Eco-Innovation – Does Additional Engagement Lead to Additional Rewards?

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Structured Abstract

Purpose
Eco-innovation is any form of product, process or organisational innovation that contributes towards sustainable development. Firms can eco-innovate in a variety of ways. In this paper we identify nine different eco-innovation activities - including such items as reducing material use per unit of output, reducing energy use per unit of output, reducing CO_2 'footprint' - and we ask whether these act as substitutes or complements to one another.

Design/ Methodology/ Approach
Using data for over 2,000 Irish firms collected in a special module included in the sixth Community Innovation Survey we test whether the introduction of two eco-innovation activities over a short period of time provide a greater (lesser) benefit to the firm, in terms of turnover, than the introduction of these eco-innovations individually.

Findings
Introducing only one eco-innovation activity has little payoff (in terms of turnover per worker) with only those firms who reduce their CO_2 'footprint' having higher levels of turnover per worker. When introducing more than one eco-innovation activity we find that certain eco-innovation activities complement one another (e.g. reducing material use within the firm at the same time as improving the ability to recycle the product after use) others act as substitutes (e.g. reducing material use within the firm at the same time as recycling waste, water, or materials within the firm).

Practical Implications
Our results suggest that firms can maximise their productive capacity by considering specific combinations of eco-innovation. This suggests that firms should plan to introduce eco-innovation which act as complements, thereby, boosting productivity. It also suggests that eco-innovation stimuli, introduced by policy makers, should be targeted at complementary eco-innovations.

Originality
We analyse whether eco-innovations act as complements or substitutes. While a number of studies have analysed the importance of eco-innovation for firm performance, few have assessed the extent to which diverse types of eco-innovation interact with each other to complement or substitute one another.

Introduction

To achieve profitable growth firms must successfully navigate today's more dynamic, competitive and regulatory global marketplace. Firms, regardless of size and sector, must carefully evaluate every investment decision as they deal with rising raw material costs, rising taxes, and frequent changes in consumer demand for goods and services. Many economists argue that innovation is the key to successful growth (Schumpeter 1975; Van de Ven 1999; Baumol 2002; Tohidi and Jabbari 2012). While there are many types of innovation, this paper focuses on eco-innovation. Eco-innovation, also known as environmental innovation, includes any form of product, process or organisational innovation that contributes towards sustainable development. The European Commission contends that eco-innovation is central to creating new jobs and delivering the Europe 2020 strategy for smart, sustainable and inclusive growth (Soares 2012).

A recent (Eurobarometer 2011) survey of small and medium sized firms reports that as a result of material shortages and increases in material costs businesses are turning to eco-innovation. According to the survey 76% of firms within the EU have invested in eco-innovation activities since 2006. A little less than half of these firms (41%) reported that over 10% of their innovation investments are related to eco-innovation, whilst sixteen per cent spend 30% of their innovation budgets on eco-innovation related activities. Many of those surveyed acknowledge the benefits of eco-innovation; 42% of those that introduced at least one type of eco-innovation between 2009 and 2011 reported a 15-19% reduction in their materials use for every unit of output. As a result the eco-innovation industry is thriving. Eco-industries in the European Union (EU) have an annual turnover of €319 billion (2.5% of EU gross domestic product) and are growing by 8% a year (European Commission 2011). The sector employs 3.4 million people and is attracting increasing amounts of interest from European venture capitalists who invested over €1.3 billion in 2010 alone (European Commission 2011).

Firms eco-innovate for a number of reasons including to satisfy consumer demand (Horbach 2008; Horte and Halila 2008), interest group pressures (Wagner 2007), and changes in regulation (Porter and van der Linde 1995). (Barsoumian et al. 2011) argue that in many industries the decision to eco-innovate is driven by economic considerations such as a reduction in costs, whilst (Saxena and Khandelwal 2012) argue that a socially responsible strategy is important if firms want to gain a competitive advantage and ensure sustainable growth. According to the (European Commission 2013), the efficient use of resources could greatly reduce firms' operation costs. They estimate the inefficient use of resources (including raw material, energy resources and operating supplies) in manufacturing firms in Europe to be €630 billion per year. This can be translated into substantial gains in each manufacturing company (Greenovate 2012). (REMake 2013) argue that many resource efficiency measures are simple and inexpensive to implement. In a study of 100 small and medium sized firms in Germany from 2006-2010 they noted that investments in material efficiency were paid off within 13 months (Greenovate 2012). If this simple and cheap efficiency alone was scaled up to Europe then it would result in €10 billion saved each year (Eco-Innovation Observatory 2012).

As firms turn to eco-innovation this paper analyses whether different eco-innovation activities act as complements or substitutes to each other. Using the Community Innovation Survey for Ireland we identify six eco-innovation activities which may add value during the production stage (including reducing material use, reducing energy use, reducing the firms CO_2 'footprint', replacing materials with less polluting or hazardous substitutes, reducing soil, water, noise, or air pollution, and increasing the recycling of waste, water, or materials) and three eco-innovation activities which may add value to the after sales use of the good or service (including reduced energy use, reduced air, water, soil or noise pollution, and improved recyclability of the product after use). Building on work by (Porter and van der Linde 1995) who find that a firm's decision to eco-innovate impacts on its performance, this paper examines whether the introduction of two eco-innovation activities, over a short time period, results in additional benefits (costs) to the firm than the introduction of these eco-innovations individually. In essence we are testing for complementarity/ substitutability between eco-innovation activities. The premise is that the benefit from introducing two innovations at the same time is greater/less than the sum of the parts (Milgrom and Roberts 1990).

While the impact of eco-innovation on firm performance is discussed in both management and economic literature (See for example Porter and van der Linde 1995; Hemmelskamp 1997; Crowley 1999; Desrochers 2008; Horbach 2008) there has been little focus on whether a dynamic complementary/ substitution relationship exists among eco-innovation activities. Since (Porter and van der Linde 1995) there has been an intense debate about whether regulation can stimulate eco-innovation and if so, whether these eco-innovations benefit the firm. If eco-innovation activities are found to be complements then this would lend more support to the (Porter and van der Linde 1995) hypothesis, suggesting that eco-innovation is not only beneficial for the firm, but that the more eco-innovation activities a firm introduces the more benefits it acquires. On the other hand, if eco-innovation activities are found to be substitutes then firms would be better off focussing on one form of eco-innovation and specialising in this rather than expanding the scope of their eco-innovation activities. In analysing these possibilities we contribute to the discussion on the role of eco-innovation in promoting firm productivity.

In order to test for complementarity a knowledge augmented production function is estimated. These functions capture the impact of innovation activities on firm performance (Crépon et al. 1998; Lööf and Heshmati 2002; Hall et al. 2009). We augment these production functions by incorporating interaction terms which capture the additional 'benefit' of simultaneously engaging in two specific forms of eco-innovation. In doing so, we provide insights into the relative strength of the complementary/ substitution effects. In estimating this model we also acknowledge that firms' innovation decisions may be endogenous in firms' production functions and we adjust our estimations using appropriate instrumental techniques (Hall et al. 2009).

The remainder of this paper is structured as follows. Section 2 briefly reviews pertinent literature. Section 3 presents the empirical model, while Section 4 gives an overview of the data. The results of the empirical analysis are presented in Section 5. Finally, Section 6 concludes.

Literature Review

Today policy makers consider eco-innovation to be an important real economic multiplier (Montalvo et al. 2011). In particular eco-innovation is seen as a key enabler for securing a knowledge-based, resource efficient, greener, and competitive European economy. In this section we begin by defining what is meant by eco-innovation and what we mean by complementarity. Following this we examine the relationship between eco-innovation and firm performance, and finally we construct our testable hypotheses which examine complementarities between eco-innovation activities.

What is Eco-Innovation?

Horbach (2008; 163) defines eco-innovation as "consist[ing] of new or modified processes, techniques, systems and products to avoid or reduce environmental damage". 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. An eco-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 (Hemmelskamp 1997). The Oslo Manual, developed by the OECD (2005), identifies four distinct types of innovation activity; (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). In line with authors such as (Hemmelskamp 1997) and (Porter and van der Linde 1995) we use this OECD (2005) definition of innovation.

Over the last two decades, many studies have examined the drivers and dynamics of eco-innovation (See for example Porter and van der Linde 1995; Hemmelskamp 1997; Horbach 2008; Kammerer 2009). As a result, our understanding of the characteristics, shaping factors and effects of eco-innovation has been improved. In addition to the traditional demand-side factors and supply-side factors which are known to drive innovation, this literature highlights the importance of regulation as an influential driver of eco-innovation. Consequently today many national and EU policies are directed towards fostering and supporting eco-innovation (Kemp and Oltra 2011). The power of eco-innovation rests in its ability to act as a 'double win' for society. It does this by contributing to sustainable development and to economic growth. In 2008, the Executive Agency for Competitiveness and Innovation (EACI) of the European Commission launched a programme dedicated to eco-innovation with the aim of supporting innovative products, services and technologies that can make better use of our natural resources and reduce Europe's ecological footprint. The Competitiveness and Innovation Programme (CIP), which has a budget of nearly €200 million for 2008 to 2013, helps good ideas for innovative products, services and processes that protect the environment become fully-fledged commercial prospects, ready for use by business and industry. Many national initiatives have also been established which support and promote eco-innovation. Given the increased funding, resources and encouragement it is pertinent that we ask whether the introduction of multiple types of eco-innovation within a firm, over a relatively short period of time, increase or decrease its performance i.e. is it wise for a firm to eco-innovate in more than one way at any given time?

What is Complementarity?

In line with Milgrom and Roberts (1990) this paper defines complementarity to mean the relationship among groups of activities. The key characteristic of this definition is that "if the levels of any subset of the activities are increased, then the marginal return to increases in any or all of the remaining activities rises" (Milgrom and Roberts 1990: 514). When examining complementarity two criteria must be full-filled (Hou and Mohnen 2011); firstly, the adoption of one activity must not preclude the adoption of another, and secondly when it is possible to implement each activity separately, the sum of the benefits of the activities introduced separately must be less than the benefit of introducing both simultaneously.

Following Schmiedeberg (2008), when applying the concept of complementarity in subsequent sections of this paper, complementarity relates to whether firms which undertake two forms of innovation simultaneously benefit more than firms which undertake the same forms of innovation separately. When two or more activities in a firm are in a complementary relationship, firm and policy efforts should be targeted to all these activities, since improvements to only one area might result in reduced overall firm performance (Cainelli et al. 2011).

Substitution is the exact reverse of complementarity. Again two characteristics are required, firstly, firms must be able to undertake both activities simultaneously and secondly when the activities are conducted separately, the benefit from the sum of them being introduced separately is greater than that if they were introduced simultaneously. Substitution in eco-innovation outputs may occur when both types of innovation activity are not compatible, resulting in productivity losses for the firm.

Eco-Innovation and Firm Performance

Existing literature links the undertaking of eco-innovation to firm performance. The so called Porter and van der Linde (1995) hypothesis suggests 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 which views the socially desirable outcome of less pollution as being incompatible with the desirable business outcome of profit maximisation (Horbach 2008). Many authors, such as Rassier and Earnhart (2010), concur with this traditional view when they find that tighter clean water regulation in the US reduced the profitability of publicly held firms operating within the chemical manufacturing industries. Horbach (2008) notes that since most environmental problems represent negative externalities there is no clear economic incentive for firms to develop new environmentally benign products and processes.

Porter and van der Linde (1995) raise the point that if we assume there is a trade-off between what is good for society (less pollution) and what is good for business (more growth) then to what extent should we restrict business in order to benefit society. 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 have made their cost-minimising decisions and these choices do not vary. Environmental regulation raises costs and will result 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. This paper tests the hypothesis that eco-innovation can raise productivity, while specifically considering the role of complementarities in eco-innovation performance.

Complementarity in Innovation Activities

While papers such as Crépon et al. (1998), Klomp and Van Leeuwen (2001; 2006), Lööf and Heshmati (2002; 2006) and Roper et al. (2008) analyse the importance of product and process innovation for firm performance, they do not address whether these forms of innovation complement or substitute one another in the augmented production function. Furthermore, while Doran and Ryan (2012) analyse the impact of eco-innovation on firm performance the presence of possible complementarities across eco-innovation activities is largely neglected. These papers all assume that innovations impact on firm performance in different, individual and mutually exclusive ways. However, Freeman and Soete (1997) note that since the work of Schumpeter (1975) there has been general acknowledgement in economics of the existence of complementarity among innovation types. This is supported by Swann (2009) and Mohnen and Roller (2005), who suggest that the introduction of one type of innovation may necessitate the introduction of a different form of innovation. Yet in the eco-innovation literature this possibility has been largely neglected.

As mentioned above two forms of eco-innovation are considered in this paper, (i) eco-innovations which affect the production process of the firm (i.e. process innovation) and (ii) eco-innovations which affect the products offered by the firm (i.e. product innovation). Using these generalisations we formulate hypotheses as to whether eco-innovation activities complement or substitute one another. Kraft (1990) proposes a hypothesis that both product and process innovation are not independent of each other, and that while engaging in one type of innovation the benefit/cost of undertaking the second increases/decreases. He notes that frequently the manufacture of a new product will only be possible if a new production process is introduced. Similar arguments are proposed by Martinez-Ros and Labeaga (2009). This theory is consistent with Schumpeter's (1975) view, that a positive relationship exists among innovation activities. This complementarity relationship is further proposed and supported by papers such as Martinez-Ros (2000), Miravete and Pernías (2006) and Percival and Cozzarin (2008). However, none of these consider eco-innovation.

As this paper identifies nine distinct eco-innovation activities ranging across the spectrums of product and process innovation a number of general hypotheses can be developed. These are displayed below:

> H_1: *Product eco-innovations and process eco-innovations complement one another*
> H_2: *Product eco-innovations complement other forms of product eco-innovations*
> H_3: *Process eco-innovation complement other forms of process eco-innovations*

These hypotheses suggest that complementarity may be present between product and process eco-innovations and also within product and process eco-innovation activities. By testing these hypotheses this paper aims to shed light on the extent to which complements exist among different innovation activities.

Empirical Model

The key focus of this paper is to identify whether eco-innovation activities exhibit complementary behaviour in firms' production functions. However, there is the potential for innovation indicators in firms' production function to be endogenous (Crépon et al. 1998). This can happen when similar unobservable characteristics drive both firm performance and innovation and it results in biased estimates. To control for this endogeneity we adopt a two step approach to modelling complementarity. The two-step approach is consistent with Crépon et al. (1998), Hall et al. (2009) and Griffith et al. (2006). Simply, it involves estimating a first stage model where innovation output depends on innovation inputs. This model is then used to generate predicted probabilities of a firm innovating. These predicted probabilities are then used as instruments for innovation output in the second step model. This eliminates the potential endogeneity problem discussed above (Hall et al. 2009). Our innovation production function (first step) is estimated using a probit model while our production function (second step) is estimated using Ordinary Least Square (OLS).

To model firms' decisions to engage in eco-innovation activity we use an innovation production function. This function relates eco-innovation inputs and conditioning factors to a firms' eco-innovation output (Roper et al. 2008; Hall et al. 2009). To determine a firms eco-innovation inputs we turn to the literature. Much attention has been given to the drivers of eco-innovation and these are largely broken down into regulation drivers, supply-side drivers and demand-side drivers (See for example Hemmelskamp and Mattei 1999; Horbach and Rennings 2007; Rehfeld et al. 2007; Desrochers 2008; Horbach 2008). Using these factors we specify our eco-innovation production function as follows:

$$IO_{ih} = \alpha_0 + \alpha_j REGULATION_{ji} + \alpha_k SUPPLY_{ki} + \alpha_l DEMAND_{li} + \alpha_m X_{mi} + \varepsilon_{1i} \quad (1)$$

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 activities identified above), α_0 is the intercept coefficient, $REGULATION_{ji}$ is a series of j variables which indicate whether firm i experienced regulatory driver j, α_j is the associated slope coefficient, $SUPPLY_{ki}$ is a series of k variables indicating whether firm i experienced supply side driver k, α_k is the associated coefficient, $DEMAND_{li}$ are a series of variables indicating whether firm i experienced demand side driver l, 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 first and most important driver of eco-innovation, as suggested by the literature, is regulation (Porter and van der Linde 1995; Kammerer, 2009). Environmental regulation serves two purposes; firstly it provides valuable information regarding the demand for greener products and services, and secondly it provides strict guidelines about what is required (Kemp 2000). Regulations can work in many ways including rewarding firms for good behaviour (e.g. government grants to reduce energy use) and by punishing them for bad behaviour (e.g. carbon tax). To capture the importance of regulation we include three dummy variables; *Exiting Regulation* (which equals one if the firm eco-innovated in response to exiting regulation), *Expected Regulation* (which equals one if the firm eco-innovated in expectation of future regulations), and Government Grants (which equals one if the firm eco-innovated in response to a government grant).

The second key driver of eco-innovation is supply side factors (Rehfeld et al. 2007; Horbach 2008; Kesidou and Demirel 2012). These include both internal and external factors. Internal factors include a firm's technological capability, organisational capability, and ability to engage in research and development activities. (Triebswetter and Wackerbauer 2008) and (Gliedt and Parker 2007) argue that the more innovative the firm, the more likely it is to eco-innovate, while (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. (Horbach et al. 2011) argue that only expenditure on internal R&D is an important predictor of innovation (i.e. expenditure on external R&D does not drive eco-innovation). The external supply-side drivers focus around the firms level of engagement with consumers, suppliers, competitors, and knowledge providers (Roper et al. 2008). Within this field of study there is conflicting evidence as to whether competition or collaboration between firms drives eco-innovation, with Cainelli et al. (2011) finding evidence to support the former and Wagner (2007) finding evidence to support the latter. To capture internal drivers we include six variables; *Internal* R&D (€), *External* R&D (€), *Forward Linkages* (which equals one if the firm has links with customers), *Backward Linkages* (which equals one if the firm has links with suppliers or consultants), *Horizontal Linkages* (which equals one if the firm has links to competitors) and *Public Linkages* (which equals one if the firm has links to universities or public research institutes).

The third driver of eco-innovation is demand. This includes factors such as consumer demand, public procurement requirements, and industry codes and practices. (Kemp and Oltra 2011) argue that it is important that suppliers and consumers understand the environmental issues in a way that is meaningful to them. For example, they argue that consumers are unlikely to pay more for a low-carbon product if they are unable to see how it will benefit climate change. Authors such as (Guagnano 2001) and (Manget et al. 2009) find evidence to support the view that consumers are willing to pay more for environmentally friendly products and as a results the pressure to eco-innovate is stronger in industries close to final consumers. We include two dummy variables to capture this driver; *Customer Perceptions* (which equals one if the firm eco-innovated in response to consumer demand) and *Voluntary Agreements* (which equals one if the firm eco-innovated in response to codes or agreements for environmental good practice within their sector).

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 we use a series of probit models to estimate equation (1). This approach is consistent with (Roper et al. 2008).

To answer our research question - do eco-innovation activities display complementary characteristics - 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:

$$PROD_i = \beta_0 + \beta_h IO^*_{ih} + \beta_{hj} INTER^*_{i,hj} + \beta_k Z_{ki} + \varepsilon_{2i} \qquad (2)$$

Where $PROD_i$ indicates firm i's turnover per employee, IO^*_{ih} is a series of variables which contain the predicted probabilities of eco-innovation h derived from equation (1) for firm i, $INTER^*_{i,hj}$ is a series of 36 interaction terms between eco-innovation activity h and eco-innovation activity j (where $h \neq j$) for firm i, Z_{ki} is a series of firm specific variables, ε_{2i} is the error term and the βs are the associated coefficients. The use of interaction terms is consistent with Roper et al. (2010). 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 (Doran and O'Leary 2011; Doran and Ryan 2012).

Data

In this paper we use data collected as part of the 2006-2008 Irish Community Innovation Survey. This survey gathered data on new and significantly improved products (good or services), processes, organisational and marketing innovations. 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 (note, these questions were not repeated in latter surveys and therefore a longitudinal study is not possible). As discussed above firms were asked if they introduced (i) eco-innovations which affected the production process of their firm and/or (ii) eco-innovations which affected the products offered by their firm. The process innovation question, which identified environment benefits from the production of the good or service within the enterprise, was sub-divided into five key eco-innovation activities; an eco-innovation which

(Eco1) Reduced material use per unit of output,
(Eco2) Reduced energy use per unit of output,
(Eco3) Reduced CO_2 'footprint' (total CO_2 production),
(Eco4) Replaced materials with less polluting or hazardous substitutes,
(Eco5) Reduced soil, water, noise, or air pollution,
(Eco6) Recycled waste, water, or materials;

while the product innovation question, which identified environment benefits from the after sales use of the good or service by the user, was subdivided into three key eco-innovation activities; an eco-innovation that

(Eco7) Reduced energy use,
(Eco8) Reduced air, water, soil or noise pollution,
(Eco9) Improved recycling of product after use.

Descriptive statistics for these eco-innovations can be viewed in Table 1. Focusing first on process innovation we notice that during the period 2006-2008 approximately 34% of firms had recycled waste, water, or materials, 22% had reduced energy use per unit of output, and 22% had reduced their CO_2 footprint, 19% replaced materials with less polluting substances and 19% had reduced material use per unit of output, while 17% reduced soil, water, noise or air pollution. The most popular type of product eco-innovation involved improving the recyclability of the product after use (22%) while only 14.5% reduced the after-sale air, water, soil or noise pollution of the product or service.

[Insert Table 1 near here]

Turning to the eco-innovation drivers; when asked why they introduced an eco-innovation between 2006 and 2008 the most commonly selected answers related to regulatory and consumer demand drivers. The key drivers of eco-innovation were *Voluntary Agreements* with 17.88% of firms introducing an eco-innovation in response to voluntary industry codes, *Existing Regulations* with 16.87% introducing an eco-innovation in response to current regulations, and *Customer Preferences* with 16.23% introducing an eco-innovation in response to consumer demand. Supply-side factors and government grants were not key drivers of eco-innovation in Ireland between 2006 and 2008 with less than 10% of firms selecting any of these options for the reason they introduced eco-innovation. The average expenditure on internal research and development per employee was much higher than that spent on external research and development (€2,054 for internal and €460 for external).

To measure firm performance we use *Turnover Per Worker*. This data is collected by the Central Statistics Office, Ireland. While the eco-innovation data refers to eco-innovation over the three year period 2006 to 2008 inclusive, the turnover data refers to 2008 only. The mean turnover per employee in 2008 was €696,000 with a standard deviation of €6,309,000.

Turning to the control variables we see that 76% of the firms surveyed were Irish owned small-to-medium sized enterprises, with an average of 89 employees (associated standard deviation of 246). The majority of the firms in the sample are either High-Technology Manufacturing firms (30%) or Wholesale, Transport, Storage and Communication firms (35%). The remaining firms are Computer, Architecture and Engineering Services firms (14.5%), Financial Intermediation firms (11%) and All Other Manufacturing firms (9.5%). Finally, 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) and Doran and Ryan (2012) 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.

Results

This section presents the results of our analysis of complementarity. Initially, we estimate equation (1), the results of which are displayed in Appendix 1. This equation is estimated in order to derive credible instruments of eco-innovation for inclusion in firms' production functions as endogeneity may exist between eco-innovation activity and firm performance. Predicted probabilities are derived from the estimates of equation (1) and included as instruments for eco-innovation in our estimation of equation (2). The results of the drivers of eco-innovation are not the concern of this paper and are therefore not discussed. It is sufficient to say that we find that demand-side, supply-side, and regulatory drivers impact on the likelihood of a firm engaging in eco-innovation, but the relative magnitude of these impacts vary across the nine eco-innovation activities considered. Table 2 displays the key results of this paper.

We begin by looking at the direct impact of introducing the nine eco-innovation activities. The first thing we notice is that only one activity has a positive and significant effect on firm productivity, all other activities have no significant impact. Specifically our results show that firms which reduce their CO_2 'footprint' (total CO_2 production) have higher levels of turnover per worker than firms which do not engage in this form of eco-innovation. It is not usual to find mixed results when examining the impact of eco-innovation on turnover. (Porter and van der Linde 1995) suggest that eco-innovation can increase firm performance by endowing onto them a competitive advantage over their rivals, while others such as (Palmer et al. 1995) argue that additional costs resulting from the introduction of the innovation (e.g. purchase of new machinery, staff-training, etc) may hide the benefit of the innovation. The finding of a lack of significant results is not unusual in the literature. For example Roper and Love (2010) note only a small subset of their innovation capability variables as being statistically significant.

Next we examine whether there are additional benefits to the firm (or costs borne by the firm) if they decide to introduce two eco-innovation activities simultaneously. These costs and benefits are measured using an array of interaction variables. The interaction terms indicate the presence of both complementarity and substitutability. A positive and significant coefficient indicates a complementary relationship i.e. that performing both types of eco-innovation results in an additional productive benefit for the firm. A negative and significant coefficient implies a substitution effect, i.e. performing both types of innovation reduces the efficiency of the innovations and results in productivity losses for the firm. An insignificant coefficient implies no complementary or substitution effects are present and that regardless of the innovations being co-introduced, no additional benefits/losses are observed for the firm above and beyond those which already accrue from the innovation.

[Insert Table 2 near here]

When considering the interaction terms, a total of seven complementary/substitution effects out of a possible 36 are observed. The finding of so few significant effects among innovation types is consistent with Roper and Love (2010) who also observe that only a sub-set of innovation activities exhibit complementary/substitution characteristics. Of these seven significant effects four exhibit negative signs and three exhibit positive signs, suggesting four substitution effects and three complementary effects. Interestingly, only one of these effects includes reduced CO_2 'footprint' (total CO_2 production), suggesting that while this form of innovation, in isolation, has a positive effect on firm performance, the possibilities for economies of scope arising from engaging in this form of innovation are minimal.

Taking the complementary effects first, it can be noted that firms which

(i) reduced their material use per unit of output (Eco1) and improved the recyclability of their product after use (Eco9), or which
(ii) recycled waste, water, or materials (Eco6) and reduced energy use (Eco7), or which
(iii) reduced soil, water, noise, or air pollution (Eco5) and recycled waste, water, or materials (Eco6)

experienced increased levels of productivity. While the first two cases involve one process innovation and one product innovation, the remaining case involves process innovation only. Therefore we find limited evidence to support hypothesis 1 (product and process eco-innovations complement one another) and hypothesis 3 (process eco-innovations complement each other) and we find no support for hypothesis 2 (product eco-innovations complement each other). Moreover, our results show that the type of eco-innovation activity implemented is key when looking for complementarities.

We can postulate many reasons as to why the first two complementary effects may be present. For example the benefits may relate to a reduction in production costs, to a reduction in waste management costs, or to an increase in sales by making the product more appealing to customers. However, we should note that the finding of a complementary relationship does not give us any insight into the causal direction of this complementary relationship. In the case of the first relationship (Eco1 and Eco9) it is possible that as a result of reducing the quantity of materials a firm uses when producing a good or service they may also reduce the amount of material which needs to be disposed of once the product had been purchased /used by the end customer. Furthermore, if the reduction in the material used is achieved through the utilisation of more environmentally friendly/recyclable material this may further improve the efficiency of recycling after use. In the second case it is possible that the firm as a whole has become more environmental aware and as a result is recycling more itself while also producing more energy efficient products and services for the end user. Firms which are innovating the way they recycle waste, water, or materials may be doing so by upgrading existing machinery which was environmentally inefficient or they may be producing new products from recycled material (see Björklund and Finnveden 2005). Both have been shown to significantly reduce production costs. The final complementary relationship exists between two process innovations: reduced soil, water, noise, or air pollution and recycled waste, water, or materials. The synergies between these forms of eco-innovation could result from firms reducing pollution by recycling the by-products of their production. This may result in increased consumer demand for the more environmentally friendly product or a reduction in costs accruing from reduced waste disposal, explaining the complementary effect on productivity.

Turning next to the substitution effects. Here we note that firms which engaged in any of the following four combinations of eco-innovation activities experienced reduced turnover per employee;

(i) reduced material use per unit of output (Eco1) and recycled waste, water, or materials (Eco6),
(ii) reduced CO_2 'footprint' (total CO_2 production) by your enterprise (Eco3) and recycled waste, water, or materials (Eco6),
(iii) reduced soil, water, noise, or air pollution (Eco5) and improved recycling of product after use (Eco9),
(iv) reduced energy use (Eco7) and improved recycling of product after use (Eco9).

Here the first two cases combine two process innovations, the third case combines one product with one process innovation and the last case combines two process eco-innovations. Firms which combine these types of eco-innovation suffer from productivity losses, suggesting a substitution effect is present. These productive losses may be due to disruption effects resulting from a combination of these forms of innovation. Roper et al. (2008) suggests that immediately following the introduction of product innovation there may be short term disruptive effects which reduce the productivity of the workforce as they attempt to adapt to the new product and production process. The combination of these eco-innovations may result in a temporary lowering of workers' productivity while they adapt to these new methods. Alternatively, it may be that firms which engage in these combinations of eco-innovation activities suffer from competitive disadvantages resulting from incurring large innovation costs or that these eco-innovations are not compatible with each other.

Conclusion

This paper provides an analysis of whether different forms of eco-innovation act to complement or substitute one another in firms' production functions. In order to undertake this analysis a two-step procedure consistent with Hall et al. (2009) is adopted. Initially a series of nine innovation production functions are estimated and predicted probabilities for eco-innovation are derived from each of these. This is done in order to derive credible instruments for inclusion in the production function. A series of 36 interaction terms are included in the production function to capture the possible complementary/substitution effects between each pair-wise combination of eco-innovations.

The results suggest that differing combinations of eco-innovation can result in benefits or costs to firms' productivity. However, out of a potential 36 combinations only seven exhibit a significant relationship. For instance firms which simultaneously introduce eco-innovations which reduce material use per unit of output and improve recycling of product after use gain an increase in productivity. However, firms which replaced materials with less polluting or hazardous substitutes and recycled waste, water, or materials experience lower levels of productivity. This suggests that firms considering eco-innovation may wish to target specific combinations in order to maximize the potential gains from eco-innovation and may also wish to avoid specific forms of eco-innovation as the combinations may result in a loss of productive capacity.

These results point to the need for firms to strategise and plan the types of eco-innovation activities they wish to engage in so as to maximise the benefits from these innovations. Through strategic choice firms can gain productive benefits from the eco-innovations they introduce. This is consistent with the Porter and van der Linde (1995) hypothesis. However going beyond their theory it appears that by engaging in a number of difference activities firms can reap a benefit which is greater than the sum of the parts. This positive effect is not ubiquitous, with substitution effects also being observed.

References

Barsoumian, S., A. Severin and T. Van der Spek (2011). "Eco-innovation and National Cluster Policies in Europe, A Qualitative Review". *Report by Greenovate*, Vol. No., pp. 1-95.

Baumol, W. J. (2002). *The free-market innovation machine: Analyzing the growth miracle of capitalism*.Princeton Univ Pr.

Björklund, A. and G. Finnveden (2005). "Recycling revisited—life cycle comparisons of global warming impact and total energy use of waste management strategies". *Resources, Conservation and Recycling*, Vol. 44, No. 4, pp. 309-317.

Cainelli, G., M. Mazzanti and R. Zoboli (2011). "Environmental innovations, complementarity and local/global cooperation: evidence from North-East Italian industry". *International Journal of Technology, Policy and Management*, Vol. 11, No. 3, pp. 328-368.

Crépon, B., E. Duguest and J. Mairesse (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.

Crowley, K. (1999). "Jobs and environment: the "double dividend" of ecological modernisation?". *International Journal of Social Economics*, Vol. 26, No. 7/8/9, pp. 1013 - 1026.

Desrochers, P. (2008). "Did the invisible hand need a regulatory glove to develop a green thumb? Some historical perspective on market incentives, win-win innovations and the Porter hypothesis". *Environmental and Resource Economics*, Vol. 41, No. 4, pp. 519-539.

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.

Doran, J. and G. Ryan (2012). "Regulation and Firm Perception, Eco-Innovation and Firm Performance". *European Journal of Innovation Management*, Vol. 15, No. 4, pp. 421 - 441.

Eco-Innovation Observatory (2012). Closing the Eco-Innovation Gap, An Economic Opportunity for Business, European Commission.

Eurobarometer, F. (2011). "Attitudes of European entrepreneurs towards eco-innovation". Vol. No., pp.

European Commission. (2011). "Eco-innovation Action Plan Launched: helping business to deliver green growth and environmental benefits.", from http://eeas.europa.eu/delegations/malaysia/documents/press_corner/all_news/2011/20111220_eumsiagreentech_en.pdf.

European Commission (2013). The Opportunities to Business of Improving Resource Efficiency, AMEC Environment & Infrastructure and Bio Intelligence Service.

Freeman, C. and L. Soete (1997). *The Economics of Industrial Innovation*.Pinter, London.

Gliedt, T. and P. Parker (2007). "Green community entrepreneurship: creative destruction in the social economy". *International Journal of Social Economics*, Vol. 34, No. 8, pp. 538-553.

Greenovate (2012). Guide to Resource Efficiency in Manufacturing; Experiences from Improving Resource Efficiency in manufacturing Companies. Europe Innova, REMake.

Griffith, R., E. Huergo, J. Mairesse and B. Peters (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 & Environment*, Vol. 22, No. 4, pp. 425-438.

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. and F. E. E. Mattei (1999). *The Influence of Environmental Policy on Innovative Behaviour: An Econometric Study*.Fondazione Eni Enrico Mattei.

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*.ZEW, Zentrum für Europäische Wirtschaftsforschung.

Horbach, J. and K. Rennings (2007). "Panel-Survey Analysis of Eco-Innovation: Possibilities and Propositions". Vol. No., pp.

Horte, S. A. and F. Halila (2008). "Success factors for eco-innovations and other innovations". *International Journal of Innovation and Sustainable Development*, Vol. 3, No. 3, pp. 301-327.

Hou, J. and P. Mohnen (2011). "Complementarity between in-house R&D and technology purchasing: evidence from Chinese manufacturing firms". *UNU-MERIT Working Paper Series*, Vol. 048, No., pp.

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". *Innovation and the Environment*, Vol. No., pp. 35-61.

Kemp, R. and T. Foxon (2007). "Eco-innovation from an innovation dynamics perspective". *MEI project, UNU-MERIT*, Vol. No., pp.

Kemp, R. and V. Oltra (2011). "Research Insights and Challenges on Eco-Innovation Dynamics". *Industry and Innovation*, Vol. 18, No. 03, pp. 249-253.

Kesidou, E. and P. Demirel (2012). "On the drivers of eco-innovations: Empirical evidence from the UK". *Research Policy*, Vol. No., pp.

Klomp, L. and G. Van Leeuwen (2001). "Linking Innovation and Firm Performance: A New Approach". *International Journal of the Economics of Business*, Vol. 8, No. 3, pp. 343-364.

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.

Kraft, K. (1990). "Are Product- and Process-Innovations Independent of Each Other?". *Applied Economics*, Vol. 22, No. 8, pp. 1029 - 1038.

Lööf, H. and A. Heshmati (2002). "Knowledge Capital and Performance Heterogeneity: A firm Level Innovation Study". *International Journal of Production Economics*, Vol. 76, No. 1, pp. 61-85.

Lööf, H. and A. Heshmati (2006). "On the Relationship between Innovation and Performance: A Sensitivity Analysis". *Economics of Innovation and New Technology*, Vol. 15, No. 4, pp. 317-344.

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.
Manget, J., C. Roche and F. Münnich (2009). "For real, not just for show". *Sloan Management Review*, Vol. No., pp.
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.
Martinez-Ros, E. (2000). "Explaining the Decisions to Carry out Product and Process Innovations: The Spanish Case". *The Journal of High Technology Management Research*, Vol. 10, No. 2, pp. 223-242.
Martinez-Ros, E. and J. Labeaga (2009). "Product and Process Innovation: Persistence and Complementarities". *European Managment Review*, Vol. 6, No. 1, pp. 64 - 75.
Milgrom, P. and J. Roberts (1990). "The Economics of Modern Manufacturing: Technology, Strategy, and Organization". *American Economic Review*, Vol. 80, No. 3, pp. 511 - 528.
Miravete, E. and J. Pernías (2006). "Innovation Complementarity and Scale of Production". *The Journal of Industrial Economics*, Vol. 54, No. 1, pp. 1 - 29.
Mohnen, P. and L. Roller (2005). "Complementarity in Innovation Policy". *European Economic Review*, Vol. 49, No. 6, pp. 1431 - 1450.
Montalvo, C., F. J. Díaz López and F. Brandes (2011). "Potential for eco-innovation in nine sectors of the European economy". Vol. No., pp.
OECD (2005). *The Measurement of Scientific and Technological Activities Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*.OECD publishing, Luxembourg.
Palmer, K., W. E. Oates and P. R. Portney (1995). "Tightening environmental standards: The benefit-cost or the no-cost paradigm?". *The Journal of Economic Perspectives*, Vol. 9, No. 4, pp. 119-132.
Percival, J. and B. Cozzarin (2008). "Complementarities affecting the Returns to Innovation". *Industry and Innovation*, Vol. 15, No. 4, pp. 371 - 392.
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). "Does the Porter hypothesis explain expected future financial performance? the effect of clean water regulation on chemical manufacturing firms". *Environmental and Resource Economics*, Vol. 45, No. 3, pp. 353-377.
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.
REMake. (2013). "Welcome to ecomanufacturing.eu Recycling and resource efficiency in manufacturing." Retrieved 17 July 2013, from http://www.ecomanufacturing.eu/.
Roper, S. (2001). "Innovation, Networks and Plant Location: some evidence from Ireland". *Regional Studies*, Vol. 35, No. 3, pp. 215-228.
Roper, S., J. Du and J. Love (2008). "Modeling the innovation value chain". *Research Policy*, Vol. 37, No. 6-7, pp. 961-977.
Roper, S., J. Youtie, P. Shapira and A. Fernández-Ribas (2010). "Knowledge, Capabilities and Manufacturing Innovation: A USA-Europe Comparison". *Regional Studies*, Vol. 44, No. 3, pp. 253 - 279.
Saxena, R. P. and P. K. Khandelwal (2012). "Greening of industries for sustainable growth: An exploratory study on durable, non-durable and services industries". *International Journal of Social Economics*, Vol. 39, No. 8, pp. 551-586.

Schmiedeberg, C. (2008). "Complementarities of innovation activities: An empirical analysis of the German manufacturing sector". *Research Policy*, Vol. 37, No., pp. 1492 - 1503.

Schumpeter, J. (1975). *Capitalism, Socialism and Democracy*.Harper and Row, New York.

Soares, M. (2012). "Framework for sustainable and responsible innovation." Speech at ENERO Workshop 20th Anniversary 'Boosting and securing eco-innovations through new partnerships' Retrieved 24 July 2012, from http://www.enero.eu/files/files/ECOINOVATION_WS_2012/2_ENERO_workshop_speech_M_Soares_29.3.12.pdf.

Swann, P. (2009). *The Economics of Innovation: An Introduction*.Edward Elgar, Cheltenham, UK.

Tohidi, H. and M. M. Jabbari (2012). "The important of Innovation and its Crucial Role in Growth, Survival and Success of Organizations". *Procedia Technology*, Vol. 1, No., pp. 535-538.

Triebswetter, U. and J. Wackerbauer (2008). "Integrated environmental product innovation in the region of Munich and its impact on company competitiveness". *Journal of Cleaner Production*, Vol. 16, No. 14, pp. 1484-1493.

Van de Ven, A. H. (1999). *The innovation journey*.Oxford University Press, USA.

Wagner, M. (2007). "On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms". *Research Policy*, Vol. 36, No. 10, pp. 1587-1602.

Table 1: Descriptive Statistics of CIS 2006-08

	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%
Eco 2 - Reduced energy use per unit of output	22.19%
Eco 3 - Reduced CO_2 'footprint' (total CO_2 production) by your enterprise	21.64%
Eco 4 - Replaced materials with less polluting or hazardous substitutes	19.12%
Eco 5 - Reduced soil, water, noise, or air pollution	17.29%
Eco 6 - Recycled waste, water, or materials	33.70%
Environmental benefits from the after sales use of a good or service by the end user	
Eco 7 - Reduced energy use	20.17%
Eco 8 – Reduced air, water, soil or noise pollution	14.53%
Eco 9 - 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%
Internal R&D (€)	€2,054 (€10,253)
External R&D (€)	€460 (€5,064)
Performance Indicator	
Turnover per Employee (€)	€696,000 (€6,309)
Control Variables	
Firm Specific Factors	
No. Of Employees	89 (246)
Capital per Employee (€)	€3,606 (€36,718)
Irish Owned (%)	76
Sector	
Sector 1	30.03
Sector 2	9.54
Sector 3	35.12
Sector 4	10.82
Sector 5	14.49

Table 2: Knowledge Augmented Production Function Estimates

	Coeff	s.e.
Constant	4.9384	(0.2824)
Environmental benefits from the production of goods or services within your enterprise		
Eco1 - Reduced material use per unit of output	-1.9550	(2.8605)
Eco 2 - Reduced energy use per unit of output	-1.5832	(4.2773)
Eco 3- Reduced CO_2 'footprint' (total CO_2 production) by your enterprise	9.9921***	(3.1364)
Eco 4- Replaced materials with less polluting or hazardous substitutes	4.8990	(4.0850)
Eco 5 -Reduced soil, water, noise, or air pollution	-5.8777	(5.1903)
Eco 6 -Recycled waste, water, or materials	-0.6308	(1.5086)
Environmental benefits from the after sales use of a good or service by the end user		
Eco 7 - Reduced energy use	-4.1621	(4.5695)
Eco 8 - Reduced air, water, soil or noise pollution	0.2562	(3.8396)
Eco 9 -Improved recycling of product after use	0.0611	(3.3429)
Interaction Terms		
eco1*eco2	21.7119	(14.4158)
eco1*eco3	-4.4973	(16.4688)
eco1*eco4	-25.8298	(17.5899)
eco1*eco5	13.2290	(17.5787)
eco1*eco6	-21.5227*	(12.1108)
eco1*eco7	-5.4233	(16.8014)
eco1*eco8	5.6006	(20.0024)
eco1*eco9	30.9639*	(17.3568)
eco2*eco3	-10.3681	(9.7229)
eco2*eco4	16.5499	(25.6138)
eco2*eco5	-14.4907	(22.0145)
eco2*eco6	18.3199	(12.8685)
eco2*eco7	-26.4518	(26.5300)
eco2*eco8	25.7691	(28.0713)
eco2*eco9	-26.5358	(18.7607)
eco3*eco4	10.8577	(22.0722)
eco3*eco5	-10.9216	(20.7698)
eco3*eco6	-16.0025*	(8.6781)
eco3*eco7	17.9926	(19.4572)
eco3*eco8	-21.5243	(21.0750)
eco3*eco9	22.3986	(14.9380)
eco4*eco5	10.3719	(10.1403)
eco4*eco6	-23.7487	(15.4323)
eco4*eco7	0.2075	(23.9010)
eco4*eco8	-24.4932	(18.3052)
eco4*eco9	29.7834	(19.6780)
eco5*eco6	29.5868**	(13.8003)
eco5*eco7	-10.7485	(18.9286)

eco5*eco8	7.5580	(18.4679)
eco5*eco9	-27.2813*	(16.2793)
eco6*eco7	25.0065*	(13.9219)
eco6*eco8	-1.8885	(12.0331)
eco6*eco9	-7.5277	(6.8514)
eco7*eco8	19.0138	(18.1194)
eco7*eco9	-21.4450*	(12.6831)
eco8*eco9	-4.0660	(17.7228)
Sector[2]	-0.0315	(0.0702)
All Other Manufacturing (0/1)	0.1588	(0.1461)
Wholesale, Transport, Storage and Communication (0/1)	0.5083***	(0.1552)
Financial Intermediation (0/1)	0.3919*	(0.2215)
Computer, Architecture and Engineering Services (0/1)	-0.4855***	(0.1947)
Firm Specific Factors		
Employment	-0.0315	(0.0702)
Obs		2127
F		5.80
Prob > F		0.0000
R2		0.1248

Note 1: ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 level of significance.
2: High-technology manufacturing is the reference category.