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Abstract

The environmental economics literature emphasises the key role that environmental regulations play in stimulating eco-innovations. Innovation literature, on the other hand, underlines other important determinants of eco-innovations, mainly the supply-side factors such as firms' organisational capabilities and demand-side mechanisms, such as customer requirements and societal requirements on corporate social responsibility (CSR). This paper brings together the views of these different disciplines and provides empirical insights on the drivers of eco-innovations based on a novel dataset of 1566 UK firms that responded to the Government Survey of Environmental Protection Expenditure by Industry in 2006. By applying the Heckman selection model, our findings indicate that demand factors affect the decision of the firm to undertake eco-innovations while these factors exhibit no impact upon the level of investments in eco-innovations. Hence, we suggest that firms initiate eco-innovations in order to satisfy the minimum customer and societal requirements, yet, increased investments in eco-innovations are stimulated by other factors such as cost savings, firms' organisational capabilities, and stricter regulations. Finally, the paper offers interesting insights for policy makers by showing that the stringency of environmental regulations affects eco-innovations of the less innovative firms differently from those of the more innovative firms.

Keywords: Eco-innovations, environmental regulations, organisational capabilities.

JEL Classifications: **Q5** Environmental Economics, **O3** Technological Change.

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1. Introduction

While most researchers and policy makers are well acquainted with the concept of innovation[1], *eco-innovation* is a new concept for which a standardised definition does not exist yet. OECD illustrates that eco-innovation differs from generic innovation on two significant characteristics: 'It is innovation that reflects the concept's explicit emphasis on a reduction of environmental impact, whether such an effect is intended or not. *And*, it is not limited to innovation in products, processes, marketing methods and organisational methods, but also includes innovation in social and institutional structures' (OECD, 2009, p. 13). Additionally, the merit of eco-innovation has been highlighted by academics and policy-makers in the European Commission (see Kemp, 2009 about the MEI project) not only because of its beneficial environmental impact but also due to the expected increased competitiveness of the firms and countries that eco-innovate (Arundel and Kemp, 2009).

The UK environmental policy clearly sets out the urgent challenges in meeting the increasing demands of the economy while moving towards a low emission and sustainable environment (DTI Energy White Paper, 2007). 'The vast majority of, if not all, economic activity in Britain will have to reduce its carbon impact… This is going to transform [the] whole economy' (BIS, 2009, p.12). On the way to an environmentally sustainable economic growth, integrating environmental and innovation insights and understanding where the UK stands in terms of its existing capabilities and potential for creating eco-friendly technologies is crucial.

A number of contributions from the field of innovation and environmental economics are seeking to determine the factors that drive eco-innovation. Studies leaning towards the field of innovation indicate that demand factors in general (Horbach, 2008), and collaboration with environmentally concerned stakeholders in particular (Wagner, 2007) play an important role for the generation of eco-innovations. On the other hand, insights from the management literature on corporate social responsibility (CSR) suggest that societal pressure and demand for environmentally friendly product and processes may not necessarily lead to increasing

[1] Innovation refers to 'the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations' (OEND and Eurostat, 2005, p.46).

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investments in eco-innovation, but rather be limited to initiate a minimum investment in eco-innovation that will signal the commitment of the firm to 'green issues' (Bansal and Hunter, 2003; Darnall, 2006; Potoski and Prakash, 2003; Suchman, 1995).

Other scholars have highlighted the importance of technological and organisational capabilities in stimulating eco-innovations in manufacturing firms (Horbach, 2008). The implementation of environmental management systems (EMS) is seen as the reflection of the strong organisational capabilities of firms in environmental management, which facilitate eco-innovation (Horbach, 2008; Wagner, 2007).

Studies closer to the field of environmental economics underline the significance of environmental regulation and standards that aim to combat firms' pollution activities (Magat, 1979; Malueg, 1989; Milliman and Prince, 1989). Recently, increasing attention has been given to the role of regulation in increasing investments in eco-innovations (Brunnermeier and Cohen, 2003). Regulation is not as an undesirable cost-increasing factor but a stimulator of firms' innovativeness that in turn, would lead to a first-mover advantage in markets for eco-innovations (Porter, 1991; Porter and Van Der Linde, 1995). Yet, an issue that is overlooked in these studies is related to the heterogeneity in firms' innovation capabilities and their respective strategies for eco-innovation. Low innovative firms may adopt eco-innovation as a means to reduce production costs and comply with the minimum environmental standards, while high innovative firms may adopt eco-innovation in order to enter new markets (Grubb and Ulph, 2002). As a result, the effectiveness of regulations for firms could potentially differ depending on whether or not they are already ahead of their peers in eco-innovation investments and activities.

This paper contributes to the literature by pooling together insights from the innovation literature on eco-innovation, the management literature on CSR strategy, and the environmental economics literature. The paper considers three key factors that potentially drive eco-innovation: (1) Demand factors, (2) Organisational capabilities, and (3) Stringency of environmental regulations.

With respect to the demand factors and organisational capabilities, by applying the Heckman Selection model we are able to distinguish between the factors that affect the decision of the firm to conduct eco-innovation, and those factors that affect the level of investments in eco-innovation. The application of this methodology enables us to examine the extend that demand factors –namely societal requirements of CSR and demand for environmentally friendly products- affect the decision of the firm to conduct eco-innovation and/or the level of investment on eco-innovation. Additionally, we use Quantile regression techniques to look at firm heterogeneity and to analyse whether environmental stringency affects eco-innovation differently in less innovative firms and/or more innovative firms.

The paper is structured as follows: in Section 2, we review the theoretical and empirical literature on eco-innovation and formulate the research hypotheses. Section 3 presents the data and explains the methodology that was applied. Section 4 presents the empirical results, while Section 5 discusses the findings and the policy implications of the study.

2. Theoretical framework and research questions

2.1. Demand Factors: CSR and customer requirements

Theoretical insights from the innovation literature underline the critical role of demand pull factors for innovations. In the late 1980s, the linear model of innovation was replaced by new insights that emphasised the feedback mechanisms that take place at every stage of the innovation process (Kline and Rosenberg, 1986). Consequently, numerous other studies from innovation management literature emphasised that not only producers participate in the innovation process but also consumers and users, universities, as well as public and private institutes shape the process of innovation (Edquist, 2004; Nelson, 1993; Von Hippel, 1987).). Innovation is now seen as a cumulative and interactive process integrating technology push and market pull (Dosi, 1988; Lundvall, 1992).

However, the eco-innovation concept has been overlooked by the innovation literature. Only recently a small number of empirical studies indicated that demand factors play an important role for the creation of eco-innovations (Horbach, 2008; Wagner, 2007). In particular, Horbach (2008) shows that demand, namely expectations of increases in the turnover of the firm, is an important determinant of eco-innovations in the case of German manufacturing firms. Additionally, Wagner (2007) underlines the importance of active consumer associations for eco-innovation. His empirical study on German manufacturing firms indicates that collaboration with predominantly environmentally concerned stakeholders –partly reflecting the activities of consumer protection associations- plays an important role for the generation of eco-innovative products (Wagner, 2007). Moreover, recent years have witnessed an increase in government efforts to increase eco-innovations through the use of centralised 'green purchasing' plans (see for example BIS, 2009). Overall, this evidence pinpoints that demand factors and in particular, calls for corporate responsibility and consumer demand for environmentally friendly products and processes, will affect the decision of the firm to invest in eco-innovation. However, most studies examine the impact of demand factors upon a binary dependent variable that reflects the decision of the firm to eco-innovate (eco-innovations = 1 vs. no eco-innovation = 0). We still know very little about the impact of the demand factors upon the intensity of eco-innovations.

Insights from the management literature on CSR suggest that demand factors may not affect the level of investment in eco-innovation. The CSR literature illustrates that firms align their practices with societal expectations so as to ensure the legitimacy of their business (Iatridis, 2009; Palazzo, 2006; Sethi, 1975). Consequently, the adoption of CSR policies may reflect a reinforcing or reorienting of the firm strategy through signalling commitment to 'green issues' and building the 'green' image of the company (Bansal and Hunter, 2003; Darnall, 2006; Potoski and Prakash, 2003). As a result, firms may undertake only the minimum investment in eco-innovation so as to legitimise their practices and improve their 'green' image (Suchman, 1995). Thus, CSR and customer demand for green products and processes may not bring the expected increasing investments in eco-innovations.

Therefore, we test whether demand factors and in particular customer demand for environmentally friendly innovations and CSR will affect the decision of a firm to invest on ico-innovation, as well as the level of investment in eco-innovation.

Hypothesis 1. Demand factors influence (1) the decision of the firm to invest in eco-innovation; and (2) the level of investment in eco-innovation.

2.2. Organizational Capabilities: Environmental Management Systems (EMS)

The innovation literature focusing on eco-innovations has shown that increasing investments in eco-innovation are influenced by the capabilities of the firms. In particular, those firms that build organisational capabilities and practices such as source reduction, recycling, pollution prevention, and green product design are more likely to invest in eco-innovation (Kemp et al., 1992; Georg et al, 1992; Winn and Roome, 1993). Florida et al., (2001) demonstrate that two types of organisational factors -organisational resources and performance monitoring systems- play an important role for the adoption of eco-innovations. Organizational capabilities are often developed with the implementation of environmental management systems (EMS) [2].

EMS are voluntary organisational frameworks that detail the procedures used to manage the impacts of the organisation on the natural environment (Darnall, 2006). Their purpose is to continuously improve corporate environmental performance so as to get ahead of the existing government regulations to reduce emissions and waste disposal (Kollman and Prakash, 2002). EMS are viewed as an indicator of the strong but latent organisational capabilities of the firm in environmental management (Fryxell and Szeto, 2002; Russo and Harrison, 2005). A number of empirical studies from the innovation literature have found that implementation of EMS has a positive impact upon eco-innovation (Horbach, 2008; Wagner, 2007). Even though the implementation of EMS signals the building of organisational capabilities, management research on EMS has shown that solely external certification does not boost eco-innovation (Boiral, 2007; Fryxell and Szeto, 2002; Rondinelli and Vastag, 2000, Russo and Harrison, 2005).Hence, we investigate how the organisational environmental capabilities of the firm affect its eco-innovativeness.

Hypothesis 2. Organisational factors influence (1) the decision of the firm to invest in eco-innovation and (2) the level of investments on eco-innovation.

2.3. Stringency of Environmental Regulations

Most research on environmental economics is focussed on the effectiveness of various policy measures, namely regulations (Pigouvian taxes), market-based

[2] 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.

instruments (tradable permits), and standards for limiting firms' pollution activities (Magat, 1979; Milliman and Prince, 1989; Malueg, 1989). Presently the attention has shifted to the role that environmental regulations play in stimulating eco-innovations (Lanjouw and Mody, 1996; Brunnermeier and Cohen, 2003). Empirical firm-level studies suggest that more stringent environmental regulations boost eco-innovations (Cleff and Rennings, 1999; Frondel et al., 2008; Green et al., 1994).

This hypothesis, initially formalised by Porter (1991) and Porter and Van Der Linde, (1995) has been empirically tested several times in different contexts and with different datasets as the interest to control emissions and environmental pollution heavily mounts on the industry and governments (Horbach, 2008; Mazzanti and Zobboli, 2005; Popp, 2006; Brunnermeier and Cohen, 2003). The 'win-win' situation underlying the Porter hypothesis suggests that regulations can force firms to invest in environmental research and development in order to cut down the costs of complying with environmental regulations standards. In turn, firms that undertake eco-innovations will be able to reduce their production costs and/or enter into expanding markets for eco-products. Indeed, regulations may be the only means to break out of existing technological lock-ins and move towards eco-technologies that usually have higher costs at least in the short term (Arthur, 1989; Klaassen et al., 2005).

The majority of evidence on the relationship between environmental regulations and eco-innovations comes from a small number of developed countries, namely the USA and Germany, and to a lesser extent from other European countries such as Italy, UK and Denmark. The differences in stringency of environmental regulations across countries are accompanied by different levels of development in their eco-innovation capabilities (Klaassen, 2005; Popp, 2006). Eco-innovations respond heavily to national and local regulations and therefore, country-specificity is an important element in understanding the dynamics of eco-innovations. Therefore, we anticipate that stringency of environmental regulations may stimulate eco-innovations.

Yet, we know very little about the response of different types of firms to environmental regulations. Firm heterogeneity with respect to innovative capabilities implies that some firms may be ahead of others in their investments into environmental R&D. Thus, higher levels of environmental stringency may increase eco-innovation in less innovative firms, which assume a reactive strategy by adopting eco-innovations in order to reduce production costs. In contrast, more innovative firms, which are more proactive, may adopt eco-innovation ahead of their peers for strategic reasons; in order to gain an advantage in product markets (Grubb and Ulph, 2002). Consequently, stricter regulations may not be the main driver of eco-innovation for highly innovative firms that are already involved in environmental R&D.

Hypothesis 3. The stringency of environmental regulations affects the level of investments in eco-innovation differently for less innovative firms and more innovative firms.

3. Data and methodology

3.1. Data

The data we use in the empirical analysis was collected by the Department for Environment Food and Rural Affairs (DEFRA) in 2006 for the 'Government Survey of Environmental Protection Expenditure by Industry'. The objective of the survey was to gather firm level data on environmental protection expenditure across industrial sectors in the UK. The survey is designed to collect information on operating and capital environmental expenditure, environmental management systems, environmental research and development expenditures, motivation for environmental expenditure, and general information on firm characteristics such as employment and turnover. From a sample of 7,850 manufacturing firms 1,599 responded to the survey, which represents an approximately 20.4 per cent response rate. Because of missing responses to some of the variables, the sample that is used in the analysis is reduced to 1,566.

We use environmental research and development expenditures (ECORD) as a proxy of eco-innovation. This variable measures the level of firms' R&D investments into eco-innovations and is more specific and precise compared to the majority of R&D based eco-innovation indicators found in the literature. Survey questions that investigate environmental R&D activities often ask firms 'whether or not' they conduct environmental research and development activities and not specifically 'how much' they invest into environmental research and development activities (Horbach, 2008). Hence, the first advantage of the ECORD variable used in this study is its ability to indicate not only whether firms conduct environmental research and development but also to provide information on the level of such investments. The second advantage of the ECORD variable is that it is specifically aimed at R&D expenditures allocated for eco-innovations and not all types of innovations. Some previous studies have utilised the firm's total R&D as a proxy of eco-innovations even though these measures do not immediately indicate the rate of eco-innovations but assume a strong correlation between eco-innovations and generic innovations (Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2003).

The stringency of environmental regulations is often proxied with abatement costs (i.e. the capital and operating costs of complying with environmental regulations as in the US PACE survey), the number of pollution related inspections to companies (Brunnermeier and Cohen, 2003), qualitative survey questions on whether existence (or anticipation) of regulations 'prompt' product and process eco-innovations (Cleff and Rennings, 1999; Green et al., 1994) and also by considering the pre and post periods of a specific environmental legislation (Popp, 2006). In this study we measure regulatory stringency by taking into account the environmental operating and capital costs of the firm (AC).

Organisational capabilities related to eco-innovations are measured with a dummy variable that indicates whether a firm has implemented environmental management systems (EMS). Table 1 presents the main variables, their definition and some summary statistics.

Table 1

Variables and summary statistics

Variable	Definition	Mean	Std
ECORD	Environmental research and development (£).	7,687	134,186
EOC	Environmental operating costs (£).	512,298	12,239,109
ECC	Environmental capital costs (£).	196,478	4,135,495
AC	Total abatement costs= EOC+ECC (£).	708,921	13,565,860
EMS	=1 if the firm has implemented environmental management (EM) systems.	0.26	
CS	Total cost savings resulting from environmental improvements (£).	24,800	265,313
BP	Total income obtained from the sale of by-products arising from environmental improvements (£).	0.03	0.304
ENV_REG_COM	=1 if the firm invested in environmental protection because of environmental regulation compliance.	0.18	
EQU_UPGRADE	=1 if the firm invested in environmental protection because of equipment upgrade.	0.13	
E_TAXES	=1 if the firm invested in environmental protection because of environmental taxes.	0.03	
CUST_REQ	=1 if the firm invested in environmental protection because of customer environmental requirement.	0.02	
CSR	=1 if the firm invested in environmental protection because of parent company or owner policy/CSR.	0.06	
TOPCOM	=1 if the firm is a Top Company[a].	0.03	
TURNOVER	Company turnover in 2006.	5.44e+07	4.55e+08
EMP	Number of employees in 2006.	180	606
SIZE	=log(EMP)	3.94	1.39

[a] DEFRA selected Top Companies by ranking the top 50 companies by turnover and by number of employees. In addition the companies with over 250 employees in SICs 10–14 (Mining and quarrying), 23 (Coke/petroleum/nuclear fuel), 40 and 41 (Energy & water supply) were included and the five largest (by number of employees) companies for each SIC, were also selected as Top Companies.

3.2. Methodology

Eco-innovation is modelled following a Heckman model (1979) that estimates the determinants of eco-innovation. Let us use i = 1, 2, …, N to index firms. This equation specifies the determinants of eco-innovation ($ECORD_i$):

$$ECORD_i^* = \alpha x_{0i} + \varepsilon_{0i}$$

Here, x_{0i} is a vector of the determinants of eco-innovation, α is a vector of parameters of interest, and ε_i an error term. Environmental research and development

(ECORD) can be used as a proxy for eco-innovation but, this is possible if –and only if- firms spend on ECORD. Many firms do not perform ECORD; in particular, 1314 out of 1566 firms do not undertake any environmental R&D. As a result, the dependent variable ECORD is left censored, with a lower threshold of zero. Hence, the above equation cannot be estimated with an OLS regression; this would produce inconsistent estimations of the α coefficients because of selection bias and truncation (Amemiya, 1985). This is resolved by employing a two-step Maximum Likelihood Heckman model by first estimating a selection equation, and then the outcome equation adjusting for selection bias (Greene, 2002). In particular, the selection equation indicates whether or not a firm performs ECORD:

$$ECORD_i = \begin{cases} 1 & \text{if} \quad ECORD_i^* > 0 \\ 0 & \text{if} \quad ECORD_i^* \leq 0 \end{cases} \quad \text{where } ECORD_i^* = \beta_0 + \beta_1 x_{1i} + \varepsilon_{1i}$$

Where $ECORD_i^*$ is the corresponding latent variable indicating that firms decide to perform ECORD if it is above the threshold level of zero. Hence, conditional on firm i performing ECORD[3], it is possible to observe the determinants of eco-innovation as follows:

$$\ln(ECORD_i) = \begin{cases} \ln(ECORD) & \text{if} \quad ECORD_i^* > 0 \\ - & \text{if} \quad ECORD_i^* \leq 0 \end{cases}$$

Since the data is cross sectional, problems of endogeneity may arise especially with regard to issues of reverse causality between environmental research and development (ECORD) and abatement costs (AC). We were able to check empirically the potential problems of reverse causality by examining whether ECORD in 2003 is significantly correlated with abatement costs in 2006 for a subset of 64 firms that appear in both years. The analysis shows that ECORD in 2003 is not significantly correlated with AC in 2006 (0.153). In contrast, ECORD in 2006 is significantly correlated with AC in 2006 (0.310 at 5 per cent level of significance). This empirical test shows that the data does not suffer from serious endogeneity problems.

[3] Following previous studies, we use the logarithmic form of the environmental research and development variable, since it is a highly skewed variable (Jaffe and Palmer, 1997).

We also tested the data for possible bias arising out of common method variance (CMV). CMV is a type of spurious correlation which occurs among indicators or constructs when these derive from a common source. Podsakoff et al., (2003) have categorised the sources of CMV: (a) common rater effect, (b) item characteristics effect, (c) item context effect, and (d) measurement context effect. Note that CMV varies with the discipline of study. In particular, it has been shown that the levels of CMV are approximately 15.8% in marketing, 3.8% in other business areas, 28.9% in psychology, and 30.5% in education (Malhotra et al., 2006). The current study is based on the measurement of simple, objective, and unambiguous constructs –such as environmental expenditure, environmental management systems, environmental research and development, motivations for environmental expenditure, firm size and turnover- that we would expect to be associated with lower levels of CMV as it is in the case of 'other business areas'. Yet, we tested the survey for potential presence of CMV (Appendix A). Our results indicate that CMV is not a problem in this study.

In order to address potential multicollinearity problems, especially between firm size (i.e. ln(EMP)) and abatement expenditure (AC), we normalised the AC variable by dividing it with TURNOVER. Additionally, we carried out a Principle Component Analysis (see appendix B) on the dummy variables that reflect the motivation for environmental protection. Three factors explain 68 per cent of the cumulative variance. The first factor is mainly explained by customer requirements (CUST_REQ), the second factor by equipment upgrade (EQU_UPGRADE), and the third factor by corporate social responsibility (CSR). In order, then, to avoid problems of multicollinearity, we use only three of the original variables that indicate the motivation for environmental protection, namely CUST_REQ, EQU_UPGRADE, and CSR.

4. Empirical Results

Environmental research and development (ECORD) for firms of different size and sector are presented in Table 2. A T-test on differences in mean values was conducted, comparing the mean of various subgroups of firms with the sample mean. Table 2 indicates that investment in environmental research and development is significantly related to the size of the firm, namely large firms spend on average £3,139 per annum on ECORD, while small and medium firms invest considerably less. It is also interesting to note that small firms invest more in ECORD compared to medium-sized firms, potentially suggesting an inverse U shape relationship between firm size and ECORD investments. Additionally, table 2 indicates the sectoral variation regarding investments in ECORD. Primary sectors of environmental spending are energy production and water, coke petroleum and nuclear fuel and chemical products.

Table 2

Environmental R&D by size and sector

	ECORD (Mean)	No firms
SIZE		
Micro (1 to 9 employees)	220	84
Small (10-49 employees)	1,187***	1,061
Medium (50 to 249 employees)	1,068	307
Large (≥ 250employees)	3,139***	1,452
SECTOR		
Mining and quarrying	6,395	73
Food, beverages and tobacco products	3,244	234
Textiles, clothing and leather products	2,131	93
Wood and wood products	3,263	36
Pulp and paper products, printing	680	159
Coke, petroleum and nuclear fuel	19,145	14
Chemicals and man-made fibres	11,371	223
Rubber and plastic products	1,828	141
Other non-metallic mineral products	1,928	54
Basic metals and metal products	1,665	157
Machinery and equipment	4,229	93
Electrical, medical and optical equipment	4,629	132
Transport equipment	1,903	86
Other manufacturing	6,707	52
Energy production and water	227,500***	25
Total		**1566**

Note: *significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.

4.1. Demand Factors and Eco-innovation

The impact of the demand factors –corporate social responsibility and customer requirements- is exhibited in Model 1 in Table 3. Note that we use the variable equipment upgrade (EQU_UPGRADE) to identify the selection equation. This variable does not affect the level of investment on environmental research and development (ECORD). Thus it can be excluded from the outcome equation.

The results of the Heckman selection model show that the demand factors, namely corporate social responsibility (CSR) and customer requirements (CUST_REQ) do not exhibit any statistical significant impact upon the level of investment in environmental research and development (ECORD). Yet, these demand factors affect the decision of the firms to conduct ECORD.

Hence, Hypothesis 1 holds only partially as the results suggest that the interaction between demand factors and eco-innovation are rather complex. More specifically, the selection equation indicates that both variables –CSR and CUST_REQ- explain differences in firms' decision to invest in ECORD and hence, we infer that societal and market requirements encourage firms to undertake the minimum eco-innovations. Yet, these factors do not go beyond this initial step and boost the levels of investments in ECORD.

4.2. Organisational Capabilities and Eco-innovation

We conduct the Heckman analysis without the variables CSR and CUST_REQ, which were not statistically significant. From Model 2 we can infer on the role that organisational capabilities play for eco-innovation. In particular, building organisational capabilities related with the management of environmental systems (EMS) affects the decision of the firm to invest in environmental research and development (ECORD). Additionally, our findings indicate that firms that implemented an EMS invest more in ECORD, compared to firms that do not have an EMS.

The above results confirm Hypothesis 2. Firms that build organisational capabilities accumulate the necessary soft skills that enable them to initiate environmental research and development activities. More importantly, our findings indicate that organisational capabilities related to EMS explain significant differences in the level of investment in ECORD between firms.

Table 3

Heckman (ML) model on the determinants of eco-innovation: ln(ECORD)

	Model 1	*Model 2*
Variable	***Coeff.*** *(Std. Err)*[a]	***Coeff.*** *(Std. Err)*[a]
EMS	0.740 (0.324)**	0.627 (0.308)**
AC/turnover	0.052 (0.023)**	0.050 (0.023)**
CSR	0.017 (0.303)	
CUST_REQ	0.309 (0.569)	
CS	0.905 (0.305)***	0.839 (0.299)***
BP	-0.143 (0.093)	-0.145 (0.093)
TOPCOM	1.281 (0.469)***	1.282 (0.468)***
ln (**EMP**)	0.598 (0.104)***	0.571 (0.100)***
_ cons	4.803 (1.152)***	5.311 (1.015)***
Selection eqn		
EMS	0.660 (0.097)***	0.660 (0.097)***
AC/turnover	0.010 (0.007)	0.010 (0.007)
CSR	0.531 (0.169)***	0.529 (0.170)***
CUST_REQ	0.733 (0.287)**	0.723 (0.273)***
CS	0.418 (0.207)**	0.417 (0.208)**
EQU_UPGRADE	0.064 (0.139)	0.072 (0.129)
ln (**EMP**)	0.151 (0.031)***	0.151 (0.031)***
_ cons	-1.968 (0.131)***	-1.968 (0.131)***
Rho[b]	0.1436 (0.309)	0.002 (0.285)
Sigma[b]	1.5536 (0.104)	1.542 (0.091)
Censored Obs:	230	230
Number of obs:	1389	1389
Wald: X^2 =	77.42***	63.19***
Log-pseudo Likelihood:	-962.6389	-962.77919

Note: *significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
[a]Robust standard errors.
[b]Rho and Sigma are the estimated coefficients of the decomposed lambda estimation on the Inverse Mill's Ratio. The estimated Rho coefficient is not statistically significant, implying no existence of selection bias.

4.3. Abatement costs and Eco-innovation

The Quantile regression produces important insights about the different factors that determine investments into environmental research and development (ECORD) in low eco-innovative and high eco-innovative firms. Note that, in this part of the study, we focus only on those firms with positive ECORD investments. Ideally, one would combine a selection equation with the quantile regression model to correct for the sample selection problems as discussed in Section 3. While there are examples of quantile regression models that include a selection equation (Buchinsky, 2001), this theoretically poses a conflict between the main equation and the selection equation since the Heckman model evaluates the results at the mean and not at different quartiles. Hence, we omit the selection equation and simply focus on those firms that invest in ECORD.

Table 4 displays the results for the lower and upper quartiles based on firms' level of investment in ECORD. For firms in the lower quartile, ECORD is mainly driven by cost savings (CS), the presence of environmental management systems (EMS), and abatement costs (AC).

Similarly, cost savings (CS) and the presence of environmental management systems (EMS) play an important role in increasing ECORD for the upper quartile firms. However, the highly innovative firms in the upper quartile do not respond to environmental stringency (proxied by AC) unlike the less eco-innovative firms in the lower quartile. This implies that environmental regulation plays an important role in stimulating environmental research and development in firms that are not at the technological frontier with respect to eco-innovation, while it exerts no impact upon highly innovative firms that are ahead of their peers in eco-innovation. This finding confirms Hypothesis 3.

Finally, the total income obtained from the sale of by-products arising from environmental improvements (BP) does not exert any influence on the level of ECORD in the Heckman Selection model or the Quantile regression.

Table 4
Quantile Regression on the determinants of eco-innovation: ln(ECORD)

	Quantile Regression		
Variable	***Lower quartile (q25)*** *(Std. Err.)* [a]	***Median (q50)*** *(Std. Err.)* [a]	***Upper quartile (q75)*** *(Std. Err.)* [a]
AC/turnover	0.047	0.027	0.091
	(0.013)***	(0.020)	(0.058)
EMS	0.643	0.496	0.518
	(0.235)***	(0.198)**	(0.268)*
CS	0.760	0.668	0.731
	(0.242)***	(0.351)*	(0.423)*
BP	0.020	-0.058	-0.309
	(0.648)	(0.505)	(0.705)
TOPCOM	2.277	1.498	0.982
	(1.077)**	(0.586)**	(0.699)
ln (**EMP**)	0.493	0.575	0.610
	(0.104)***	(0.096)***	(0.118)***
_ cons	4.650	5.423	6.142
	(0.472)***	(0.374)***	(0.471)***
Pseudo R-squared	0.177	0.207	0.230
Number of obs:	230	230	230

Note: *significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
[a]Standard errors were bootstrapped.

5. Conclusions

The empirical results in this paper shed light on the determinants of eco-innovation based on a new dataset of manufacturing firms in the UK. The main contribution of this paper is twofold: (a) we bring a new theoretical lens to the field of eco-innovation by integrating concepts from the innovation, environmental economics and management literatures on organisational capabilities, stringency of environmental regulations and corporate social responsibility; (b) we apply a novel methodological approach to the analysis of the determinants of eco-innovation that allows us to disentangle the effect that various factors exert upon the decision of the firms to invest in eco-innovation as well as upon the *level* of investment in eco-innovation. Additionally, these new methods enable us to look at firm heterogeneity related to different eco-innovative capabilities and examine whether the above factors affect less innovative and more innovative firms in the same way.

In line with previous studies in the field of eco-innovation (Horbach, 2008; Wagner, 2007), the findings of this paper indicate that demand factors affect the decision of firms to invest in eco-innovation. Yet, our paper extends this debate further by showing empirically that demand factors, especially CSR and customer requirements for environmentally friendly products, do not affect the level of investment in eco-innovation. Hence, the study provides evidence that firms undertake some minimum level of eco-innovation activities in response to societal pressures and market requirements but these factors do not necessarily encourage firms to commit large amounts of resources into eco-innovation.

Secondly, this study confirms previous findings that stress the importance of organisational capabilities related to environmental management systems (EMS) for eco-innovation (Kemp et al., 1992; Georg et al, 1992; Winn and Roome, 1993). Such organisational capabilities are not only important in firms' decision to undertake eco-innovation activities, but also play a key role in increasing the level of resources allocated to eco-innovation activities.

Finally, the results suggest that stringency of environmental regulations affects eco-innovation as firms respond to stricter environmental regulations with higher levels of eco-innovations (Lanjouw and Mody, 1996; Brunnermeier and Cohen, 2003; Cleff and Rennings, 1999; Frondel et al., 2008; Green et al., 1994). Yet, surprisingly, we find that only the eco-innovations in less innovative firms are driven by regulatory requirements. More innovative firms do not necessarily need the regulatory push for eco-innovation. This brings a further insight into the Porter Hypothesis by showing that environmental regulations are especially important in encouraging the less innovative firms to participate in the eco-innovation activities.

This study deepens understanding of the factors that initiate and boost eco-innovations in the UK industries. While demand factors such as CSR and customer requirements are important initiators of eco-innovations, presence of organisational capabilities and environmental regulations are the key factors that boost the level of eco-innovations. Hence, current government policies such as centralised green public procurement plans that aim to boost eco-innovations through demand need to be supported by correctly aligned regulatory frameworks for pollution abatement and strong innovation platforms upon which innovative firms can get support to strengthen their organisational capabilities.

Appendix A. Common Method Variance (CMV)

(a) *Common rater effect* occurs when respondents provide answers because of reasons of social desirability and not because this is what they truly believe (Podsakoff et al., 2003; Malhotra et al. 2007). The information of the variables was obtained by the accounting department of every firm. Since environmental expenditure, environmental management systems, environmental research and development, firm size and turnover are factual information, which derived from a second source we do not have any reason to believe that it can be a source of CMV. However, social desirability may have influenced the information regarding the motivation for environmental expenditure since this is a more subjective evaluation of the motives of each firm and it was measures with a discrete method.

(b) *Item characteristics effect* is a problem when the questions are ambiguously phrased and as a result the responded becomes confused (Podsakoff et al., 2003; Malhotra et al. 2007). The bias caused by the measurement items is not a problem in the current study because most of the items were simply and concisely defined.

(c) *Item context effect* occurs when several questions lead to respondent fatigue, or when the positioning of the questions related to the dependent and independent variables may imply a causal relationship (Podsakoff et al., 2003; Malhotra et al. 2007). Item context we expect not to be a potential source of bias in this study since the questions related to the dependent and independent variables were presented in a balanced manner in the questionnaire.

(d) *Measurement context effect* is a problem when a single respondent provides answers to the independent and dependent variables at the same time (Podsakoff et al., 2003; Malhotra et al. 2007). Measurement context effects may be present in the current study because the independent and dependent variables were measured at the same time.

Additionally, we use Harman's (1967) single factor test to examine whether the potential presence of CMV inflates or even attenuates the results of this study. An un-rotated factor analysis is applied to all variables in the survey. If CMV is present, a single factor emerges from the factor analysis or one general factor accounts for the majority of the variance in the variables (Podsakoff and Organ, 1986). Under the assumption that eigen-value is greater than one, the un-rotated factor analysis produced five factors that accounted for 60 per cent of the cumulative variance. Hence, no single factor emerged out of the analysis. Moreover, the most influential factor explains only 17 per cent of the variance in the data.

Appendix B. Principle Factor Analysis on the motivation for environmental protection

Principle components

Component	Eigenvalue	Difference	Proportion	Cumulative
1	1.31093	0.22061	0.2622	0.2622
2	1.09032	0.06888	0.2181	0.4803
3	1.02144	0.18658	0.2043	0.6845
4	0.83486	0.09241	0.1670	0.8515
5	0.74245	.	0.1485	1.0000

Eigenvectors

Variable	1	2	3
CUST_REQ	0.63293	0.14573	0.06433
E_TAXES	0.57625	0.00737	-0.19690
ENV_REG_COM	0.42406	-0.62666	-0.18372
EQU_UPGRADE	0.14264	0.72143	-0.46832
CSR	0.25917	0.25601	0.83905

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