are a mix of both technological and non-technological innovation; (i) product innovation, (ii) process innovation, (iii) organisational innovation and (iv) marketing innovation. Each of these forms of innovation can contain components of eco-innovation (Hemmelskamp 1997).

Horbach (2008) defines eco-innovation as "consist[ing] of new or modified processes, techniques, systems and products to avoid or reduce environmental damage". While Kammerer (2009) notes that an eco-innovation can be defined as 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 simply an analysis of new product technologies which are introduced by firms. This constitutes only a small proportion of the innovations introduced by firms and other forms of innovation such as process innovation and organisational change can also be thought of as important innovations. He argues that this 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.

In keeping with Hemmelskamp's (1997) this paper does not narrow its focus to the consideration of only technological innovation, but instead utilises the full scope of the OECD's (2005) definition of innovation.

2.2 Eco-Innovation Drivers

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. 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. As a result firms harm the environment too much and innovate too little (Johnstone, Haščič and Kalamova 2010). Consequently while researchers examining the broad field of innovation comment on the importance of technology push (supply side) and market pull (demand side) drivers (Åstebro and Dahlin 2005), those focusing on eco-innovation stress the additional importance of regulation, environmental policy, institutional and political drivers (Horbach 2008; Horbach and Rennings 2007; Rehfeld, Rennings, and Ziegler 2007; Hemmelskamp 1999). We examine each of these drivers below.

2.2.1 Supply and Demand Eco-Innovation Drivers

Kesidou and Demirel (2010) argue that supply-side drivers, such as a firms' technological and organisational capability, are important triggers of eco-innovation. Technology push drivers are particularly important in the initial development phase of eco-innovation (Horback 2008; Rehfeld et. al. 2007). These drivers are nurtured by developing a firm's internal innovation capabilities (Triebswetter et al. 2008) - the more innovative a company and the more knowledge it has accumulated, the higher its capacity to apply these factors to environmental innovation. Firms with a high engagement in R&D activities may be viewed as possessing more potential for eco-innovation. Kemp et al. (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. Horbach (2008) builds on this argument by noting that firms interested in eco-innovation will implement an environmental management system. This is a voluntary framework which creates awareness within firms (Rehfeld et al. 2007), assesses their impact on the environment (Darnall 2006), stimulates them to eco-innovate (Rehfeld et al. 2007), and in some cases helps them get ahead of existing government regulations (Kollman and Prakash 2002). Since "innovation breads innovation" (Baumol 2002: 284) firms that invest in R&D and build technological and organisational capabilities are likely to induce further innovation.

Demand side drivers (also known as market-pull drivers) become more important at the diffusion stage of innovation (Horback 2008; Wagner 2007; Rehfeld et. al. 2007). Consumer demand for environmentally friendly products, public procurement requirements, and exports all have a part to play in the market for eco-innovation. Horbach (2008) in his study of German manufacturing firms finds that firms who expect their turnover to increase are more likely to be eco-innovators while Wagner (2007), in his study of German manufacturing firms, finds that collaboration with environmentally concerned stakeholders is an important determinant of eco-innovation. Cainelli et al. (2011) argue that competition between firms can drive eco-innovation while Wüstenhagen (2009) claims that some firms brand themselves as 'eco-friendly' and then use this as a quality-signal to consumers in the market. Empirical evidence shows that the pressure to eco-innovate is strongest in product markets which are close to final consumers. Guagnano (2001), for example, report that eighty-six percent of customer will pay more for household products which are less harmful to the environment and this willingness to pay fuels eco-innovation. Manget, Roche and Münnich (2009) find that consumers in Canada, France, Germany, Italy, Japan, Spain, the United Kingdom and the United State are willing to pay five to ten percent more for green goods.

While many authors find evidence that consumer demand is a key driver of eco-innovation, Belin, Horbach and Oltra (2009) note that in general demand side factors are better triggers of innovation rather than eco-innovation. Loureiro et al., (2002) find that while females with children may pay a small premium for eco-friendly goods, other consumers are not always willing to pay a premium for environmental friendly products and as a result Zhang, Gensler and Garcia (2011) argue that firms contemplating eco-innovation can be faced with a prisoners' dilemma where eco-innovation may be a losing strategy. Others such as Kesidou and Demirel (2010) find that consumer demand and societal requirements for corporate social responsibility impact on a firms likelihood of eco-innovating but does not impact on the level of their investment. In their study of 1,566 UK firms, they found that firms undertake some minimum level of eco-innovation activities in response to market pressure but these factors do not necessarily encourage them to commit large amounts of resources into eco-innovation. Similar results were found by Suchman (1995) who noted that firms may undertake only the minimum investment in eco-innovation so as to legitimise their practices and improve their 'green' image. This issue is a major concern for environmental regulators and standards authorities who strive to design policies which incentivise firms to do much more than meet minimum requirements.

2.2.2 Regulation as an Eco-Innovation Driver

Surprisingly there is no commonly agreed definition of the term 'regulation'. While the most widely cited definition by Selznick (1985, p.363) defines regulation as "sustained and focused control exercised by a public agency over activities that are valued by a community," Baldwin and Cave (1999) argue that this definition is old-fashioned and fails to reflect the many regulatory strategies used in markets today. Despite the lack of an agreed definition Dewing and O. Russell (2004, p. 108) argue that "regulation is justified since the market fails to produce behaviour or results that are in the public interest." There are many regulatory strategies at the disposal of governments and regulatory agencies including command and control regulation, self-regulation, incentive based regimes, market harnessing controls, disclosure regulation, direct action, rights and liabilities and public compensation schemes (Baldwin and Cave 1999). The effectiveness of policies based on these strategies is largely shaped by the compliance culture and implementation process in each country/region (Kemp et al. 2000). As a result Kemp et al. (2000) argue that regulation does not start or stop innovation but instead shapes it.

Many authors argue that regulation is the most important driver of eco-innovation (Porter and van der Linde 1995; Kammerer, 2009) with other incentives such as cost reductions, interest group campaigning and the effect of supply chain pressure also playing a large role in nurturing a greener environment (Leitner, Wehrmeyer and France 2010). In an imperfect market Rennings (1998) argues that eco-innovation policy is the most cost efficient strategy to deal with the double externality facing firms (this is due to the spill-over effects resulting from R&D expenditure on new innovations and from the spill-over effects resulting from the new products and services themselves). Kemp et al. (2000) propose 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) concurs with this view and argues that regulations can drive innovation by incentivising firms to think differently while also providing them with information about how to change/adapt their technologies. In addition environmental regulation can often help firms with limited information about consumer needs and wants. Indeed 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, Gensler and Garcia 2011). It is important to note at this point that regulation is not always needed. In some cases consumer demand, interest group pressures and social corporate responsibility is enough to induce firms to develop/adapt/use more environmentally friendly products, process and management systems (Hörte and Halila, 2008).

Of the many instruments available to eco-innovation regulators Requate (2005) finds evidence that command and control regulation is less effective than market based regulation. Command and control regulation works through technology standard setting (for example a regulatory authority may tell firms that they must adopt a certain technology or process), emission standards setting or through the setting of relative standards (this is where firms' face a cap on the ratio of emissions per output). Market based instruments, on the other hand, work by offering incentives through prices. Based on the charges imposed firms can then decide how much they wish to pollute. Of the many instruments available to regulators (e.g. taxes, subsidies, tradable permits) Requate (2005) finds evidence that taxes and subsidies are most effective, particularly when the regulator is myopic or is unable to anticipate new technology. Both of these instruments operate in the same way, in that a regulator levies a linear tax per unit of a pollutant or pays a subsidy per unit of abatement. In this way the firm pays the same marginal price for each unit of pollution. While Johnstone (2005) argues that the choice of regulatory strategy should be flexible and be able to adapt to changing market conditions, Johnstone, Haščič and Kalamova (2010) find evidence that less rigid innovation regulations based on taxes and tradable permits are more effective at inducing eco-innovation than strict performance standards or technology based controls. They also find evidence that any policy that sets a strict price for polluting incentivises firms to search for ways to avoid these costs and they find that any increase in that price induces further innovation (especially air, water and waste management innovation). Horbach et al. (2011) find additional support for this claim in his analysis of German manufacturing firms.

Within the literature there are two opposing views regarding the impact of environmental regulation on innovation and performance. The traditional view, also known as the cost-based view, argues that the costs incurred by a firm as a result of strict environmental regulation reduce its competitiveness and productivity (Palmer et al., 1995). Advocators of this view argue that following the introduction of new environmental regulations firms redistribute their exiting labour and capital resources so as to meet the new requirement and consequently resources are diverted away from productive investments. Thus regulations infer with the competitive nature of firms and in many cases this can impact on a firms' ability to trade internationally. The second view purported by authors such as Porter and van de Linde (1995) argues that correctly designed environmental regulations stimulate innovation and open up 'win-win' opportunities which result in increased productivity and a greener environment. These regulations may lead to innovation which can compensate for the costs of adaptation and in addition may give firms a competitive advantage (based on either a learning effect or patent protection) particularly if the new innovation later diffuses internationally (Leitner, Wehrmeyer and France 2010). As there is considerable support for the Porter and van der Linde Hypothesis (see review in Ambec et al. 2011) we examine this in greater detail below.

2.3 The Porter and van der Linde (1995) Hypothesis

Porter and van der Linde (1995) hypothesise that regulation can drive eco-innovation and that this eco-innovation has a positive effect on firm performance. This is counter to the traditional view of eco-innovation, mentioned above, which views the socially desirable outcome of less pollution as being incompatible with the desirable business outcome of profit maximisation (Horbach 2008). Horbach (2008) notes that since most environment problems represent negative externalities there is a lack of engagement by firms in eco-innovation. As a result there is a need for policies which push firms into eco-innovating.

Porter and van der Linde (1995) raise the point that when considered this way the question is to what extent should we restrict business to benefit society if we assume that there is a trade-off between what is good for society (less pollution) and what is good for business (more growth). This perception results in "one side push[ing] for tougher standards; [while] the other tries to beat the standards back" (Porter and van der Linde 1995: pp 97). This is the case in a static world, however, the real world is far from static and there is a need for businesses to continually innovate. In a static world all firms make their cost-minimising decisions and these choices do not vary. The introduction of environmental regulation raises costs and results in a negative outcome for businesses. However, in the real world, where dynamic competition exists, innovation and movement from one cost-minimising position to the next is necessary. This implies that change brought about by eco-innovation may not be negative, provided it moves the firm from one cost minimising position to another.

Porter and van der Linde (1995) argue that environmental regulation can trigger innovation that may partially or more than fully offset the costs of complying with them. Such "innovation offsets" not only lower the net costs of meeting the environmental regulation but also can lead to absolute advantage over other firms in other countries which are not subject to the regulation. Basically providing the firm with a first mover advantage. Innovation offsets often occur as reducing pollution often involves the improvement of the productivity with which resources are used. In other words, firms can actually benefit from regulation as it forces them to innovate which has benefits for the business.

These "innovation offsets" outlined by Porter and van der Linde (1995) can occur in two ways. The first is that firms become more adept at dealing with pollution once it occurs. This sort of innovation reduces the cost of complying with pollution controls but changes nothing else. The second form of innovation addresses environmental impacts while simultaneously improving the affected product itself and/or related process. In this instance it is possible for the innovation offsets to exceed the cost of compliance with environmental regulation.

Arguments against this line of thought suggest that businesses, by the principle of profit seeking behaviour, will pursue all profitable innovations of their own accord. If introducing an environmental innovation would benefit the firm then Jaffe, Peterson, Portney and Stavins (1995) argue that the firm would already have taken this profit maximising action. Porter and van der Linde (1995) argue against this reasoning by noting that dynamic competition implies changing technologies coupled with highly incomplete information, organisational inertia and control problems reflecting the difficulty of aligning individual, group and corporate incentives. They argue companies have numerous avenues for technological advancement, but only limited attention. Essentially suggesting that they pass some innovation opportunities by or that they do not even identify some innovation opportunities. In addition, recent research in the behavioural finance field argues that managers may not be profit-maximising for a number of reasons including, they may be risk-averse (Ravidy 1994), hesitant to make any changes which could impose large additional costs on their firm (Ambec and Barla 2007), or the ideas could be outside the managers habits and routines, i.e. they could be rationally bounded (Gabel and Sinclair-Desgagné 1998). Ambec et al. (2011) argues that environmental regulations could help managers overcome many of these behavioural problems.

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). Porter and van der Linde (1995) note that properly crafted regulation can have six uses; (i) regulation can signal companies about likely resource inefficiencies and potential technological improvements, (ii) regulation focused on information gathering can raise corporate awareness, (iii) regulation reduces the uncertainty that investments to address the environment will be values, (iv) regulation can create pressure that motivates innovation and progress, (v) regulation levels the transitional playing field and (vi) regulation is needed in the case of incomplete offsets. The strictness of the regulation may also impact of the propensity to eco-innovate. It is worth noting that Porter and van der Linde do not argue that all regulation leads to innovation or indeed that all innovation offsets the cost of regulation. They simply argue that *well-designed* regulations lead to innovation and that in *many* cases these innovations will off-set the cost of the regulation (Ambec et al. 2011).

2.4 Other Factors Which May Impact Eco-Innovation

Other firm specific characteristics may also impact of the likelihood of eco-innovation. Sak and Taymaz (2004) contend that small firms are likely to be more flexible and adaptable and therefore more responsive to changes in consumer demand to eco-innovative. On the other hand, larger firms have a higher degree of financial and human capital and are therefore in a better position to fund more long term and speculative projects (Baylis et al. 1998). Additionally, larger firms may be better known and therefore subject to increased levels of consumer scrutiny than smaller firms. As a result they will be keener to show that they are attempting to reduce their impact on the environment through the introduction of eco-innovations (Kammerer 2009). Moreover, many authors show that larger firms patent more than smaller firms and therefore innovate more (Kleinknecht et al. 2002; Rehfeld et al. 2007;

Wagner 2007). Leitner, Wehrmeyer and France (2010) argue that when strict environmental regulations are imposed, smaller firms are likely to experience a greater immediate financial burden and consequently are less likely to be in a position to innovate. This impact adjusts over time as these smaller firms use new greener products and process which have been designed and tested by other firms in the market. In a way these firms are eco-innovation adopters rather than eco-innovation inventors.

2.5 Eco-Innovation and Firm Performance

There is no overall consensus in the literature regarding the relationship between environmental regulation and productivity. Alpay, Buccola, and Kerkvliet (2002) in a comparison of the US and Mexican food industries, found that when Mexico increased its pollution controls this lead to enhanced food production and productivity growth. Lanoie et al. (2011), in a study of 4200 facilities in seven OECD countries, find evidence that environmental regulation induces innovation and that the costs of complying with this regulation are partially offset by this new innovation. Rassier and Earnhart (2010), on the other hand, find that tighter water regulation increases costs and hence reduces the profitability of publicly held firms operating within the chemical manufacturing industries. Similarly Brännlund and Lundgren (2010) find evidence that the CO_2 tax in Sweden reduces the profitability of most firms, especially those in energy-intensive industries. Iraldo, Testa, Melis and Frey (2011) argue that the source of the regulation and the environmental assets it seeks to protect has a large impact on productivity growth/ decline. In addition other business characteristics, such as the industrial sector in which the firm is located and the associated ability of the firm to pass any increased costs to the consumer, are also likely to play a large part in the impact on productivity.

Mazzanti and Zoboli (2006) argue that the need for environmental policies and regulation differs across industrial sectors. Moreover, the ability of firms to adapt to or comply with new policies and regulations varies across sectors. In general when consumer demand for green products and services is strong there no need for strict regulations, but when demand is low, as in the petroleum products and metal manufacturing sectors, then regulation is particularly important (IVA, 1995). In addition Horbach (2008) notes that firms with high average sales are likely to be more innovate in general, and by default more eco-innovative. In certain industries, such as electronics, where demand for products has exploded over the last few decades, firms are using large-scale Internet discussion groups, known as "innovation jams", to look for and harness innovative ideas which can help them to produce more energy efficient products and to find ways to dispose of these products at the end of their life (OECD, 2009b). Barsoumian, Riggio, Severin and van der Spek (2011, p. 7) report that industries which build tight-knit networks can benefit greatly from highly integrated supply chains which allow for cost reductions as these firms share "key assets such as infrastructure and services, including environmental services, access to major transport modes and proximity to market and customers." This allows these industries to remain globally competitive while also reducing their energy use and carbon footprint.

3. Methodology

The methodology employed by this paper is a modified version of which is typically referred to in the literature as the CDM model. The CDM model, derived by Crépon, Duguest and Mairesse (1998), analyses the process whereby firms generate knowledge, use this knowledge to derive innovation output and exploit this innovation output for productivity gains. This paper focuses on the latter two stages, (i) the determination of innovation output and (ii) the exploitation of this innovation output for productivity gains. As noted earlier the central focus is on what drives eco-innovation and whether eco-innovation is as efficient as non-eco-innovation at generating higher levels of turnover for firms.

The starting point for the empirical analysis is an innovation production function. The innovation production functions relates innovation inputs and conditioning factors to a firms' innovation output (Roper, Du and Love 2008; Hall, Lotti and Mairesse 2009; Doran and O'Leary 2011). Equation (1) specifies the innovation production function estimated by this paper.

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

Where IO_i is a binary variable indicating whether firm *i* engaged in eco-innovation, 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.

$$X = (IrishOwned, Employment, Sector) \quad (2)$$

Where 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. Previous research has shown that these factors can impact on the innovation propensity of firms (Pavitt 1984; Love and Roper 1999; Freel 2003).

As the dependent variable in equation (1) is a binary indicator of innovation output, a probit model is utilised to estimate the model. Also, as is standard in the literature, continuous variables such as R&D expenditure and Employment are expressed in natural logarithms. White's heteroskedastic standard errors are used to avoid the problem of heteroskedasticity which can occur in cross sectional data (Greene 2008).

Following from the above, in order to analyse the impact of eco-innovation on firm performance a knowledge augmented production function is estimated (Griliches 1979; Klomp and Van Leeuwen 2006; Love and Mansury 2007). The production function specified is displayed as equation (3):

$$\Pr od_i = \beta_0 + \beta_1 Innovator_i + \beta_2 EcoInnovator_i + \beta_j Z_{ji} + \varepsilon_{2i} \quad (3)$$

Where $Prod_i$ indicates firm *i*'s turnover per employee, $Innovator_i$ indicates whether the firm has introduced an innovation (either ecological or non-ecological), $EcoInnovator_i$ is an interaction term which indicates whether firm *i*'s innovation was an eco-innovation, Z_{ji} is a series of firm specific variables, ε_{2i} is the error term and the βs are the associated coefficients. An interaction term is utilised in equation (3) to identify the unique impact of an eco-innovation on firm performance. The use of an interaction term is necessary as the data identifies whether a firm introduces a number of types of innovation and subsequently whether any one of the innovations introduced by the firm was an eco-innovation. Therefore, it is not possible, using the CIS data, to create two mutually exclusive variables for eco-innovation and non-eco-innovation. However, the use of an interaction term distinguishes between their effects on productivity (Green 2008).

The series of control variables Z_{ji} is defined as:

$$Z_{ij} = (Capital_i, Employment_i, Sector_i) \qquad (4)$$

Where $Capital_i$ is the expenditure of the firm per employee on the acquisition of capital for the production of new products or services during the reference period, which acts as a proxy for the capital stock of the firm. The use of this flow variable as a proxy for capital is consistent with Doran and O'Leary (2011). All other variables are defined as before.

Again, 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 both forms of innovation output in equation (3) are actually endogenous (Crépon et al. 1998). Therefore, estimation of equation (3) 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, Huergo, Mairesse and Peters 2006). Initially, equation (1) is estimated for eco-innovators and innovators (see Appendix 1 for a discussion of the estimation of equation (1) for innovators and for the results of this estimation). Predicted probabilities are then derived from each of these estimations. These predicted probabilities are then utilised as instruments in equation (3), correcting for the potential endogeneity problem (Greene 2008).

4. Data

The data set utilised by this paper is the Irish Community Innovation Survey 2006-08. This survey was conducted jointly by Forfás (Ireland's national policy advisory body) and the Central Statistics Office in Ireland. The survey is directed to companies employing more than 10 persons engaged in a range of sectors. The CSO and Forfás jointly conducted a postal survey in December 2009. Consistent with the OECD's Oslo manual, the survey includes a reference period, which in this case is 2006 to 2008, for innovation inputs and outputs (OECD 2005). A total of 4,650 surveys were issued with 2,181 responses. The target for the Irish CIS is the complete range of manufacturing sectors, with selected service sectors (CSO 2010). The motivation for the CIS survey is to provide a comprehensive survey of the innovation performance of Irish firms. The survey is conducted as part of the European wide Community Innovation Survey project and is completed every two years (CSO 2010).

This paper identifies two types of innovation; regular innovation and eco-innovation. The Irish CIS is structured in such a way as to provide information on whether firms engaged in regular innovation activity (defined as product, process, organisational or marketing innovation) and subsequently whether any of these innovations were eco-innovations. This allows for the definition of two innovation indicators, a binary variable indicating whether the firm engaged in any innovation activity and a binary variable indicating whether any of those innovations were eco-innovations. Due to the phrasing of the questionnaire it is not possible to distinguish between innovations which were ecological and innovations which were not ecological in mutually exclusive terms.

Eco-innovation is defined as a new or significantly improved product (good or service), process, organisational method or marketing method that creates environmental benefits compared to alternatives. The Irish CIS essentially defines eco-innovation as a subset of other innovation activities. A number of different types of innovation activity are considered to have ecological benefits; these are displayed in Table 1. Firms which engage in any of these activities are defined as eco-innovators.

[Insert Table 1 around here]

Table 2 displays the descriptive statistics of the variables utilised in this paper. Approximately 59% of firms are identified as innovators. Innovators are defined as firms which have engaged in product, process, organisational or marketing innovation during the reference period. While 42% of firms introduced eco-innovation during the reference period.

[Insert Table 2 around here]

Regarding factors which may impact on the likelihood of firms engaging in eco-innovation, the CIS provides five variables which indicate the impact of regulation and firm perception on firms' decisions to engage in eco-innovation. Firms are required to indicate whether (i) existing government regulation or taxes on pollution, (ii) Environmental regulations or taxes they expect to be introduced in the future, (iii) the availability of government grants, subsidies or other financial incentives for environmental innovation, (iv) current or expected market demand from their customers for environmental innovations or (v) voluntary codes or agreements for environmental good practice within their sector impacted on their decision to engage in eco-innovation. The availability of government grants appears to be the least important (experienced by only 6% of firms) while existing regulation, customer perceptions and voluntary agreements appear to be the most frequently experienced (ranging from 16.23% to 17.88%).

Freel (2003), McCann and Simonen (2005) and Roper et al. (2008) highlight the importance of external knowledge sources for innovation. The Irish CIS provides information on whether firms engage in collaboration with customers, suppliers, consultants, competitors, universities and public research institutes in the development of new innovations. In line with Roper et al. (2008), this paper classifies these differing types of interaction into four categories; 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.

As outlined above numerous studies have highlighted the importance of research and development (R&D) for innovation activity (Cohen and Levinthal 1990). This paper considers two forms of R&D; 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 with a standard deviation of €10,253 and the mean expenditure of firms per employee on extramural R&D is €460 with a standard deviation of €5,064.

The measure of firm performance utilised by this paper is turnover per worker. Turnover is taken from the business register held by the Irish CSO. It can be observed that the mean turnover per employee of firms is €696,000 with a standard deviation of €6,309,000. The mean employment size of firms is 89 with a standard deviation of 246. 76% of firms are Irish owned.

To proxy for the capital stock per worker the firm's expenditure on the acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes is used. While, ideally, the capital stock per worker should be included this is not possible for a lot of studies which use CIS type datasets as this information is not available. Mansury and Love (2008) also use a flow variable, using capital investment per employee, as a proxy for capital stock for their sample of US manufacturing firms while Doran and O'Leary (2011) use an identical measure of capital to this paper. The mean expenditure by a firm per employee on the acquisition of capital is €3,606 with a standard deviation of €36,718.

The Irish CIS targets a broad range of sectoral classes. The NACE Rev2 sectoral classifications are utilised by the Irish CSO to categorise firms into sectors. This paper follows these sectoral definitions and identifies nine broad sectors in which firms operate. Further information on the NACE Rev2 definitions can be obtained from EuroStat (2008).

5. Empirical Results

Table 3 presents the results of the probit estimation of equation (1) for the probability of eco-innovation. It can be observed that all of the regulation and perception variables are statistically significant, indicating that the propensity for firms to engage in eco-innovation is strongly dependent on regulations and perceptions. Regarding the magnitude of the marginal effects, it can be observed that voluntary agreements have the largest impact on the probability of eco-innovation. Firms which enter into voluntary agreements are 47% more likely to eco-innovate than firms which do not enter these agreements. This perhaps suggests that firms which agree to implement eco-innovations are reluctant not to follow through on their promises even though they voluntarily entered into the agreement. Alternatively, it may suggest that firms enter into voluntary agreements which are relatively minor and that they know they can complete. This is similar to the argument put forward by Hemmelskamp (1997) who suggests that firms may be cautious of implementing too great a reduction in negative pollution externalities as, to markedly reduce pollution, may send a signal to policy makers that further reductions may be possible. Therefore, voluntary agreements may require a less radical form of eco-innovation explaining their strong positive effect.

The next largest effect is customer perceptions. Firms which believe customers expect environmentally friendly products are 43% more likely to eco-innovate. This is consistent with the empirical results of Kammerer (2009). As noted by Horbach (2008) market-pull factors such as changing customer demands and preferences may impact on the direction and rate of eco-innovation. Consumers are becoming increasingly demanding of products and services which have a lower impact on the environment (Porter and van der Linde 1995). Hemmelskamp (1997) notes that these changing consumer preferences force firms to innovate and reduce the environmental impact of their product. The results in Table 3 suggest that firms respond strongly to consumer demands when considering whether or not to eco-innovate.

Following this, existing regulation is found to have a significantly positive effect on the likelihood of eco-innovation. Firms which experience regulation are 27% more likely to eco-innovate relative to firms which do not experience environmental regulation. This is consistent with existing literature which suggests a strong positive association between environmental regulation and subsequent eco-innovation (Rennings and Rammer 2011). This result is anticipated as with the introduction of a regulation firms have no option but to comply through introducing new innovations (Porter and van der Linde 1995). Government grants, as oppose to regulation, can be viewed as a potential alternative approach to encouraging eco-innovation. Again, firms which avail of grants are more likely to introduce eco-innovation; however, the responsiveness of firms to this incentive is less than regulation. This is consistent with Porter and van der Linde (1995) view that less stringent measures of environmental protection impact less on firms decisions than more forceful measures.

Finally, expected regulation also has a positive impact on the likelihood of firm eco-innovation, however, the size of the coefficient is relatively small. This suggests that while firms do attempt to pre-empt possible new regulations, they respond more strongly to regulations which actually come into force. This is consistent with Hemmelskamp's (1997) argument that firms will only move to meet the exact requirements of regulations as to surpass the requirements may signal to regulators that further regulation could be introduced. Therefore, firms may be reluctant to pre-empt possible regulations as to do so may signal to regulators the potential for further environmental savings which could necessitate a cost to the firm.

[Insert Table 3 around here]

It is also interesting to note that backward linkages to suppliers and consultants has a significant positive effect on the probability of eco-innovation. Linkages with suppliers are often regarded as being a critical factor in determining innovation with Roper et al. (2008) suggesting that cooperation with suppliers can increase the likelihood of engaging in both product and process innovation. The remaining external agents are found to have no significant impact on the likelihood of eco-innovation. However, higher levels of expenditure by the firm on intramural R&D increase the likelihood of eco-innovation, suggesting that internal R&D plays an important role in the development of eco-innovations. Extramural R&D is found to have no significant impact on eco-innovation. Hemmelskamp (1997) and Horbach (2008) both note the importance of internal capabilities in the development of eco-innovation. The performance of internal R&D may act to develop these internal resources and the absorptive capacity of the firm which can be leveraged for the introduction of new eco-innovations (Cohen and Levinthal 1989; Cohen and Levinthal 1990).

It can also be noted that larger firms are more likely than smaller firms to engage in eco-innovation. This supports Kammerer's (2009) proposition that larger firms have better opportunities and abilities to reduce their impact on the environment due to their higher degree of financial and human capital and that larger firms may be better known and therefore subject to increased levels of consumer scrutiny than smaller firms. Irish owned firms are found to be just as likely as non-Irish firms to engage in eco-innovation. No sectoral effects are found to be present, suggesting that eco-innovation is all pervasive across the Irish economy.

Turning to the impact of eco-innovation on firm performance, Table 4 displays the results of the OLS estimation of equation (3). Firstly, it can be observed that both the innovation coefficient and the eco-innovation interaction coefficient are significant. When interpreted in conjunction with one another the results suggest that firms which engage in innovation activity have lower levels of turnover per worker than firms which do not engage in innovation activity, unless their innovation is an eco-innovation. Firms which engage in eco-innovation have higher levels of turnover per employee than firms which introduce non-eco-innovations and firms which do not engage in innovation activity. These results imply that eco-innovation can drive performance growth faster than non-eco-innovation and the absence of innovation.

[Insert Table 4 around here]

These results provide support for Porter and van der Linde's (1995) theory that eco-innovation can generate offsets which benefit the firm. They note that innovation offsets can occur for all subsets of innovation. For example, product offsets occur when environmental regulation produces not just less pollution but also creates better performing products, safer products or lower cost products while process offsets occur when environmental regulation leads not only to reduced pollution but also higher resource productivity, materials savings, better utilisation of by-products or lower energy consumption (Smith and Crotty 2008).

Turning to the control variables, as would be expected, there is substantial variation in turnover per worker across sectors. Relative to *Mining and Quarrying* firms in the *Manufacturing, Water Supply; Sewerage and Remediation activities*, *Transportation and Storage*, *Information and Communication* and *Architectural and Engineering Activities* have lower levels of turnover per worker while firms in the *Electricity, Gas, Steam and Air Conditioning Supply* sector have higher levels of turnover per worker. Larger firms have higher levels of turnover per worker, suggesting economies of scale in production processes. Finally, the capital flow per worker does not significantly effect on the turnover per worker.

6. Conclusions and Implications

The phenomenon known as 'Eco-innovation' is gaining momentum in markets around the world today. Within the European Union, for example, two important documents - Europe 2020 Strategy: A European Strategy for Smart, Sustainable and Inclusive Growth (2011) and A Resource Efficient Europe (2011) - have highlighted the importance of sustainable growth and a more resource efficient, greener and more competitive economy. Since eco-innovation is an important tool which can generate both employment and growth in these recessionary times, this paper asks what drives eco-innovation in Ireland today. A review of the literature identified three key eco-innovation drivers - supply side, demand side, and regulation drivers. These factors are intrinsically linked and changes in any one factor, such as an increase in demand or in regulatory stringency, has important implications for the other factors.

Using a new dataset, collected as part of the CIS 2006-08 survey, we find that demand-side, supply-side and regulation drivers play an important role in motivating eco-innovation in Ireland. Turning first to the supply-side we find that internal expenditure on R&D has a positive and significant impact on a firms' predisposition to engage in eco-innovation. Expenditure on external R&D, on the other hand, does no induce eco-innovation by the firm. This finding supports the idea purported in the literature that the more innovative a firm and the more knowledge it has accumulated, the higher its capacity to apply these factors to environmental innovation (Kesidou and Demirel 2010; Triebswetter et.al. 2008). Turning next to the demand side factors we find strong support for the notion that consumers, and in particular, consumer demand, drives eco-innovation. This is hardly surprising in the current context as many of the firms surveyed produce goods and services which are close to the final consumer. This reflects the findings of many authors including Kesidou and Demirel (2010) who find that consumer demand for environmentally friendly products and processes affects the decision of the firm to invest in eco-innovation.

In relation to environment regulations we find that exiting and expected regulations, government incentives in the form of grants, and voluntary industrial agreements all impact on the firms' inclination to engage in eco-innovation. Of these effects we find that voluntary agreements have the largest impact. This, coupled with the strength of the consumer demand variable, suggests that firms engage in some, possibly minimum, level of eco-innovation in response to industry and society pressures and expectations. It is possible that there is a causal relationship between these variables. In other words it is likely that increased regulation raises the awareness and educates the public about certain environmental issues, and this in turn prompts their demand for these new friendlier products, processes and services. According to Fukasaku (2005) social awareness is more important for eco-innovation than for other types of innovation as it helps to create a demand for the new products and to create pressure groups which motivate firms to eco-innovate.

Eco-innovation, unlike innovation, is found to have a positive and significant impact on firm performance. Firms which engage in eco-innovation have higher levels of turnover per employee than firms which introduce non-eco-innovations and firms which do not engage in innovation activity. This supports the Porter and van der Linde's (1995) that innovation, in many cases, offsets the costs induced by environmental regulations.

While this study confirms the importance of demand, supply and regulation drivers of eco-innovation it is limited in that the CIS only provides general information for the company as a whole and does not provide information about specific technologies or products (Arundel and Kemp, 2009). In addition we have no access to data on the costs associated with eco-innovation or indeed on the degree to which a firm eco-innovates. Bearing these limitations in mind we do find evidence that eco-innovation offers a double-win opportunity to business and governments alike.

References

Alpay, E., S. Buccola and J. Kerkvliet (2002). "Productivity Growth and Environmental Regulation in Mexican and U.S. Food Manufacturing". *American Journal of Agricultural Economics* Vol. 84, pp. 887–901.

Ambec, S., M.A. Cohen, S. Elgie and P. Lanoie (2011). "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?" Discussion Paper, Resources for the Future, Washington, D.C.

Ambec, S. and P. Barla (2006). "Can Environmental Regulations be Good for Business? An Assessment of the Porter Hypothesis", *Energy Studies Review*, Vol. 14 No. 2, pp. 42-62.

Arundel, A and Kemp, R. (2009) "Measuring Eco-innovation". UNU-MERIT Working Paper Series-017.

Åstebro, T. And K. Dahlin (2005). "Opportunity Knocks". Rotman Working Paper, University of Toronto.

Baldwin, R. and M. Cave (1999). *Understanding Regulation: Theory, Strategy, and Practice*. Oxford: Oxford University Press

Barsoumian, S., A. Severin and T. Van der Spek (2011). "Eco-innovation and National Cluster Policies in Europe, A Qualitative Review." Report by Greenovate! Europe EEIG for the European Cluster Observatory managed by the Center for Strategy and Competitiveness at the Stockholm School of Economics, 1-95.

Baumol, W. (2002). *The Free-Market Innovation Machine - Analysing the Growth Miracle of Capitalism*. New Jersey, Prinston University Press.

Baylis, R., L. Connell and A. Flynn (1998). "Company Size, Environmental Regulation and Ecological Modernization - Further Analysis at the Level of the Firm", *Business Strategy and the Environment*, Vol. 7 No. 5, pp. 285-296.

Belin, J., J. Horbach and V. Oltra (2009). "Determinants and Specificities of Eco-innovations – An Econometric Analysis for France and Germany Based on the Community Innovation Survey", Working Paper, Dynamics of Institutions and Markets in Europe.

Beise, M. and K. Rennings (2003). "Lead Markets of Environmental Innovations: A Framework for Innovation and Environmental Economics", Centre for European Economic Research (ZEW), Mannheim.

Bleischwitz, R., S. Giljum, M. Kuhndt and F. Schmidt-Bleek (2009). "Eco-innovation – Putting the EU on the Path to a Resource and Energy Efficient Economy", Wuppertal Spezial 38.

Brännlund, R. and T. Lundgren (2010). "Environmental Policy and Profitability: Evidence from Swedish Industry", *Environmental Economics and Policy Studies*, Vol. 12 No. 1-2, pp. 59-78.

Cainelli, G., M. Mazzanti and R. Zoboli (2011). "Environmentally Oriented Innovative Strategies and Firm Performance in Services. Micro-evidence from Italy", *International Review of Applied Economics*, Vol. 25 No. 1, pp. 61-85.

Carraro, C. (2000). "Environmental Technological Innovation and Diffusion: Model Analysis", in Hemmelskamp, J., F. Leone and K. Rennings. (eds.), *Innovation-oriented Environmental Regulation: Theoretical Approaches and Empirical Analysis*, Physica, Heidelberg, New York, 269-297.

Cohen, W. and D. Levinthal (1989). "Innovation and Learning: The Two Faces of R&D", *The Economic Journal* Vol. 99 No. 397, pp. 569 - 596.

Cohen, W. and D. Levinthal (1990). "Absorptive Capacity: A New Perspective on Learning and Innovation", *Administrative Science Quarterly* Vol. 35 No. 1, pp. 128-152.

Crépon, B., E. Duguest, et al. (1998). “Research, Innovation and Productivity: An Econometric Analysis at the Firm Level”, *Economics of Innovation and New Technology* Vol. 7 No. 2, pp. 115-158.

CSO (2010). *Community Innovation Survey 2006-08*. Dublin, Stationary Office.

Darnall, N. (2006). “Why Firms Mandate ISO 14001 Certification”, *Business & Society*, Vol. 45 No. 3, pp. 354–381.

Department of Enterprise, Trade and Employment (2008). “Innovation in Ireland”. Report by Department of Enterprise, Trade and Employment, Ireland, 1-40.

Dewing, I.P. and P. O Russell (2004). “Regulation of UK Corporate Governance: Lessons from Accounting, Audit and Financial Services”, *Corporate Governance: An International Review*, Vol. 12 No. 1, pp. 107-115.

Doran, J. and E. O’Leary (2011). “External Interaction, Innovation and Productivity: An Application of the Innovation Value Chain for Ireland”, *Spatial Economic Analysis* Vol. 6 No. 2, pp. 199 - 222.

Ekins, P. (2010). “Eco-innovation for Environmental Sustainability: Concepts, Progress and Policies”, *International Economics and Economic Policy*, Vol. 7 No. 2-3, pp. 267-290.

Forfas (2010). “Future Skills Needs of Enterprise within the Green Economy in Ireland”, Report by Expert Group on Future Skills Needs, Forfas, November.

Eco-innovation Observatory (2011). “Country Report for Ireland”. Available at http://www.eco- innovation.eu/index.php?option=com_content&view=article&id=46&Itemid=94 (accessed 20 September 2011)

EuroStat (2008). *NACE Rev2 Statistical Classification of Economic Activities in the European Community*. Luxembourg, Office for Official Publications of the European Communities.

Freel, M. (2003). “Sectoral Patterns of Small Firm Innovation, Networking and Proximity”. *Research Policy* Vol. 32 No. 5, pp. 751-770.

Fukasaku, Y. (2005). “The Need for environmental Innovation Indicators and Data from a Policy Perspective”, in Weber, M. and J. Hemmelskamp, *Towards environmental innovation systems*, Berlin: Springer.

Gabel L.H. and B. Sinclair-Desgagné (1993). “Managerial Incentives and Environmental Compliance”. *Journal of Environmental Economics and Management* Vol. 24, pp. 940–955.

Garcia, R. and R. Calantone (2002). “A Critical Look at Technological Innovation Typology and Innovativeness Terminology: A Literature Review”, *The Journal of Product Innovation Management* Vol. 19 No. 1, pp. 110 - 132.

Greene, W. (2008). *Econometric Analysis*. United States, Pearson-Prentice Hall..

Griffith, R., E. Huergo, et al. (2006). “Innovation and Productivity Across Four European Countries”, *Oxford Review of Economic Policy* Vol. 22 No. 4, pp. 483-498.

Griliches, Z. (1979). “Issues in Assessing the Contribution of Research and Development to Productivity Growth”. *Bell Journal of Economics* Vol. 10 No. 1, pp. 92-116.

Guagnano, G.A. (2001) “Altruism and Market-Like Behavior: An Analysis of Willingness to Pay for Recycled Paper Products”, *Population and Environment*, Vol. 22 No. 4, pp. 425-438.

Halila, F. and J. Rundquist (2011). “The Development and Market Success of Eco-innovations, A Comparative Study of Eco-innovations and “Other” Innovations in Sweden”, *European Journal of Innovation Management*, Vol. 14 No. 3, pp. 278-302.

Hall, B., F. Lotti and J. Mairesse (2009). “Innovation and Productivity in SMEs: Empirical Evidence from Italy”, *Small Business Economics* Vol 33 No. 1, pp. 13-33.

Hemmelskamp, J. (1997). “Environmental Policy Instruments and their Effects on Innovation”. *European Planning Studies* Vol. 5 No. 2, pp. 177 - 194.

Hemmelskamp, J. (1999). “The Influence of Environmental Policy on Innovative Behavior – An Econometric Study”, Fondazione Eni Enrico Mattei Working Paper No. 18.99, Milan.

High Level Group on Green Enterprise (2011). “Progress Report on the Implementation of the Recommendations of the Report of the High Level Group on Green Enterprise” Department of Enterprise, Trade and Innovation and Forfás, 1-32.

Horbach, J. (2008). “Determinants of Environmental Innovation - New Evidence from German Panel Data Sources”, *Research Policy* Vol. 37 No. 1, pp. 163 - 173.

Horbach, J., C, Rammer and K. Rennings (2011). “Determinants of Eco-innovations by Type of Environmental Impact, The Role of Regulatory Push/Pull, Technology Push and Market Pull”, Discussion Paper, Paper No. 11-027, ZEW Centre for Economic Research.

Horbach, J. and K. Rennings (2007). “Panel-Survey Analysis of Eco-Innovation: Possibilities and Propositions”, Deliverable 4 and 5 of MEI (Measuring ecoinnovation) project. Mannheim: MEI (Measuring eco-innovation) project.

Hörte, S.A. amd F. Halila (2008). “Success Factors for Eco-innovations and Other Innovations”, *International Journal of Innovation and Sustainable Development*, Vol. 3 No. 3/4, pp. 301–327.

Iraldo, F., F. Testa, M. Melis and M. Frey (2011). “A Literature Review on the Links Between Environmental Regulation and Competitiveness”, *Environmental Policy and Governance,* Vol. 21 No. 3, pp. 210-222.

Jaffe, A., S. Peterson, et al. (1995). “Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?”, *Journal of Economic Literature* Vol. 33 No. 1, pp. 132 - 163.

Johnstone, N. (2005). “The Innovation Effects of Environmental Policy Instruments”, in Horbach, J. *Indicator systems for sustainable innovation*. Heidelberg, Springer Verlag. pp. 21-42

Johnstone, N., I. Haščič and M. Kalamova (2010). “Environmental Policy Design Characteristics and Technological Innovation: Evidence from Patent Data”, *OECD Environment Working Papers 16*.

Kammerer, D. (2009). “The Effects of Customer Benefit and Regulation on Environmental Product Innovation: Empirical Ecidence from Appliance Manufacturers in Germany”, *Ecological Economics*, Vol. 68 No. 8-9, pp. 2285 - 2295.

Kemp, R. (2000). “Technology and Environmental Policy: Innovation Effects of Past Policies and Suggestions for Improvement”, in *Innovation and the Environment*, OECD, Paris, pp 35–61.

Kemp, R. and M.M. Andersen (2004). “Strategies for Eco-efficiency Innovation”, Strategy paper for the Informal Environmental Council Meeting, Maastricht, VROM, Den Haag.

Kemp, R. and T. Foxon (2007). “Eco-innovation from an innovation dynamics perspective”, Proyecto Measuring Eco-innovation (MEI).

Kesidou, E. and P. Demirel (2010). “On the Drivers of Eco-Innovations: Empirical Evidence from the UK”. Paper presented at the Opening Up Innovation: Strategy, Organization and Technology Conference, Imperial College London Business School, June 15 - 18.

Kleinknecht A., K. van Montfort and E. Brouwer (2002). “The Non-trivial Choice Between Innovation Indicators”. *Economics Innovation New Technology,* Vol. 11 No. 2, pp. 109-121.

Klomp, L. and G. Van Leeuwen (2006). "On the Contribution of Innovation to Multi-Factor Productivity Growth", *Economics of Innovation and New Technology* Vol. 15 No. 4, pp. 367-390.

Kollman, K. and A. Prakash (2002). "EMS-based Environmental Regimes as Club Goods", *Policy Sciences,* Vol. 35 No. 1, pp. 43–67.

Lanoie P., J. Liaurent-Lucchetti, N. Johnstone and S. Amber (2011). "Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis", Jour*nal of Economics & Management Strategy*, Vol. 20 No. 3 pp. 803-842.

Leitner, A., W. Wehrmeyer and C. France (2010). "The Impact of Regulation and Policy on Eco-Innovation– the Need for a New Understanding", *Management Research Review*, Vol. 33 No. 11, pp. 1022 - 1041.

Loureiro, M.L., J.J. McCluskey and R.C. Mittelhammer (2002). "Will Consumers Pay a Premium for Eco-labeled Apples", *Journal of Consumer Affairs,* Vol. 36, pp. 203–219.

Love, J. and M. Mansury (2007). "External Linkages, R&D and Innovation Performance in US Business Services", *Industry and Innovation*, Vol. 14 No. 5, pp. 477-496.

Love, J. and S. Roper (1999). "The Determinants of Innovation: R&D, Technology Transfer and Networking Effects", *Review of Industrial Organisation* Vol. 15 No. 1, pp. 43-64.

Manget, J., C. Roche, and F. Münnich. (2009). "For Real, Not Just For Show", *MIT Sloan Management Review,* February 25.

Mansury, M. and J. Love (2008). "Innovation, Productivity and Growth in US Business Services: A Firm Level Analysis", *Technovation* Vol. 28 No. 1-2, pp. 52-62.

Mazzanti, M., and R. Zoboli (2006). "Examining the Factors Influencing Environmental Innovations", FEEM Working Paper.

McCann, P. and J. Simonen (2005). "Innovation, Knowledge Spillovers and Local Labour Markets", *Papers in Regional Science* Vol. 84 No. 3, pp. 465-485.

OECD (1991). *The Nature of Innovation and the Evolution of the Productive system, Technology and Productivity: The Challenge for Economic Policy*. Paris, OECD.

OECD (2005). *The Measurement of Scientific and Technological Activities Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*. France, OECD Publication.

OECD (2009). Towards Green ICT Strategies: *Assessing Policies and Programmes on ICT and the Environment.* OECD: Organisation for Economic Co-operation and Development, 1-51.

OECD (2009a). *From Grim to Green, OECD Messages on Green Growth*. OECD: Organisation for Economic Co-operation and Development, 1-2.

OECD (2009b). *Sustainable Manufacturing and Eco-innovation: Towards a Green Economy*. OECD: Organisation for Economic Co-operation and Development, 1-8.

OFWAT (2011). Inputs, Outputs and Outcomes – What Should Price Limits Deliver? The Water Services Regulation Authority, Discussion Paper, 1-41.

Palmer, K., Oates, W. E., and Portney, P. R. (1995). "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?" *Journal of Economic Perspectives*, Vol. 9 No. 4, pp. 119-132.

Pavitt, K. (1984). "Sectoral Patterns of Technical Change: Towards a Taxonomy and Theory", *Research Policy*, Vol. 13 No. 6, pp. 343-374.

Porter, M. and C. van der Linde (1995). "Toward a New Conception of the Environment-Competitiveness Relationship", *The Journal of Economic Perspectives* Vol. 9 No. 4, pp. 97 - 118.

Rassier, D.G. and D. Earnhart. (2010). "The Effect of Clean Water Regulation on Profitability: Testing the Porter Hypothesis", *Land Economics,* Vol. 86 No. 2, pp. 329-344.

Ravid, S.A. (2004). "Are They All Crazy or Just Risk Averse? Some Movie Puzzles and Possible Solutions", in Ginsburgh, V. (ed), *The Economics of Art and Culture, Contributions to Economic Analysis*, Elsevier Science, Amsterdam, pp. 33-47.

Rehfeld, K.M., K. Rennings and A. Ziegler (2007). "Integrated Product Policy and Environmental Product Innovations: An Empirical Analysis", *Ecological Economics,* Vol. 61 No. 1, pp. 91-100.

Rennings K., (1998), "Towards a Theory and Policy of Eco-Innovation - Neoclassical and Co-Evolutionary Perspectives", ZEW Discussion Paper 98-24, Mannheim: Center for Economic Research (ZEW).

Rennings, K. and C. Rammer (2011). "The Impact of Regulation-Driven Environmental Innovation on Innovation Success and Firm Performance", *Industry and Innovation* Vol. 18 No. 3, pp. 255 - 284.

Requate, T. (2005). "Dynamic Incentives by Environmental Policy Instruments – A Survey", *Ecological Economics*, Vol. 54 No. 2-3, pp. 175-195.

Roper, S., J. Du, et al. (2008). "Modeling the innovation value chain", *Research Policy* Vol. 37, No. 6-7, pp. 961-977.

Sak, G. and Taymaz, E. (2004). "How Flexible are Small Firms? An Analysis on the Determinants of Flexibility", *ERF Eleventh Annual Conference*, 14–16 December, Beirut, Lebanon.

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

Schweinfurth, A. (2009). "Car-Scrapping Schemes: An Effective Economic Rescue Policy?", *The Global Subsidies Initiative*, 1-8.

Selznick, P. (1985). "Focussing Organizational Research on Regulation", in Noll, R.G. (ed.) *Regulatory Policy and the Social Sciences*. Berkeley: The University of California Press.

Smith, M. and J. Crotty (2008). "Environmental Regulation and Innovation Driving Ecological Design in the UK Automotive Industry", *Business Strategy and the Environment*, Vol. 17 No. 6, pp. 341 - 349.

Suchman, M. (1995). "Managing Legitimacy: Strategic and Institutional Approaches", *Academy of Management Review*, Vol. 20 No. 3, pp. 571-610.

Triebswetter, U. and J. Wackerbauer, J. (2008). "Integrated Environmental Product Innovation in the Region of Munich and its Impact on Company Competitiveness", *Journal of Cleaner Production,* Vol. 16, pp. 1484-1493.

Vinnova (2001). "Drivers of Environmental Innovation". The Swedish Agency for Innovation Systems, Stockholm.

Wagner, M. (2007). "On the Relationship between Environmental Management, Environmental Innovation and Patenting: Evidence from German Manufacturing Firms", *Research Policy*, Vol. 36, pp. 1587-1602.

Wüstenhagen, R. (2009). "Market Research for Eco-Innovation: Lessons from Residential Energy", Paper presented at OECD Workshop entitled Household Behaviour and Environmental Policy, Paris, June.

Zhang T, S. Gensler and R. Garcia (2011). "A Study of the Diffusion of Alternative Fuel Vehicles: an Agent-based Modelling Approach", *Journal of Product Innovation Management,* Vol. 28 No. 2, pp.152–168.

Table 1: Types of Eco-Innovation

Environmental benefits from the production of goods or services within your enterprise	
	Reduced material use per unit of output
	Reduced energy use per unit of output
	Replaced materials with less polluting or hazardous substitutes
	Recycled waste, water, or materials
	Reduced soil, water, noise, or air pollution
	Reduced air, water, soil or noise pollution
Environmental benefits from the after sales use of a good or service by the end user	
	Reduced energy use
	Reduced CO ’footprint’ (total CO production) by your enterprise
	Improved recycling of product after use

Note 1: Definitions are taken directly from the Irish CIS questionnaire

Table 2: Descriptive Statistics of the Irish CIS 2006-08

	Mean	S.D.
Innovation Activity		
Innovator (1/0)	58.78	n.a.
Eco-Innovator (1/0)	42.14	n.a.
Regulation & Perception		
Existing Regulation (1/0)	16.87	n.a.
Expected Regulation (1/0)	12.61	n.a.
Government Grants (1/0)	5.96	n.a.
Customer Perceptions (1/0)	16.23	n.a.
Voluntary Agreements (1/0)	17.88	n.a.
External Linkages		
Forward Linkages (1/0)	7.48	n.a.
Backward Linkages (1/0)	9.87	n.a.
Horizontal Linkages (1/0)	3.06	n.a.
Public Linkages (1/0)	6.44	n.a.
Knowledge Generation		
Intramural R&D (€)	€2,054	€10,253
Extramural R&D (€)	€460	€5,064
Firm Specific Factors		
Employment	89	246
Irish Owned (1/0)	76	n.a.
Capital (€)	€3,606	€36,718
Performance Indicator		
Turnover per Employee	€696,000	€6,309,000
Sector[2]		
B (05-09) Mining and quarrying	1.19	n.a.
C (10-33) Manufacturing	36.36	n.a.
D (35) Electricity, gas, steam and air conditioning supply	0.37	n.a.
E (36-39) Water supply; sewerage and remediation activities	1.65	n.a.
G (46) Wholesale trade, except of motor vehicles & motorcycles	24.58	n.a.
H (49-53) Transportation and Storage	10.55	n.a.
J (58,61,62,63) Information and communication	8.25	n.a.
K (64-66) Financial and insurance activities	10.82	n.a.
M(71) Architectural and engineering activities	6.24	n.a.

Note 1: Sectoral definitions are based on NACE Rev2

2: NACE Rev 2 codes given in brackets

Table 3: Probit Estimation of Equation (1)

	Marginal Effects	s.e.
Constant		
Regulation & Perception		
Existing Regulation	0.2770***	(0.0450)
Expected Regulation	0.1677***	(0.0650)
Government Grants	0.2441***	(0.0807)
Customer Perceptions	0.4303***	(0.0371)
Voluntary Agreements	0.4772***	(0.0296)
External Knowledge Sources		
Forward Linkages	-0.0583	(0.0777)
Backward Linkages	0.1943***	(0.0637)
Horizontal Linkages	0.0118	(0.0964)
Public Linkages	0.0122	(0.0793)
Knowledge Generation		
Intramural R&D[2]	0.0248***	(0.0052)
Extramural R&D[2]	0.0130	(0.0083)
Sector[3]		
C	0.1759	(0.1273)
D	-0.0871	(0.2796)
E	0.0441	(0.1717)
G	0.1080	(0.1297)
H	0.0289	(0.1359)
J	0.0535	(0.1361)
K	-0.0552	(0.1367)
M	0.0735	(0.1382)
Firm Specific Factors		
Employment[2]	0.0664***	(0.0140)
Irish Owned	0.0260	(0.0351)
Obs		2127
Chi^2		1111.89
Prob > Chi^2		0.0000
Pseudo R^2		0.3824
Log-Likelihood		-897.85

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: Sector B is the reference category.

Table 4: OLS Estimation of Equation (3)

	Coeff	**s.e.**
Constant	4.9686	(0.2626)
Innovation Activity		
Innovation	-0.5145**	(0.2117)
Eco-Innovation	0.7520***	(0.1615)
Sector		
C	-0.5176**	(0.2480)
D	1.0623**	(0.4962)
E	-0.7482**	(0.3185)
G	0.2899	(0.2492)
H	-0.7877***	(0.2550)
J	-0.4962*	(0.2665)
K	0.1328	(0.2565)
M	-1.0144***	(0.2658)
Firm Specific Factors		
Employment	0.1501***	(0.0278)
Capital	0.0135	(0.0087)
Obs		2127
F		29.29
Prob > F		0.0000
R^2		0.1426

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: Sector B is the reference category.

Appendix 1

In order to overcome the issue of the endogeneity of innovation output in the production function equation (3), a two step procedure is adopted. For eco-innovation, equation (1) is estimated and the predicted values of this estimation are included in equation (3). The results of this estimation are displayed in Table 2 to facilitate discussion of the determinants of eco-innovation. It is also necessary to control for the issue of endogeneity of the remaining innovation variable in equation (3). Therefore, a separate probit estimation of equation (1) is conducted for innovators (as oppose to specifically eco-innovators) with the $R\&P_{ji}$ variables excluded. Table A1 presents the results of this estimation. Predicted probabilities from this estimation are included in equation (3).

Table A1: Probit Estimation of Modified Equation (1) for Innovators

	Marginal Effects	s.e.
Constant		
External Knowledge Sources		
Forward Linkages	0.0427	(0.0889)
Backward Linkages	0.2481***	(0.0261)
Horizontal Linkages	0.1388	(0.0678)
Public Linkages	0.1610	(0.0677)
Knowledge Generation		
Intramural R&D	0.0752***	(0.0067)
Extramural R&D	0.0822***	(0.0179)
Sector		
C	0.1628***	(0.0728)
D	0.0416	(0.1559)
E	0.0762	(0.0814)
G	0.1646***	(0.0621)
H	0.0739	(0.0711)
J	0.1744***	(0.0433)
K	0.1120	(0.0620)
M	0.1315***	(0.0539)
Firm Specific Factors		
Employment	0.0500***	(0.0101)
Irish Owned	-0.0512**	(0.0220)
Obs		2127
Chi^2		693.94
Prob > Chi^2		0.0000
Pseudo R^2		0.2425
Log-Likelihood		-1083.79

Note 1: *** indicates significant at 1% level, ** indicates significant at the 5% level and * indicates significant at the 10% level.
2: Marginal effects are presented for ease of interpretation
3: Variables expressed in natural logarithms.
4: Sector B is the reference category.

[1] The six sectors are Energies; Efficient Energy Use and Management; Water and Waste Water Treatment; Waste Management, Recovery and Recycling; Environmental Consultancy and Services; and “Green” ICT Applications/ Software