SCIENCE AND TECHNOLOGY POLICIES RESEARCH CENTER
TEKPOL Working Paper Series
STPS-WP-12/03

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Government Policies and Firm Motivations

Pelin Demirel

Effie Kesidou

TEKPOL | Science and Technology Policies Research Center
Middle East Technical University
Ankara 06531 Turkey
http://www.stps.metu.edu.tr

Stimulating Different Types of Eco-Innovation in the UK: Government Policies and Firm Motivations

Pelin Demirel* and Effie Kesidou

Nottingham University Business School, UK

Abstract:

In this paper, we adopt a recent OECD framework and examine the role of external policy tools and internal firm specific factors for stimulating three different types of eco-innovations that range on a spectrum of lower to higher technological and environmental impact: *End-of-Pipeline Pollution Control Technologies*, *Integrated Cleaner Production Technologies and Environmental R&D*. Using a novel firm-level dataset from a DEFRA survey, we estimate a Tobit model, which provides empirical evidence showing that these eco-innovations are motivated by different external policy tools and internal firm specific factors. Our findings indicate that *End of Pipeline Technologies* and *Integrated Cleaner Production Technologies* are mainly driven by equipment upgrade motives with a view of improving efficiency while environmental regulations are effective in stimulating the *End-of-Pipeline technologies* and *Environmental R&D*. Interestingly, alongside government induced regulations, we find that market factors, mainly motivated by cost savings, are effective in driving *Environmental R&D*. Finally, ISO14001 certification is effective in strengthening the positive impact of environmental management systems on both *End-of-Pipeline technologies* and *Environmental R&D* while CSR policies have no significant impact on motivating any of the eco-innovations.

Keywords: Cleaner Production, Environmental Regulation, Environmental Taxes, Environmental Management Systems, Eco-R&D, ISO14001.
JEL Classifications: Q5 Environmental Economics, **O3** Technological Change.

* Corresponding author at: Nottingham University Business School, Wollaton Road, Nottingham NG8 1BB, UK. Email address: pelin.demirel@nottingham.ac.uk
Tel: +44 (0) 115 8467420.

1. Introduction

Due to growing concerns for the environmental impact of the industrial society, governments are carefully considering their strategies for sustainable development; an increasingly popular philosophy which promotes that the *'environment should no longer be sacrificed to economic growth: rather, the two should be reconciled'* (Aggeri, 1999, 706). In easing the unambiguous trade-offs between environmental protection and economic growth, eco-innovations have a central role to play through improving environmental technologies that measure, detect and treat pollution, avoid it at the source, and ensure that the end product has a life span with minimal environmental impact.[1]

An expanding body of empirical and theoretical literature on eco-innovation aims to understand the circumstances which are more conducive to environmental technology investments. The *'ecological, economic and social'* dimensions of eco-innovations require an inter-disciplinary approach which combines insights from environmental and innovation economics and is aware of the different methodological lenses of the neoclassical and evolutionary schools of thought (Rennings, 2000, p. 322).

In this paper, by merging the valuable insights from these disciplines, we examine the determinants of investment into different types of eco-innovations: *End-of-Pipeline Pollution Control Technologies, Integrated Cleaner Production Technologies and Environmental R&D*. Our findings, based on unique data from DEFRA's firm level survey *"Environmental Protection Expenditure by Industry"*, provide important insights on the specific external policy tools and internal firm factors that affect each type of eco-innovation by incorporating all three types of eco-innovations in the same conceptual framework.

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[1] Environmental technologies cover a broad range of different technology applications aimed at alternative energy production or providing solutions to environmental problems (Cooke, 2008). Eco-innovation is defined as *"the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organisational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives"* (OECD, 2009 p 19).

The paper is structured in the following way: Section 2 discusses the background literature and the proposed conceptual framework of the paper. Section 3 presents the data and methodology used for the empirical analysis. The results are discussed in Section 4. Finally, Section 5 includes the conclusions and discusses the policy implications of the study.

2. Background literature and conceptual framework

2.1. Types of Eco-Innovation

A general model of eco-innovation in line with the OECD framework (2009) is presented in Figure 1. We develop this model further to include a more detailed account of the characteristics specific to each type of eco-innovation, namely, end-of-pipeline pollution control technologies, integrated cleaner production technologies and environmental R&D (Kemp, 1997; Frondel et al., 2007). As indicated in the figure, these eco-innovations range on a spectrum from lower impact -more incremental innovations in pollution control technologies- to higher impact -more radical innovations in environmental R&D[2].

--FIGURE 1 AROUND HERE--

<u>End-of-Pipeline Pollution Control Technologies:</u> Manufacturing firms apply end-of-pipeline solutions in order to treat, handle, measure or dispose emissions and wastes from production (DEFRA, 2006)[3]. As the name suggests, these technological solutions are incorporated into

[2] The differences between incremental and radical innovations are well documented: incremental innovations are continuous improvements to a particular product or process, while radical innovations are discontinuous and disruptive technologies that undermine the competence of current market leaders (Abernathy and Utterback, 1978; Freeman, 1992, Swann, 2009).

[3] Examples of end-of-pipeline technologies include effluent treatment plant and exhaust air scrubbing systems (DEFRA, 2006).

existing manufacturing processes at the final stage and are not essential parts of the production process. End-of-pipeline technologies leave the production process mostly unchanged; therefore, they are considered to be highly incremental innovations. Since end-of-pipeline solutions denote the implementation of non-essential technologies, companies perceive them as costly investments that hamper their competitiveness (OECD, 2009; Porter and van de Linde, 1995).

Integrated Cleaner Production Technologies: Integrated technologies refer to new or modified production facilities, which are more efficient than previous technologies, and contribute to pollution reduction by cutting down the amount of inputs used for production and/or by substituting the inputs with more environmentally friendly alternatives[4] (OECD, 2009). Similar to the end-of-pipeline technologies, integrated cleaner production technologies mostly represent environmental process innovations (Rennings el al, 2006). However, integrated cleaner production technologies are designed to ensure that environmental protection is an integral part of manufacturing processes. In other words, unlike end-of-pipeline solutions that attempt to control pollution by adopting an 'after-event, *react and retreat* approach', integrated solutions focus on preventing pollution by adopting a 'forward-looking, *anticipate and prevent* philosophy' (Ashford, 1994, p.4). Compared to the continuous increasing costs of end-of –pipeline technologies, integrated technologies are less costly, since they have the potential to save costs by reducing the use of raw materials, energy and the costs of complying with regulations (Ashford, 1994).

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[4] Examples of integrated technologies include the following (Ashford, 1994): (a) improved housekeeping, which refers to improvements in management practices, monitoring, and maintenance; (b) changes to process technologies, through optimization, which conserves raw materials and energy; (c) changes to products with the use of new technologies, which reduces the consumption of resources, waste and emissions; (d) changes to inputs by substituting toxic materials with environmentally friendly alternatives.

Environmental R&D: The main aim of environmental R&D is to improve products and processes by providing solutions for cleaner production and consumption. Manufacturing firms that conduct environmental R&D on a systematic basis attempt to increase the stock of knowledge in the field of environmental protection and use this knowledge to devise new applications (DEFRA, 2006). Environmental R&D has a higher technological impact compared to the previously discussed categories of eco-innovation because (1) it enhances absorptive capacity as environmental R&D broadens the horizons of the company in environmental matters (Cohen and Levinthal, 1990) and (2) the scope of environmental R&D is not only limited to process innovations but also covers product innovations. Similar to the case of generic R&D, environmental R&D is subject to high risks and high costs.

2.2. Drivers of Different Types of Eco-Innovations

Since the three types of eco-innovations have different characteristics, we expect that they may have different drivers. In this paper we consider the role of two broad drivers: External Environmental Policy Instruments and Internal Firm-Level Motivations.

2.2.1. External environmental policy instruments

Various studies from environmental economics and eco-innovation literatures attempt to decipher whether command and control policies (such as environmental regulations) or market-based instruments (such as environmental taxes) are more effective and cost efficient in reducing pollution. Environmental economists see *Regulatory Push* as the main driver of eco-innovation and often suggest that market-based instruments are superior to command and control policies in reducing pollution due to cost-efficiency and flexibility advantages[5] (Milliam and Prince, 1989; Requate and Unold, 2003; Requate, 2005).

On the other hand, moving the emphasis from immediate pollution control to environmental innovations, the recent developments in eco-innovation studies highlight the value of command and control mechanisms for driving eco-innovations. Specifically, Porter (1991) and Porter and Van Der Linde (1995a, 1995b) have shown that environmental regulations indeed create 'win-win' situations: Firms achieve high profits and produce "green products" because environmental regulations boost R&D activities and thus, stimulate innovation and economic growth (Hart, 2004; Popp, 2005, Rothfels, 2002). An alternative explanation of the "win-win" situation is offered by Rothfels (2002) who shows that compliance with environmental regulations can drive firms to become leaders in "green markets" and thus, become more competitive compared to their foreign peers.

Besides highlighting the value of environmental regulations, eco-innovation literature points out that the traditional economic approach fails to understand the dynamics of radical and incremental changes in environmental technologies and the driving factors behind these changes (Kemp, 1997; Nill and Kemp, 2009; Rammel and van der Berg, 2003; van de Bergh et al., 2007). In particular, the traditional environmental economics approach focuses mainly on the impact of policy instruments upon the most incremental types of eco-innovation, namely the end-of-pipeline solutions and ignores more radical innovations in integrated cleaner production technologies or environmental R&D (Kemp and Pontoglio, 2008). This conceptual gap is addressed by a limited number of studies among which, the study by

[5] Environmental economists use models, which treat pollution as a negative externality; the generators of these externalities are induced through a set of Pigouvian taxes and/or tradable permits to pay for the full range of social costs that their activities entail (Baumol and Oates, 1988).

Frondel et al. (2007) most strongly confirms the necessity to examine the impact of external policy instruments on different types of environmental technologies. Their results indicate that command and control mechanisms play an important role in stimulating end-of-pipeline solutions but a minimal role for integrated cleaner production technologies. Market-based instruments, on the other hand, do not affect either type of eco-innovation. Similar findings regarding command and control mechanisms are reported by the OECD survey (Johnstone, 2007) but their results on market-based instruments (i.e. taxes) differ, suggesting that taxes stimulate changes in the production process. Cleff and Rennings (2000) also find evidence in favour of market-based instruments boosting eco-innovations.

In assessing the relationship between external policy instruments and environmental technologies, the complexity of environmental technologies require new socio-technical paradigms which need to combine market-based and command and control policies (Geels and Schot, 2007). Kemp (1997) argues that there is no single best policy instrument to stimulate clean technology and different instruments may play important roles depending on the context they operate in and the type of clean technology that needs to be stimulated. Indeed Jaenicke et al. (2000) find that a combination of instruments performs best in stimulating eco-innovations. Frondel et al. (2007) also agree that the type of instrument is less important but it is important to ensure that these instruments sustain a stringent environmental policy.

In the empirical part of this paper, we investigate the role played by the environmental regulations and environmental taxes implemented in the UK for boosting the different types of eco-innovations discussed in 2.1.

2.2.2. Internal firm-level motivations

In this section, we focus on three firm-level motivations that are potential drivers of eco-innovations; namely Organisational capabilities, Efficiency, and Corporate image.

(a) Organisational Capabilities: Environmental Management Systems (EMS) engender important *organisational capabilities* in the area of environmental protection. EMS are voluntary organisational frameworks that detail the procedures to manage the impacts of the organisation on natural environment (Darnall, 2006). EMS are aimed at the continuous improvement of corporate environmental performance with an attempt to get ahead of the existing government regulations to reduce emissions and waste disposal (Kollman and Prakash, 2002). European Union's Environmental Management and Audit Scheme (EMAS) and ISO14001 constitute the most diffused forms of formalised EMS and both schemes require third party certification and investigation. Bansal and Hunter (2003) argue that these two schemes reinforce legitimacy which cannot be claimed through in-house EMS.

There is little consensus on the impact of EMS upon environmental performance or eco-innovation. Russo and Harison's (2005) findings show that environmental performance does not respond to EMS implementation. Similarly, Boiral (2007) finds that formal EMS fail to improve the environmental performance, yet introduce many cumbersome and bureaucratic procedures. Rondinelli and Vastag (2000) argue that the implementation of EMS cannot ensure that the company will attain environmental sustainability.

On the other hand, other studies pin point the importance of different characteristics of EMS that affect the quality of their implementation within the firm and in turn, the organisational changes that occur and subsequently affect environmental performance (Rehfeld et al., 2007; Anton et al., 2004; Arimura et al., 2008). Rennings et al. (2006) confirm the importance of EMAS certification for environmental innovations among certified facilities in Germany. In particular, their findings indicate the role played by different aspects of EMAS (i.e. maturity and strategic importance of EMAS and the learning processes) for stimulating eco-innovation. They confirm that most features of EMAS (as noted above) affect environmental process innovations but not product innovations because the implementation of EMS is aimed at improving the environmental quality of processes. Anton et al. (2004) also finds that a more comprehensive implementation of EMS (as opposed to a limited implementation) improves the environmental performance. Finally, Wagner (2008) offers empirical evidence, which shows that EMS have a positive effect upon process innovations but no effect upon product innovations.

EMS are also expected to have an indirect effect on the organisational capabilities by boosting environmental awareness and organisational learning (Melnyk et al., 2003). Rennings et al. (2006) highlight the significant role played by learning processes that occur during the implementation of EMS.

(b) *Efficiency:* We consider two dimensions of *efficiency;* (1) cost savings arising from expenditures in environmental improvements and (2) equipment upgrades undertaken with the purpose of environmental protection.

Eco-innovations that can lead to more efficient means of production may give rise to cost savings that can in return motivate further investments into eco-innovations (Hitchens et al., 2003). Even though, many firms report environmental protection activities to be costly for them, Ashford (1994) argues that this is only the case for end-of-pipeline pollution control technologies and that, companies can save costs by investing in cleaner production technologies that reduce pollution and waste at its source. "*When cleaner production and pollution control options that solve the same environmental problems are properly evaluated against one another, the cleaner production options will usually be less costly to implement, operate and maintain … because cleaner production technologies reduce cost of raw materials, energy, pollution control, waste treatment and clean-up, and regulatory compliance*" (Ashford, 1994, p.7). In line with this statement, a recent OECD study using data from seven OECD countries indicates that there are larger cost savings from investments in cleaner production technologies (Johnstone, 2007). Frondel et al. (2007) provide evidence that cost savings are an important factor that drives cleaner production technologies.

On the other hand, Palmer et al. (1995) argue that cost savings due to environmental innovations are as low as 2% of the environmental compliance costs and are unlikely to provide enough stimuli to drive environmental innovations. They suggest that cost-offsets due to environmental innovations should be rather high in order for cost-savings to be a driver for eco-innovations.

Equipment upgrade activities can similarly lead to more efficient energy use and further cost savings. For example, Yokogawa Electric, a Japanese manufacturer, developed a technology, which controls the pumping pressure of air conditioning systems resulting in large energy savings. Several businesses such as equipment factories, hotels, and supermarkets that upgraded their existing air conditioning systems to Yokogawa's new system were able to reduce their energy consumption significantly (OECD, 2009).

(c) *Corporate Image: Corporate Social Responsibility* (CSR) which, we consider to be an important element of corporate image, is a recent and controversial concept that embraces environmental issues as one of its three pillars- the other two being the employment/labour practices, and human/social rights. The Earth Summit in Rio (1992) highlighted the importance of environmental issues for CSR and coined the term 'Environmental Social Responsibility' (Hart, 1995; Russo and Fouts, 1997).

The effectiveness of environmental actions motivated by CSR has come under question due to the 'voluntary' basis for compliance under CSR. In other words, are 'voluntary' processes such as CSR effective enough to stimulate eco-innovation? Aggeri (1999) argues that although voluntary agreements provide weaker incentives compared to external policy instruments, they are well adapted to manage uncertainty and coordination issues arising when dealing with sustainable development problems. In particular, innovation-oriented voluntary agreements include a stronger coordination scheme, which is necessary in order to achieve sustainable development.

On the other hand, Williamson et al. (2006) suggest that the voluntary nature of CSR cannot satisfy the need for sustainable production. They argue that the use of regulatory structures that provide the minimum standards for many activities covered by CSR is the only effective way to encourage green activities in companies**.** Recent empirical evidence on the influence of voluntary programs compared to formal regulation on emissions in the metal-finishing industry indicates that the effectiveness of voluntary programs yielded little, if any, reductions in emissions, while the regulator threat reduced emissions significantly (Brouhle et al., 2009). Hence, the impact and effectiveness of environmental CSR policies on eco-innovation remains unresolved begging for further research.

--FIGURE 2 AROUND HERE--

Overall, the review of the literature suggests that it is highly unlikely that all types of eco-innovations are stimulated by the same drivers. Our conceptual framework in Figure 2 attempts to explore the role played by various factors in motivating the different types of eco-innovation by disentangling the effectiveness of external and internal factors. This framework is important to ecological economics for analytical purposes in guiding empirical research and also for informing policy makers and businesses regarding the expected environmental, technological, and economic impact of various external policy instruments and internal business activities. Given the abundance of mixed evidence on the role that these internal and external factors play for different types of eco-innovations, we apply an empirically oriented strategy and leave it for the data to reveal the direction and significance of the impact of these factors in the specific case of the UK.

3. Data and Methodology

3.1. Data and Descriptive Statistics

We use a dataset of 289 UK firms that responded to the *'DEFRA Government Survey of Environmental Protection Expenditure by Industry'* in years 2005 and 2006. The Department for Environment, Food and Rural Affairs (DEFRA) conducts the survey with the aim of estimating how much the UK manufacturing sector spends (annually) to protect the environment. The survey represents a unique source of information on the UK environmental spending with a very high level of coverage across all manufacturing industries[6]. With the exception of Kesidou and Demirel (2010), the data has not been used for academic research purposes.

The survey questions give us a valuable opportunity to explore the determinants of different eco-innovations by providing information on firms' investments into (1) End-of-Pipeline pollution control technologies (EOP), (2) Integrated cleaner production technologies (INT) and (3) Environmental R&D (ECORD). As the statistics in Table 1 reveal, the majority of UK investments into environmental protection goes into the integrated cleaner production technologies, followed by end-of-pipeline pollution control technologies and environmental R&D. Frondel et al. (2007) and Lanoie et al. (2007) report similar levels of investment for 7 OECD countries based on the OECD survey of 3100 establishments.

[6] In particular, the response rates are respectively 18.7% and 20.4% in 2005 and 2006. 1466 firms responded to the survey in 2005 and 1599 firms responded to the survey in 2006. 289 firms that are included in the following analysis responded in both years.

Additionally, the DEFRA survey provides information on firms' Cost Savings from environmental activities (CS), their Equipment Upgrade (Eq_Upgrade), and Corporate Social Responsibility (CSR) motivations, whether or not they subscribe to Environmental Management Systems (EMS), the external validation status of their EMS (i.e. ISO14001) as well as how they perceive Environmental Regulations (ENV_REG) and Environmental Taxes (ENV_TAX). Table 1 reports a brief definition of all variables used in this study and the associated descriptive statistics.

---TABLE 1 AROUND HERE---

3.2. Methodology

Among the 289 firms in the dataset, only 70 firms invested in end-of-pipeline technologies (EOP), 66 invested in integrated cleaner technologies (INT) and 73 invested in environmental R&D (ECORD) in 2006. A further breakdown of investment into each eco-innovation variable is presented in Figure 3. As indicated; 54.8% of firms in the dataset did not invest into any type of eco-innovation while 45.2% of firms invested in at least one type of eco-innovation. The share of eco-innovators in this study (45.2%) is strikingly similar to that of generic innovators (45%) reported in the UK Community Innovation Survey (Community Innovation Survey, 2009).

---FIGURE 3 AROUND HERE---

We examine the determinants of different types of eco-innovation by using an econometric model where each of the three eco-innovation variables EOP, INT and ECORD (normalised by the total capital of the firm) in year 2006 are independently regressed on a set of lagged internal and external determinants from year 2005 as discussed in detail in Section 2.2. Since the dependent eco-innovation variables (ECOINN) are censored from below at zero (i.e. not all firms invest into eco-innovation), the appropriate estimation technique is a Tobit model (Greene, 2003):

$$ECOINN_{i,t}^{*} = x_{i,t-1}^{'}\beta + \varepsilon \quad \text{(Eq.1)}$$

And $$ECOINN_{i,t} = \begin{cases} ECOINN_{i,t}^{*} & if \quad ECOINN_{i,t}^{*} > 0. \\ 0 & if \quad ECOINN_{i,t}^{*} \leq 0. \end{cases} \quad \text{(Eq.2)}$$

where $ECOINN$ variable is greater than zero only when the latent $ECOINN^{*}$ variable exceeds zero. The independent variables, included in the vector x correspond to the external and internal determinants of eco-innovation as follows:

External Policy Determinants of Eco-Innovations: Prior work by environmental economists has shown that environmental regulations and environmental taxes are important determinants of eco-innovations (Hart, 2004; Popp, 2005, Rothfels, 2002). We use two proxies for the external determinants: (1) ENV_REG and (2) ENV_TAX. Both are binary variables that respectively assume the value 1 if a firm indicates that environmental regulations or environmental taxes have been effective in their decisions to invest into environmental protection in 2005.

Internal Determinants of Eco-Innovations: Previous empirical studies on innovation economics and environmental management have underlined the internal determinants of eco-innovation (Rennings et al., 2006; Frondel et al., 2007; Kollman and Prakash, 2002; Darnall, 2006). Among these firm level factors, we measure material and energy efficiency gains by considering the Cost Savings due to environmental improvements (CS) and by taking into account the Equipment Upgrade motivations (Equ_Upgrade) of firms as reported in 2005.

The environmental organisational capabilities of firms are measured by a binary variable that takes the value 1 if the firm has an Environmental Management System (EMS) in place in 2005. We further investigate whether the external certification of EMS is an important determinant of eco-innovations using another dummy variable that takes the value 1 if the firm owns an approved ISO 14001 certification. Finally, we explore the role of voluntary activities of companies to protect the environment by including an independent dummy variable, CSR that indicates whether corporate social responsibility policies have played an important role in the decisions to invest into environmental protection in 2005.

As an additional control, we account for the size differences- measured by the number of employees- that may lead to different eco-innovation behaviour among firms. We also include industry dummies based on two-digit SIC codes to control for sectoral differences[7].

3.2.1. Decomposing the Marginal Effects

To have a more comprehensive understanding of the impact of these internal and external factors upon eco-innovations, we decompose the marginal effects attained through the estimation of the Tobit Model in Equation 1 using McDonald and Moffitt's (1980) suggestion of decomposing the slope vector β into:

$$\frac{\partial E\left[ECOINN_i \middle| x_i \right]}{\partial x_i} = Prob\left[ECOINN > 0\right] \frac{\partial E\left[ECOINN_i \middle| x_i, \quad ECOINN_i \succ 0 \right]}{\partial x_i} + E\left[ECOINN_i \middle| x_i, \quad ECOINN_i \succ 0 \right] \frac{Prob\left[ECOINN > 0\right]}{\partial x_i} \qquad \text{(Eq.3)}$$

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[7] The set of industry dummies correspond to the UK SIC codes 10, 11, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 40 and 41.

such that a change in x_i has two effects: (1) the effect on the probability that the observation will fall in the positive part of the distribution (the impact upon convincing firms to undertake investments into eco-innovations) and (2) the effect on the conditional mean of $ECOINN^*$ in the positive part of the distribution (i.e. the impact upon the level of eco-innovations for those firms with positive spending) (Greene, 2003, p.766). This decomposition is especially important for understanding the factors that can motivate 54.8% of the firms that do not undertake any kind of eco-innovations. The decomposed marginal effects as in part (1) and (2) in Equation 3 are reported in all regressions across Tables 2, 3 and 4.

4. Results and Discussion

As initially anticipated, the results provided in Table 2, 3 and 4 confirm that different types of eco-innovation indeed have different determinants. Moreover, these determinants have a different impact on the level of eco-innovations and the probability of eco-innovating. These findings have important implications for policy makers who may wish to stimulate a certain kind of eco-innovation by focusing on its specific determinants. Below we discuss the role of internal and external determinants for motivating EOP, INT and ECORD.

4.1. Impact of External Factors

With regards to the external policy instruments, our results indicate that environmental regulations are effective in driving certain types of eco-innovation, while environmental taxes fail to motivate any of the three eco-innovations considered.

Environmental Regulations: Beyond the findings of the existing literature, incorporating all three types of eco-innovation in the same framework allows us to see the presence of a U-type relationship between regulations and eco-innovations: regulations are able to impact the least and most significant eco-innovations; namely end-of-pipeline technologies (EOP) and environmental R&D (ECORD). Their impact is less than clear for the integrated cleaner technologies (INT), which stand in between EOP and ECORD in terms of environmental and technological significance.

Moreover, decomposing the marginal effects of regulations indicates that their impact is especially large in getting companies to invest into EOP and ECORD while they have a smaller, yet significant impact upon the levels of EOP and ECORD undertaken by eco-innovators. This suggests that regulations are being effective in converting firms to eco-innovators either at the lower or the higher end of the eco-innovation spectrum.

These findings are in line with those of Frondel et al. (2007) who show that regulations are important for the end-of-pipeline technologies, but not for integrated cleaner technologies. According to Frondel et al. (2007, p.573), because regulations are very prescriptive, and usually '*impose technology standards that can only be met through End-of-Pipeline abatement measures'*, they stimulate investments in process innovations; specifically in end-of-pipeline technologies, while they have no impact upon integrated cleaner technologies. Hence, our findings confirm the existing literature in the context of the UK.

Simultaneously, our results show that regulations stimulate investments in ECORD, which gives rise to both process and product environmental innovations. This finding is in-line with the 'Porter Hypothesis', which states that regulations boost environmental R&D activities and thus, stimulate eco-innovation. According to the literature, companies which invest in environmental R&D gain 'strategic advantage' from innovation and become leaders in 'green markets' (Carraro, 200; Montero, 2002; Hart, 2004; Popp, 2005, Rothfels, 2002).

Environmental Taxes: In contrast to regulations, environmental taxes do not appear to have a significant impact on any of the three types of eco-innovation. This finding is, again, similar to Frondel et al.'s (2007) results which confirm that market-based instruments do not affect either end-of-pipeline or integrated technologies in Germany. In the specific case of the UK, environmental taxes have not been frequently used as a means of regulating pollution levels since environmental laws have historically been the preferred policy tool in this field (Ashford, 1994; Jordan et al., 2003). Moreover, environmental taxes are commonly set at a low level and the innovation effects are, therefore, low or insignificant (Kemp, 2000).

4.2. Impact of Internal Factors

As far as internal factors are concerned, our results indicate that efficiency (equipment upgrade motives and cost savings) and EMS factors have a varied impact on the three types of eco-innovations while CSR is not a significant driver for any type of eco-innovation.

Efficiency: Machinery and equipment upgrades are important means of increasing efficiency for companies and our results indicate that EOP and INT are driven by firms' willingness to upgrade their equipment. This suggests that firms consider the most energy efficient and environmentally friendly technologies when they are renewing existing facilities.

Another indicator of efficiency, cost savings, appear to be an important driver for only the most advanced type of eco-innovations, ECORD, while it has no significant impact on either EOP or INT. This result is understandable for the case of end-of pipeline technologies which are considered to be costly rather than cost-saving investments (Ashford, 1994). The lack of impact in the case of integrated cleaner technologies, on the other hand, gives support to the findings of Palmer et al. (1995) who suggest that cost savings might not be large enough to drive eco-innovations.

Finally, the results suggest that environmental R&D is not only stimulated by regulation but it is also market driven, mainly motivated by the cost saving potential of the outcomes that arise from environmental R&D. The decomposition of marginal effects on the cost savings variable confirms that many firms are motivated to do environmental R&D due to the cost saving possibilities while the impact of cost savings are smaller for those firms that are already investing into environmental R&D.

Environmental Management Systems (EMS): The impact of EMS, on the other hand, is similar to that of environmental regulations where the most (ECORD) and least (EOP) significant eco-innovations respond to the presence of an EMS in the company. This effect is most clearly visible especially when the impact of ISO14001 certification is considered. EOP and ECORD respond positively to adopting ISO 14001 certification while INT is not stimulated by either maintaining an EMS or subscribing to ISO 14001. A plausible explanation of this finding is related to the innovative heterogeneity of firms where the least innovative firms benefit from having an organisational environmental structure to support them with the minimum compliance requirements through EOP while the most innovative firms use EMS as an innovation platform to build upon for ECORD. The decomposed marginal effects suggest that EMS is especially effective in motivating firms to start investing in EOP and has a significant but smaller effect on increasing the EOP investments of those firms that already invest in EOP. In the case of ECORD, EMS is only effective for persuading firms to invest in ECORD but cannot motivate increased ECORD investments for firms with existing ECORD activities.

Corporate Social Responsibility (CSR): Finally, CSR fails to be a significant driver of any of the three eco-innovations. This indeed poses questions on how much we can rely on the corporate goodwill and voluntary compliance in environmental matters. While environmental awareness and protection is an important foundation for CSR, the costly nature of environmental protection and the externalities associated with these expenditures appear to get in the way of CSR as a powerful driver for environmental protection.

5. Conclusions

This paper looks into the determinants of different types of eco-innovation, namely, end-of-pipeline pollution control technologies, integrated cleaner production technologies and environmental R&D. These three types of eco-innovation differ with respect to their technological significance, costs to companies and their benefits to the environment. By integrating these three different eco-innovation activities in a single framework, we are able to analyze whether and how certain factors stimulate each of these eco-innovations.

Our findings indicate that environmental regulations affect end-of-pipeline pollution control technologies and environmental R&D while they do not influence integrated cleaner technologies. By setting strict technology standards, regulations stimulate investments in end-of-pipeline technologies, which have the lowest environmental and technological impact while, at the same time, encouraging investments in environmental R&D, which has the highest environmental and technological impact. Consequently, the results of this study suggest that regulations can play an important role in combating pollution not only in the short run, by stimulating investments in process innovations such as end-of-pipeline technologies, but also in the long run by driving investments in process and product innovations through environmental R&D. The latter provides support for Porter Hypothesis and has important implications for the environmental innovation policy. As markets for low-carbon products are estimated to be worth at least $500bn per year by 2050 (Stern Review, 2006), regulation may play a key role in motivating firms to invest in environmental R&D for the generation of eco-friendly products and services that have significant market potential.

Our results further suggest that the impact of regulations is especially large in motivating companies to adopt eco-innovations while they have a smaller, yet significant impact, upon the intensity of investments on eco-innovations. These results are in-line with the literature on the diffusion of generic innovations. In particular, at early stages of diffusion the inter-firm adoption rate dominates the intra-firm intensity of use (Battisti and Stoneman, 2003). Policies tend to focus mainly on the adoption of innovations by firms rather than on their intensity of use. Yet, once beyond the early stages of adoption, the intensity of use becomes extremely important in the generation of benefits from adoption, in general, and of eco-innovations in particular (e.g. in increasing learning and the absorptive capacity of the company) (Battisti and Stoneman, 2003). Therefore, we highlight the necessity for designing environmental regulations that do not only motivate the adoption of eco-innovations but also their intensity of use.

In contrast to environmental regulations, environmental taxes do not affect any type of eco-innovations. UK is currently adopting a growing number of market-based instruments in lieu of the EU. Policy makers should carefully consider the effectiveness of these instruments not only for reducing the immediate pollution but also for stimulating eco-innovations that will lead to a greener economy in the UK. Kemp and Pontoglio (2008) highlight the need for policy instruments that ensure the required policy stringency through appropriate design and effective enforcements. Additionally, our results suggest that market-based instruments cannot be solely relied on and they should be combined with the necessary regulations.

Our findings also point to the presence of an important number of firm-based factors that determine the adoption and/or creation of eco-innovations. Firstly, cost savings resulting from environmental efficiency appear to be only significant in driving investments in environmental R&D which are the most advanced in the spectrum of eco-innovations. Cost savings come from eliminating or re-using waste. Less advanced eco-innovations, expectedly, have a lower potential for creating such savings for companies. Therefore, it is possible that cost savings are most closely associated with the most advanced eco-innovations. Improvements to the eco-infrastructure play a significant role in ensuring that even firms with less advanced eco-innovations can reap cost benefits. For example, ensuring that firms have accessible outlets for the sale of their by-products can be highly effective in encouraging cost savings and increasing eco-innovations.

The least and medium significance eco-innovations (i.e. EOP and INT), on the other hand, are motivated by increased environmental efficiency due to equipment upgrades, which allow firms to shift to more energy efficient means of production. We note the benefits of policy incentives, such as ‘scrappage’ style programs, that will make it easier for firms to trade-in their machinery for more energy efficient alternatives.

Second of firm-based factors, environmental organisational capabilities, also impact the least and most advanced eco-innovations, possibly providing the new starters with the required organisational structure on their first attempt to eco-innovate and also the most capable innovators with a sound framework to enable them to apply their innovation skills and knowledge to environmental matters. We find that ISO14001 certification is effective in strengthening the positive impact of environmental management systems on both end-of-pipeline technologies and environmental R&D.

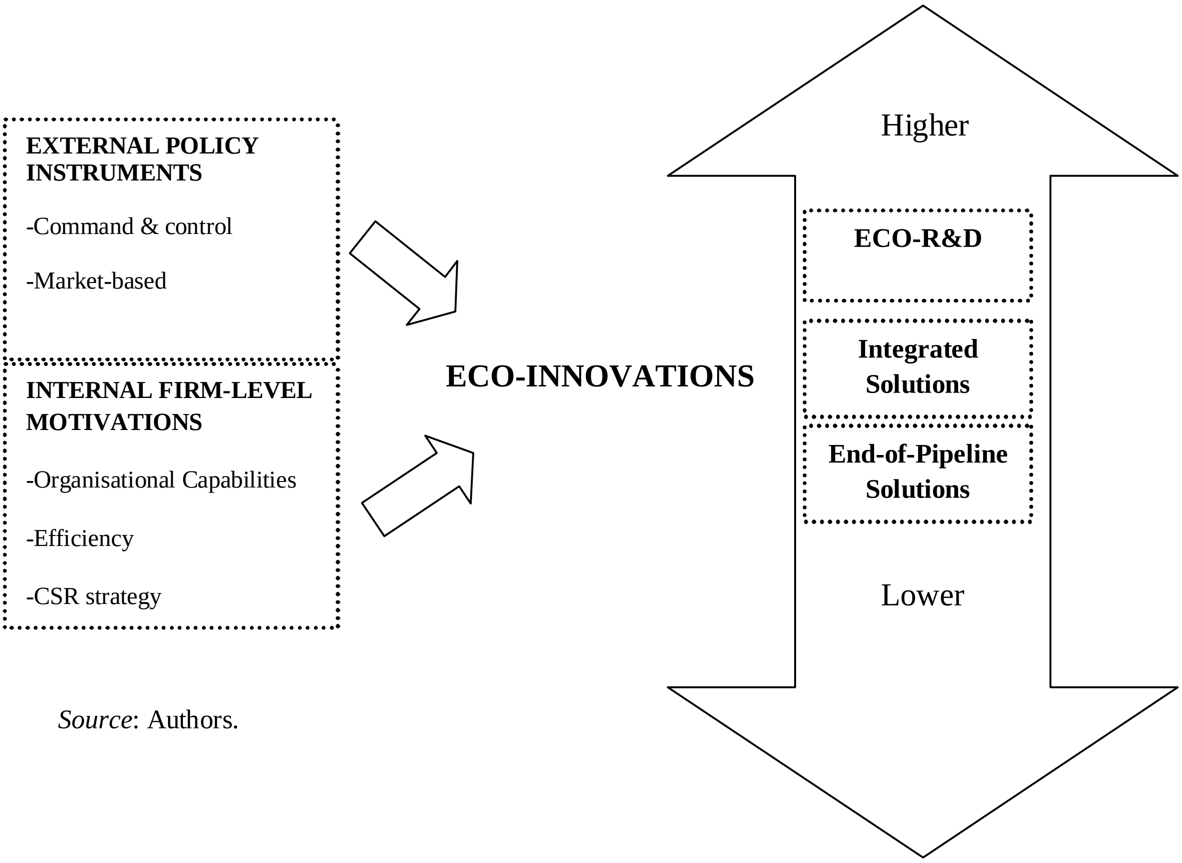
The third firm based factor, CSR, is interestingly not a significant driver of any type of eco-innovation. This casts doubt on the effectiveness of voluntary agreements by companies to reduce their environmental impact. CSR policies can most effectively be used as a supporting mechanism to environmental policies which underline the minimum basis for environmental compliance.

FIGURES AND TABLES

Figure 1: Categorisation of Eco-Innovations

End-of-Pipeline Pollution Control Technologies	**Integrated Cleaner Production Technologies**	**Environmental R&D**
	Environmental impact	
-Use of **End-of-Pipeline Solutions** -Treatment of waste and pollution	--Use of **Integrated Solutions** -Prevention of waste and pollution at source -Modification of processes -Efficiency improvements through input substitution, lower resource input and output	-Use of **R&D to generate** n**ew or improved products and processes with environmental benefits** -Increase the stock of knowledge in the field of environmental protection. -Improve products and processes (providing solutions for cleaner production and consumption)
	Technological change	
-Implementation of non-essential technologies -Most incremental of all Eco-innovations -Process innovations	-Application of new or improved technologies may lead to further adaptations and modifications of products/processes through learning-by-doing and thus generate more significant technological transformations -Process innovations	-Potential for more disruptive innovations -Product and/or process innovations
	Costs	
-Increase costs	-Lower investment costs in the long run	-High risk and high cost investments with a potential of covering the costs in the long run
	Examples	
-Waste treatment plants -Passive filters such activated carbon -Groundwater monitoring sites etc.	-Installations for reducing the use of water and reuse of waste gas in manufacturing (i.e. Closed loop manufacturing systems) -Internal recycling	-R&D conducted to industrially produce renewable energy, to lower emission vehicles (e.g. catalytic converter), to reduce packaging of products etc

Figure 2: Conceptual framework



Source: Authors.

Figure 3: Breakdown of Firms According to Eco-innovation activities

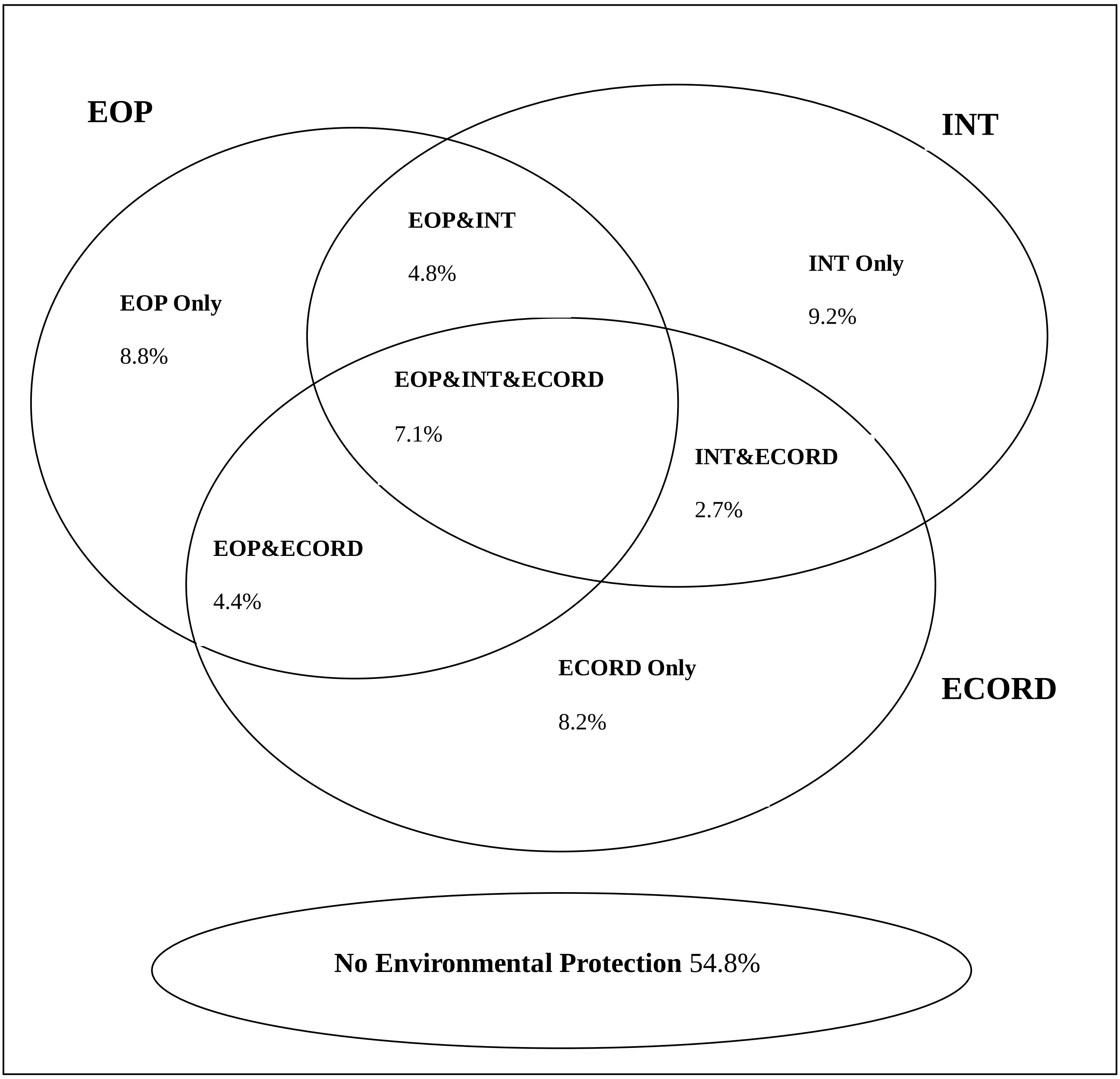


Table 1: Description of Variables and Descriptive Statistics

	2005				2006			
Variables	Mean	St. Dev	Min	Max	Mean	St. Dev	Min	Max
ECO-INNOVATION VARIABLES								
EOP: End-of-Pipeline Pollution Control Technologies (£)	201333	1790586	0	2.41e+07	85879	634398	0	1.00e+07
INT: Integrated Cleaner Production Technologies (£)	410167	3652364	0	5.83e+07	753337	1.01e+07	0	1.72e+08
ECORD: Environmental research and development (£).	11698	55332	0	530910	33873	333699	0	5448494
EXTERNAL DETERMINANTS								
ENV_REG:=1 if the firm invested in environmental protection due to environmental regulation compliance.	0.238	0.427	0	1	0.262	0.440	0	1
ENV_TAX: =1 if the firm invested in environmental protection because of environmental taxes.	0.041	0.198	0	1	0.044	0.206	0	1
INTERNAL DETERMINANTS								
CS: Total cost savings resulting from environmental improvements (£)	31056	118859	0	1244716	58363	286969	0	3761611
Equ_Upgrade:=1 if the firm invested in environmental protection because of equipment upgrade.	0.194	0.396	0	1	0.153	0.360	0	1
EMS: =1 if the firm has implemented environmental management systems.	0.384	0.487	0	1	0.446	0.498	0	1
ISO14001:=1 if the firm has and ISO 14001 certified environmental management system.	0.296	0.457	0	1	0.282	0.451	0	1
CSR: =1 if the firm invested in environmental protection because of parent company or owner policy/CSR.	0.075	0.264	0	1	0.061	0.240	0	1
EMP: Number of employees	425	1009	0	12287	434	1065	0	13427
TURNOVER (£)	2.06E+08	1.05E+09	0	1.10E+10	2.10e+08	1.08e+09	0	1.28e+10
CAP: Total Capital (£)	1.12E+07	6.82E+07	684.3343	9.27E+08	1.46e+07	8.90e+07	1.395973	1.05e+09

Table 2: Determinants of End of Pipeline (EOP) Pollution Control Technologies

Dependent Variable	EOP	Marginal Effects for the decision to conduct EOP	Marginal Effects for EOP>0	EOP	Marginal Effects For the decision to conduct EOP	Marginal Effects for EOP>0	EOP	Marginal Effects For the decision to conduct EOP	Marginal Effects for EOP>0
In (Employees)(t-1)	.042*** *.017*	.043*** *.013*	.009** .004	.044*** *.018*	.045*** *.012*	.010*** .004	.056*** *.019*	.057*** *.012*	.012*** .004
EXTERNAL DETERMINANTS									
ENV_REG (t-1)	.135*** *.043*	.137*** .042	.03*** *.010*	.145*** *.047*	.147*** *.045*	.032*** .010	.177*** *.049*	.180*** *.039*	.039*** .011
ENV_TAX(t-1)	-.135 *.097*	-.137 .092	-.029 *.021*	-.132 *.092*	-.134 *.088*	-.029 .021	-.180* *.103*	-.184** *.092*	-.040* .023
INTERNAL DETERMINANTS									
ln (CS)(t-1)	.168 *.119*	.170 *.120*	.037 .027	.175 *.115*	.177 *.116*	.039 *.026*	.201* *.108*	.206* *.108*	.045* *.024*
Equ_upgrade(t-1)	.159** *.062*	.161*** *.049*	.035** *.014*	.159*** *.062*	.161*** *.049*	.035*** .014	.163** *.064*	.166*** *.050*	.036** .014
EMS(t-1)	.124** *.051*	.126*** *.038*	.028** *.011*						
ISO14001(t-1)				.110** *.052*	.111*** *.041*	.024** .012			
CSR(t-1)							.143 *.092*	.146* *.079*	.032 .020
Constant	-.550*** *.147*			-.546*** *.145*			-.588*** *.157*		
F	2.97***			2.98***			2.91***		
Log Likelihood Pseudo R2	-66.606 0.2785			-67.535 0.269			-68.410 0.2590		
Left-censored observations	73			73			73		
Uncensored observations	216			216			216		
Number of obs	289			289			289		
Industry dummies	YES			YES			YES		

Significance *0.1, **0.5, ***0.01. Robust standard errors in italics.

Table 3: Determinants of Integrated (INT) Cleaner Production Technologies

Dependent Variable	INT	Marginal Effects For the decision to conduct INT	Marginal Effects for INT>0	INT	Marginal Effects For the decision to conduct INT	Marginal Effects for INT>0	INT	Marginal Effects For the decision to conduct INT	Marginal Effects for INT>0
In (Employees)(t-1)	.043* _.023_	.027* _.015_	.010* _.005_	.040* _.023_	.025* .015	.009* .005	.054** _.023_	.034** .014	.012** .005
EXTERNAL DETERMINANTS									
ENV_REG(t-1)	.102 _.070_	.065 _.045_	.023 _.016_	.105 _.069_	.067 _.045_	.024 .016	.138** _.068_	.087** .044	.032** .016
ENV_TAX(t-1)	.128 _.165_	.081 _.106_	.030 _.038_	.134 _.162_	.085 .104	.031 .037	.106 _.166_	.067 .106	.024 .038
INTERNAL DETERMINANTS									
ln (CS)(t-1)	.213 _.137_	0.135 _.084_	.049 .031	.213 _.137_	.136 _.086_	.049 _.086_	.239* _.131_	.151* _.080_	_.055*_ _.030_
Equ_upgrade(t-1)	.295*** _.098_	.187*** _.054_	.068*** _.023_	.294*** _.097_	.188*** _.054_	.067*** _.023_	.299*** _.100_	.189*** .054	.069*** .023
EMS(t-1)	.101 _.075_	.064 _.046_	.023 _.017_						
ISO14001(t-1)				.124 _.079_	.079 _.048_	.029 .018			
CSR(t-1)							.193* _.116_	.122* _.072_	.044* .027
Constant	-.704*** _.144_			-.682*** _.141_			-.742*** _.151_		
F	3.94***			3.97***			4.02***		
Log Likelihood Pseudo R2	-119.848 0.100			-119.46 0.103			-119.347 0.104		
Left-censored observations	70			70			70		
Uncensored Observations	219			219			219		
Number of obs	289			289			289		
Industry Dummies	YES			YES			YES		

Significance *0.1, **0.5, ***0.01. Robust standard errors in italics.

Table 4: Determinants of Environmental Research and Development (ECORD)

Dependent Variable	ECORD	Marginal Effects For the decision to conduct ECORD	Marginal Effects for ECORD >0	ECORD	Marginal Effects For the decision to conduct ECORD	Marginal Effects for ECORD >0	ECORD	Marginal Effects For the decision to conduct ECORD	Marginal Effects for ECORD> 0
In (Employees)(t-1)	.010 *.013*	.009 *.014*	.002 *.003*	.007 *.015*	.006 *.014*	.001 .003	.020 *.012*	.019 *.013*	.004 *.003*
EXTERNAL DETERMINANTS									
ENV_REG(t-1)	.096** *.045*	.089** .041	.020** .010	.099** *.045*	*.092*** *.041*	.021** *.010*	.119** *.047*	.112** *.041*	.025** *.010*
ENV_TAX(t-1)	.088 *.106*	.082 .101	.019 .023	.095 *.105*	.088 *.099*	.020 *.023*	.069 *.102*	.066 *.099*	.014 *.022*
INTERNAL DETERMINANTS									
ln (CS)(t-1)	.149*** *.056*	.140*** *.052*	.032*** *.012*	.145*** *.056*	.135*** *.052*	.031*** *.012*	.170*** *.052*	*.161**** *.046*	*.036**** *.011*
Equ_upgrade(t-1)	-.024 *.052*	-.023 *.046*	-.005 *.011*	-.023 *.052*	-.022 *.046*	-.005 *.011*	-.022 *.052*	-.021 *.047*	-.005 *.011*
EMS(t-1)	.085* *.047*	.080** *.038*	.018* *.010*						
ISO14001(t-1)				.109** *.054*	*.101**** *.039*	.023** *.011*			
CSR(t-1)							.046 *.062*	.043 *.058*	.010 *.013*
Constant	-.361*** *.104*			-.348*** *.102*			-.382*** *.107*		
F	2.64**			2.70**			3.11***		
Log Likelihood	-82.80			-81.970			-84.056		
Pseudo R2	0.089			0.1023			0.079		
Left-censored observations	66			66			66		
Uncensored observations	223			223			223		
Number of obs	289			289			289		
Industry Dummies	YES			YES			YES		

Significance *0.1, **0.5, ***0.01. Robust standard errors in italics.

Acknowledgements: The authors would like to thank Rocky Harris and Steve Wellington from DEFRA for providing us access to the dataset and clarifications on the data collection methods. We are grateful to Giuliana Battisti, Peter Swann and Sourafel Girma for useful comments and suggestions on earlier drafts. We also thank Eskandar Rashid Mohamed for excellent research assistance.

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