Drivers of eco-innovations in Catalan firms

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Abstract:

The aim this paper is to study how Catalan firms design innovative projects with the aim of reducing environments impacts. From an exhaustive sample of Catalan manufacturing firms taken from the Community Innovation Survey for the period 2008– 2015, and using a random logit model, we examine the drivers of environmental motivations for those firms that have innovated. Our empirical results suggest that regulations together with the need for efficiency through cost saving or organizational innovations, internal R&D efforts and firm characteristics such as size, are the main determinants influencing the environmental innovation strategy.

Keywords: environmental strategies, sustainability, determinants, manufacturing sector, Catalonia

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1. Introduction

The innovation activities of firms to reduce the environmental impact of production and consumption have been argued to be a relevant role in moving towards more competitive and environmentally sustainable societies (Bossle et al. 2016; Esty and Winston 2009). Identifying the main factors that activate and hinder firms' decisions to eco-innovate in specific regions can help policy-makers to implement suitable instruments to stimulate these determinants, or to overcome these barriers. In recent years, responding to pressures for a cleaner environment, many empirical papers have devoted attention to the drivers of eco-innovation at country level (Del Río et al. 2011; Díaz-García et al. 2015; Ghisetti et al. 2015; Hojnik and Ruzzier 2015; Horbach 2008; Srholec 2014; Triguero et al. 2013). However, until now, little empirical analysis has been applied to regions or metropolitan areas (Del Río et al. 2016).

The primary purpose of this study is to analyse the main drivers influencing the adoption of an environmental orientation among Catalan firms. Catalonia is an interesting case to study for various reasons. Firstly, the region of Catalonia is a Moderate + Innovator (on the Regional Innovation Scoreboard) with some structural differences, for instance the region is densely populated, an above averagr employment in manufacturing, and a higher than average GDP per capita (European Union, 2017). Secondly, although the urban system is dominated by the Barcelona metropolitan area, there is also a network of medium-sized cities with considerable economic and social vitality. Thirdly, Catalan firms are more R&D active than the rest of Spain. Although Catalonia is in a better position than Spain, the expenditures on R&D, which was 1.52% of gross domestic product (GDP) in 2015, are much lower than the EU28 average of 2.03%. Finally, in terms of green innovations, the region of Catalonia has designated the environment as a strategic priority, and stands out for its pioneering role in the creation of an environmental quality label, or clean eco-label (Estratègia Catalunya 2020 and RIS3CAT).

Since little study has been carried out on environmental determinants for regions with different features, we conducted an empirical analysis in an attempt to offer useful proposals for designing better environmental innovation policies. This paper contributes to the literature by investigating different patterns of green innovation among manufacturing firms in Catalonia, as well as for different types of eco-innovators. To overcome at least some of the limitations of earlier studies, which have used mainly cross-sectional databases, the empirical analysis carried out in this paper is based on the Technological Innovation Panel (PITEC), which incorporates an extensive sample of Catalan firms over the period 2008–2015. The study provides some new results, both on the temporal and the geographical dimension, to the eco-innovation.

Our empirical results suggest that regulations along with the need for efficiency through cost saving or organizational innovations, internal R&D efforts and firm characteristics such as size, are the main determinants influencing the environmental innovation strategy among Catalan manufacturing firms.

The paper is organized as follows. Section 2 outlines the theoretical framework relating to the determinants eco-innovations. Section 3 describes the data, variables and econometric methodology used. Section 4 presents the main empirical results. Finally, Section 5 discusses the conclusions.

2. Literature review and hypotheses

2.1. What is an environmental innovation?

In the extensive EU-funded research project "Measuring Eco-Innovation" (MEI), environmental-innovation was defined by Kemp and Pearson (2007) as the: "*production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"*.

In general, such innovations differ from more general innovations in that eco-innovations result in both economic and environmental benefits, hence the positive environmental impact of innovation is the core element of its definition (Carrillo-Hermosilla et al. 2009). This definition implies that environmental innovation corresponds to a very heterogeneous set of innovations, since it can be part of any economic activity and it neither sector- nor technology-specific. Moreover, it can be intentional or not, and relatively novel or significant as compared to conventional technologies.

A crucial question that scholars face is whether eco-innovations can be treated as normal innovations, or whether there is a need for specific management and policy approaches to foster them. Until recently, the literature mainly focused on two aspects that differentiate environmental innovations from general innovations with regard their externalities and drivers (Table 1).

Table 1 Determinants of environmental-innovation

Supply side	▪ Technological capabilities (knowledge base, R&D activities, human capital endowment) ▪ Cost savings and productivity improvements as motivation ▪ Industrial relationships and networking activities ▪ Access to external information and knowledge
Demand side	▪ (Expected) market demand ▪ Social awareness of the need for clean production, ▪ Environmental consciousness and preference for environmentally friendly products
Environmental policy influences	▪ Environmental regulation (existing and expected regulations) ▪ Access to existing subsidies and fiscal incentives

Source: Adapted from (Horbach 2008))

The main specificity of environmental innovation is found in what is known as the "double externality problem" (Rennings 2000). Environmental innovation is characterized by the common positive externalities (knowledge spillovers and imitation) produced by innovation activities, plus the environmental externalities generated. The effect of reducing environmental damage is felt by society as a whole, rather than the firm that invested in green technologies, and consequently took on higher costs than its non-green competitors, creating a disincentive for the it to invest in eco-innovations. While general innovations face the usual knowledge spillovers, environmental-innovations face both innovation and environmental externalities, hence an interdisciplinary approach should be adopted to environmental economics and innovation economics disciplines.

The second specificity, derived by the market-failure generated by the two externalities, is the need for greater public intervention, known as the "regulatory push/pull effect" (Rennings 2000). The general innovation literature highlights the role of demand-pull, technology-push and firm characteristics factors as determinants of innovation. However, the literature on environmental-innovations also emphasizes the role of regulations and institutional frameworks as additional elements to be considered in the adoption of eco-innovations (De Marchi 2012; Del Río et al. 2011; Horbach 2008, 2016; Jakobsen and Clausen 2016; Porter and Linde 1995; Rennings 2000; Triguero et al. 2013).

The literature has used different theoretical frameworks to explain a firm's intention to eco-innovate (for an overview of the subject see, for example, Aykol and Leonidou (2015) and Hojnik and Ruzzier (2015). It is widely accepted that the main elements of environmental innovation theory include the demand side, supply side and environmental policy influences (Horbach, 2008). Recent research also integrates the extended view of stakeholders and institutional theory on eco-innovation (Sarkis et al. 2010; Tang and Tang 2012; Tyl et al. 2015).

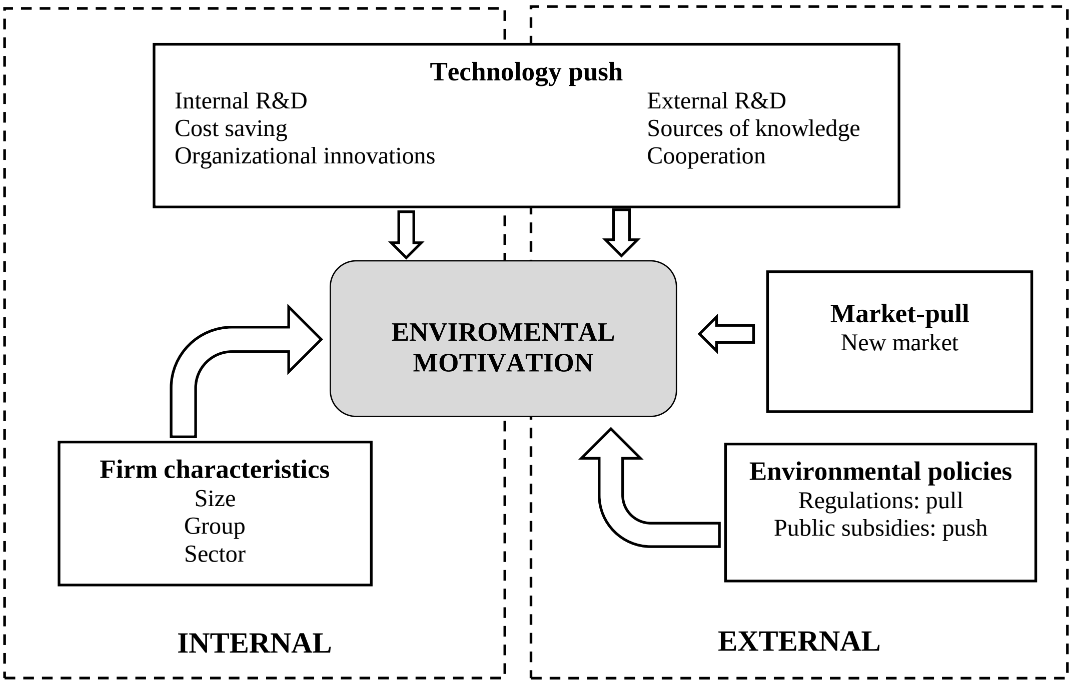
The determinants of eco-innovation are also based on the resource-based view (RBV). A firm's ability to eco-innovate is traditionally linked to the role of resources and capabilities, and to the pool of knowledge available within the firm (Cainelli et al. 2012; Horbach et al. 2012; Triguero et al. 2013). Resource-based theory highlights the importance of the internal resources of firms; however, more recently, the evolutionary perspective emphasizes the importance of innovation systems, the dynamic interaction between different actors and the internal and external factors influencing the innovation process (Nelson and Winter 1982). Several studies have identified the positive effects of incorporating external knowledge, and compared to general innovations, eco-innovation activities seem to require more external sources of knowledge and information (Cainelli et al. 2015; De Marchi 2012).

Furthermore, taking into account the resource-based and evolutionary perspective approaches some researchers have categorized the drivers of eco-innovation as internal and external factors (Cainelli et al. 2015; Carrillo-Hermosilla et al. 2009; Del Río 2009; Demirel and Kesidou 2011; Sáez-Martínez et al. 2016). Factors internal to the firm refer to internal resources such as technological capabilities, qualified employees or financial resources, while external factors refer to the firm's interaction with other agents through cooperation, collaboration, networks and market relations (Bossle et al. 2016).

2.2 Review of recent empirical literature

Following the Horbach (2008) classification, we examine the drivers of environmental-innovation motivation from the perspective of the supply side, demand side, environmental policy, as well as the firms' structural characteristics from internal and external perspectives. This classification can be combined with the internal and external perspective (Del Río et al. 2015). As a result, technology push factors can be classified as internal (firm technological capabilities) or external (cooperation and networks). Public policies can be market-pull (regulations) or a supply-push (subsidies). Finally, market demand (consumers) would be external. Figure 1 summarizes the conceptual framework deployed.

Figure 1. Main drivers influencing an environmental motivation



Source: own elaboration.

The main result in the recent literature on the determinants of eco-innovation is that eco-innovations are more dependent on regulation than are other innovations. This idea relies on the Porter hypothesis which postulates that environmental regulation may lead to a win-win situation, pollution is being reduced while profits are increased (Porter and Linde 1995). According to them, eco-innovation activities are not a result of an optimization process, since firms are still inexperienced in dealing with environmental issues. Hence, eco-innovations are not carried out because of both incomplete information, and organizational coordination problems. In this context, regulation can have an important influence on the direction of innovation. For instance, in the European context, Veugelers (2012) for Belgium and Del Río et al., (2015) for Spain, identified regulation as an important driver of eco-innovation. However, the impact of supply push instruments such as subsidies for eco-innovation, is not always clear in the manufacturing firm literature. Horbach et al. (2012) and Horbach (2008), both for a Germany manufacturing sample, find a positive and statistically significant influence of subsides on eco-innovation. Similar results have recently been found by del Río et al. (2015a) and De Marchi (2012) in the Spanish manufacturing context. Nevertheless, this variable was not found to be especially important for eco-innovation either in Horbach et al. (2013), using a sample from the Community Innovation Survey (CIS 4) for France and Germany, or in Triguero et al. (2013) for 27 European countries.

Furthermore, cost-savings actions aimed at reducing of material or energy usage may also be very important for eco-innovation as are the development of more efficient organizational capabilities and organizational support (Horbach 2016; Peñasco et al. 2017). Cost-savings are one of the main driving forces of environmental innovation, but environmental policy is needed to support firms in detecting cost saving potentials (Porter and Linde 1995).

Moreover, technological capabilities play an important role in the adoption of environmental-innovation. They depend mostly on the knowledge-capital endowment of firms (R&D investments or qualified employees), and organizational innovations. Using a sample of German firms, Horbach (2008) shows that the improvement of technological capabilities, as measured in terms of R&D and high qualification of employees, is a key determinant in favouring eco-innovations. Along the same lines, De Marchi (2012) argues that absorptive capacity is more important in contexts such as those faced by EIs, characterized by high market uncertainties and technological turbulence.

Regarding external sources and cooperation, the literature stresses that eco-innovations more often involve cooperation and the search for new knowledge than do general innovations. This is because they are characterized by a high level of uncertainty, novelty and the need to go beyond the firm's core competences (see Horbach (2008) for Germany, Horbach et al. (2013) for Germany and France, Triguero et al. (2013) for 27 European countries, Mazzanti and Zoboli (2009) for Northern Italy and De Marchi (2012) and Cainelli et al. (2015) for Spain). Possibly more so than for other innovations, the higher uncertainty in implementing an eco-innovation strategy implies a high propensity for relying on knowledge inputs from different, heterogeneous sources. For instance, in the manufacturing industry, De Marchi (2012) and Triguero et al. (2013) show that cooperation with public research institutes and universities becomes more relevant for firms with environmental motivations than it is for other innovators.

From the demand side, in general, studies show that the expectation of a future demand, created by environmentally conscious customers, triggers investments in environmental innovation. In particular, Horbach (2008) shows that, using a panel data for German firms, customer demand and public pressure are the key drivers of eco-innovation. Similarly, examining nine European countries (Belgium, France, Germany, Hungary, Netherlands, Norway, Sweden, Switzerland, United Kingdom), Wagner (2008) shows that market research on green products has a positive effect on a firm's propensity to carry out eco-innovations, since such research is likely to lead to a better understanding of profitable demand for eco-product innovations, as well as identifying eco-oriented customer segments. More recently, using a sample of 27 European countries, Triguero et al. (2013) find that increasing market demand for green products and market share are also relevant to implementing product or organizational eco-innovation.

Other important, but less frequently reported, drivers are firm characteristics such as its size, whether it belongs to a group or the sector; these are usually identified as control variables in the empirical studies. There is a positive relationship with firm size (Cuerva et al. 2014; Horbach 2016; Triguero et al. 2013), large companies tend to develop and adopt more eco-innovations, since small firms, given their lower innovation capabilities and financial resources, have more difficulties to eco-innovate.

Belonging to a multinational group may help a firm to learn about new eco-innovation possibilities, or best practices in other countries, apart from the access to capabilities and resources from the parent company. Nevertheless, evidence on the influence of this variable is still both scarce and mixed. While Peñasco et al. (2017) and Costa-Campi et al. (2015) found that foreign ownership was not a significant environmental-innovation driver, Borghesi et al. (2015) suggested that being part of a business group was important for environmental innovations.

Finally, sectoral differences can also influence the adoption of eco-innovation in the sense that firms that belong to high-emission sectors, or with greater stakeholder pressure are more prone to adopt an environmental-motivation. Environmentally critical manufacturing sectors such as chemicals, ceramic and paper are more likely to eco-innovate, whereas the textile sector is less likely to do so (De Marchi 2012; Horbach 2008). Regarding the role of technological intensity industry, Del Río et al. (2015) show that Spanish firms belonging to low-technology sectors are more likely to eco-innovate. In contrast, Triguero et al. (2016) observe for a sample of European SMEs that belonging to a high-technology manufacturing sector increases the probability of being a leading environmental firm.

3. Environmental policies at regional level

In recent years, Spain has made a considerable effort in the promotion of energy efficiency and the development and use of renewable energies (Léger 2015). It has become an average eco-innovator performer country (ranked number 9 in the Eco-Innovation Scoreboard) and has above-average overall performance, scoring 106 in 2015 (Eco-IS 2015). But it has both a relatively low level of environmental regulation stringency, and low customer awareness for green products, as compared to European countries such as Netherlands, Finland and Germany (see Appendix 1 for more details on Spanish green behaviour).

Increasing policy measures and other efforts have been put in place to promote sustainable developments in Spain. Generally, these green policies are embedded in national and regional policies targeting resource efficiency, environmental innovations, clean technologies and sustainable development. However, the politically unstable context, loss of qualified human capital due to emigration, lack of public and private funds to support eco-innovations, as well as poor framework conditions for research and innovation are the main barriers to the transition of the Spanish economy towards sustainable growth.

At the regional level, many autonomous communities defined circular economy and regional innovation as a strategic priority within their smart specialisation strategies, most often in relation to a regional energy saving policy. The EU's Europe 2020 strategy aims to create smart, sustainable and inclusive growth as a way to overcome structural weaknesses in the European economy (European Commission 2010). In accordance with this framework, in 2012 the Catalan Government launched the Catalan Strategy 2020 (ECAT 2020) and, the following year, the Research and Innovation Smart Specialisation Strategy (RIS3Cat) which the green economy is identified as one of the priority areas for improving competitiveness and increasing employment.

More recently, in 2015, the Catalan Government approved two more specific strategies to promote sustainable growth. Firstly, Government Agreement GOV/73/2015 of 26 May 2015, aimed at promoting the green economy and the circular economy with a view to increasing sustainability (environmental, economic and social) in order to achieve economic recovery, improve competitiveness, create employment and reduce environmental risks. Secondly, Government Agreement GOV/80/2015 if 2 June 2015 (Ecodiscat) set out the Catalan "eco-design" strategy for a circular and eco-innovative economy. This is a framework for eco-design in Catalonia, which includes the production and consumption of goods and services produced and/or distributed in Catalonia; it should contribute significantly to reducing the environmental impacts associated with the Catalan market.

In a wider context, the promotion of sustainable production and consumption, which includes the promotion of environmental management systems, eco-labels, green public procurement, or eco-design, has also been assumed by the Government through the Directorate General of Environmental Quality. In addition, the Catalan Government stands out for its pioneering role in the creation its own environmental quality label, or clean eco-label. The Catalan Ecolabeling system was created in 1994, and by 2015 it had more than 800 accredited products. The labelling system promotes environmentally friendly design, production and marketing processes, waste minimisation and the re-use of products and materials. The Catalan Government is also characterized by its proactive promotion of the implementation of Environmental Management Systems in firms, a voluntary environmental system that helps organizations to improve the efficiency of their resources, reduce risks and set an example by publicly declaring good practices, representing the 6.4% of the European total in 2015.

This transition to a more sustainable economy is made possible by Catalonia is one relevant region in Europe (Table 2). According to the Regional Innovation Scoreboard 2017, Catalonia is a Moderate + Innovator. Its economy is based on a long-standing industrial tradition, which has experienced a progressive transition to a new economic model. In addition, Catalan firms are characterized by high commitment investment in R&D activities. The traditional social and economic leadership of Catalonia over the other Spanish regions not only has internal impacts, but also spillover effects on them. These dynamics are particularly important when focusing on the capacity of regions to move from a traditional energy regime based on fossil fuel energy sources, towards a sustainability model where increased renewable energy sources considerably reduce pollution levels and emissions of greenhouse gases. In the European Union context, the environmental transition model relies heavily on the capacity of sub-national territories, especially on those regions that enjoy the highest levels of governance and that have designed more ambitious and inclusive environmental policies, since they have the capacity to act as regional eco-innovation "lighthouses" to other regions and countries (Cooke 2011).

Table 2. Autonomous community performance in terms of core economic, environmental and innovation indicators

	Catalonia	Madrid	Andalucía	Spain
Micro indicators				
Innovative firms 2016 (%)	32.92	31.06	25.07	28.88
Technological innovative firms	14.27	13.90	8.99	12.75
Non-technological innovative firms	28.13	26.73	21.98	24.47
Innovation objective high importance 2016 (%)				
Reduce environmental impacts	17.99	14.98	18.45	18.09
Energy efficiency	11.84	8.84	12.85	12.15
Aggregate indicators				
GDP per inhabitant in percentage of the EU average 2015	107.0	123.0	66.0	90
GDP per capita (Purchasing Power Standards) 2015	30.900	35.400	19.200	25,900
Human resources in S&T (% active population) 2016	45.1	53.8	34.6	42.3
Patent applications (EPO) (Per million inhabitants) 2012	57.0	38.3	10.0	27.3
Total intramural R&D expenditure (% GDP) 2015	1.5	1.7	1.0	1.2
Regional Innovation Scoreboard (2017)	88.5	85.9	65.1	78.3
Greenhouse gas emissions CO2-equivalent (kt) (2015)	41.467	21.543	52.310	18442.27

Sources: Eurostat, Spanish Statistical office (INE) and *El sistema español de inventario* (SEI)

4. Data and economic procedure

4.1 Database

The data source used in this study is the Technological Innovation Panel (PITEC). It is a specific statistical instrument for studying the innovation activities of a large sample of Spanish firms over time and is the result of collaboration between the Spanish National Institute of Statistics (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC).

PITEC is a panel survey based on the Community Innovation Survey (CIS) framework, enabling us to compare our results with previous empirical results on similar datasets. In addition, it is one of the most used datasets in innovation studies and has recently been applied to studying eco-innovations thanks to the inclusion of new questions in the survey (Cainelli et al. 2015; Del Río et al. 2015; Horbach 2016).

Although the PITEC database is not specifically designed to examine environmental innovations, in 2008, the panel survey introduced a new question asking firms, for the first time, what goals they were pursuing when they introduced innovation into products or processes, thus offering the possibility of making an independent analysis of environmental motivations. This question was: *"Innovation activities carried out in your firm could be oriented to different objectives, how important were each of the following objectives for your innovation activities during the three last years?"* In total 16 objectives were listed. Among these objectives, one can be strongly linked to the environmental orientation of the firm: the reduction of environmental impacts. In our analysis, this question is used to distinguish between firms oriented towards eco-innovation and the others.

However, the CIS data has several constraints. One of its limitations is the subjective nature of many of the questions addressed to the firm's management or those responsible for R&D departments. Nevertheless, Mairesse and Mohnen (2005) provide evidence that the subjective measures of innovation surveys tend to be consistent with more objective measures of innovation, such as the probability of holding a patent and sales percentage of products protected by patents. Second, the CIS is a cross-sectional dataset; in contrast, PITEC is characterized by its time dimension. It has panel data for the period 2003–2015, making it possible to analyse long-term relationships between variables and to control for standard econometric issues, such as unobserved heterogeneity and simultaneity problems that are hard to detect in simple cross-sectional data or time series (Baltagi 2008).

Our final database sample was subject to a filtering process. The main filters were as follows: 1) the data referred to those firms with headquarters located in Catalonia; 2) the data referred the period 2008–2015, because eco-innovation motivation questions were not included in the survey until 2008; 3) Catalan manufacturing firms that innovated in products or processes were analysed; 4) firms that reported confidentiality issues, mergers, employment incidents and so on were not incorporated in the sample. After all filtering, our empirical analysis was based on an unbalanced panel of more than one thousand Catalan firms for the period 2008–2015.

4.2 Variables and econometric methodology

In this study, we consider environmental motivation as the dependent variable. Consequently, we use a subjective measure of the motivational nature of the innovation from the survey to build our dependent variable (*environmental-motivation*) and differentiate firms that have a green orientation from those firms that do not, an approach that has already been used in other CIS dataset studies on eco-innovation (De Marchi 2012; Horbach 2008; Marzucchi and Montresor 2017).

Firms were asked to evaluate the importance of this objective on a Likert scale of 1 to 4, where 1 represents "high importance", 2 represents "intermediate importance", 3 represents "low importance" and 4 represents "factor not experienced". Following previous empirical studies working with the same dataset (Cainelli et al. 2015; Costa-Campi et al. 2015), we transformed these categorical variables into a single binary variable that was equal to 1 when a firm considered reducing environmental impacts to have high or medium importance, and equal to 0 when the importance was intermediate, low, or not experienced.

Regarding the independent variables, we introduced a subset of those that the existing empirical literature lists as determinants of eco-innovation orientation in capturing factors related to: (1) technology-push factors, (2) market-pull factors, (3) regulatory factors, and finally, (4) a set of firm characteristics (among others, see Horbach (2008), Triguero et al., (2013), Hojnik and Ruzzier (2015) and (Jové-Llopis and Segarra-Blasco 2017)). Appendix 2 summarises the list of variables and their definition. Appendix 3 shows the correlation matrix.

To test the role of technological factors in adopting an eco-innovation strategy, the variable *internal R&D effort* was included. It measured the total expenditures on internal R&D activities per employee, as a proxy for the stock of technological competences.

To explore further differences on whether eco-innovators rely on external innovation resources, either by acquiring them or by searching for different sources of innovation, additional variables were used. We included the variable *external R&D effort* that measured the total expenditures on external R&D activities per employee, a dummy variable *cooperation* indicating whether a firm reported having cooperated on innovation with other partners, and four dummy variables indicating different sources of information for innovation activities. These where whether the firm considered important the information (i) from sources within the enterprise or group (*Internal sources*), (ii) from suppliers, clients, competitors or private R&D institutions (*Market sources*), (iii) from universities, public research organizations or technology centres (*Institutional sources*), and (iv) from conferences, scientific reviews or professional associations (*Other sources*). We also included a dummy variable *saving* indicating whether a firm considered it relevant to reduce labour, energy and materials costs, and, finally, whether it had introduced organisational innovations (*organizational inno*).

Being restricted by the variables available to us in our dataset, as a proxy to capture the demand-pull factor, we included a dummy variable indicating if entry to new markets was an important innovation objective (*new markets*).

Concerning environmental policy influences, we captured regulation and subsidies policy measures. *Regulation* measured how important was the fulfilment of environmental government regulations or standards for firms wishing to eco-innovate, and s*ubsidies* indicated whether the firm had received public funds at the regional, national or EU level.

The econometric analysis also included a set of firm characteristics factors such as firm size (*size*), the number of employees (in natural logarithms), and whether the firm belonged to a group (*group*).

Given the binary character of the dependent variable, a probit model was specified. In addition, we used panel estimators to further account for the endogeneity, by controlling for any unobserved time-invariant heterogeneity in the model. The two most common techniques of panel estimators are fixed effects and random effects. To address concerns of unobserved heterogeneity, we employed a random-effect model rather than a fixed-effect model for several reasons. Firstly, a fixed effect estimator may be inappropriate as many crucial determinants of our variables of interest show little variation over time. Indeed, most of the independent variables like R&D activities, belonging to a group, public funding or meeting regulatory requirements are highly persistent, having considerably lower within variation than their overall and between variations. In addition, the information from the survey for most of the variables has a high degree of overlap, because PITEC poses the questions for time spans of three years and not for the current year. Secondly, estimates computed using fixed-effects models can be biased for panels over short periods and large populations. Given that our sample was drawn from a large population and included data for only a few years, a random-effects model was the preferred approach. Thirdly, fixed effects models cannot include time-independent covariates. This limitation would have meant excluding some of the control variables (for example, the sectoral variables) that are crucial for understanding the green innovation behaviours of firms. Finally, the Hausman specification tests do not support the use of fixed effects.

According with our research interest, the following equation is estimated:

$$y_{it} = \beta_0 + \beta_1 Z_{it-1} + \beta_2 X_{it-1} + \alpha_i + \varepsilon_{it} \qquad \text{Eq. [1]}$$

being $i = 1 \ldots N$ firms and $t = 1 \ldots T$ years and where y_{it} is the binary outcome variable that that takes the value 1 if firm i states that an eco-innovation orientation has been high or medium importance between t and t-2. As explanatory variables (Z), we included technology push, market pull and regulatory factors as we already mentioned.

In addition, we included different common sets of control variables (X) referring to firm characteristics such as firm size and whether the firm belonged to a group. We also introduced industry and time dummies to control differences in the probability of being an eco-innovator oriented across sector-specific markets or technological conditions and macro differences over time respectively. The inclusion of this set of covariates should mitigate the potential omitted variables bias in our econometric estimations. Finally, $\alpha_i$is the time-invariant unobserved individual effects (such as managerial ability or organizational culture) and ε_{it} is the idiosyncratic error term. In the regression analyses, we lagged explanatory variables by one period to mitigate endogeneity problems deriving from reverse causality.

In addition, to control for potential multicollinearity problems, the variance inflation factor (VIF) was calculated. The individual VIF values were substantially below the recommended cut-off point of 10, indicating that multicollinearity problems did not appear in any of the models (the mean VIF being 1.60).

4.3 Descriptive statistics

Our final sample contains about a thousand Catalan firms that innovated in processes, products or both over the period 2008–2015. Half of them had a green orientation showing a growing trend among Catalan firms to have some concern for environmental damages. However, after the impact of the economic crisis there was a considerable drop in the number of Catalan firms that remained innovative, as well as in the number of green firms.

The profile of Catalan firms giving high-medium importance to reducing environmental impacts differs significantly form those that do not (Table 3). Catalan manufacturing firms with concerns about the environment are characterized by being larger in terms of number of employees, they more often belong to a Spanish or foreign business group and invest more in internal and external R&D activities. In addition, green firms are more active in searching for different sources of innovation, cooperation, have a greater likelihood of receiving public funds and show greater sensitivity to compliance with current legislation. In short, the values reflected in the two subgroups of firms (Catalan firms with green orientation compared to these with non-green orientation) together with the substantial significance of the t-test, suggest the presence of structural differences.

Table 3. Profiles of innovative firms according to their degree of environmental motivation

	Environmental motivation low or insignificant		Environmental motivation medium or high		Mean difference	
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Technology push						
Internal R&D effort	3666.45	(6613.39)	5207.79	(8963.00)	1541.34***	(184.91)
External R&D effort	720.39	(3352.33)	1067.29	(4308.77)	346.89***	(90.36)
Internal sources	0.7979	(0.4016)	0.9450	(0.2278)	0.1471***	(0.0072)
Market sources	0.7327	(0.4425)	0.9327	(0.2504)	0.2000***	(0.0080)
Institutional sources	0.1958	(0.3968)	0.4042	(0.4908)	0.2084***	(0.0104)
Other sources	0.4011	(0.4902)	0.6679	(0.4710)	0.2667***	(0.0110)
Cooperation	0.2397	(0.4270)	0.3988	(0.4897)	0.1595***	(0.0106)
Saving	0.1853	(0.3886)	0.4873	(0.4998)	0.3019***	(0.0104)
Organizational inno.	0.3979	(0.4895)	0.6355	(0.4813)	0.2376***	(0.0111)
Market pull						
New markets	0.5772	(0.4940)	0.8445	(0.3623)	0.2672***	(0.0098)
Environmental policies						
Regulation	0.0911	(0.2879)	0.5224	(0.4995)	0.4312***	(0.0096)
Subsidies	0.2331	(0.4229)	0.3365	(0.4725)	0.1033***	(0.0104)
Firm characteristics						
Size	108.15	(202.20)	226.94	(560.86)	118.78***	(10.17)
Group	0.3904	(0.4879)	0.5324	(0.4993)	0.1420***	(0.0113)
High tech	0.4929	(0.5000)	0.5403	(0.4984)	0.0474***	(0.0115)
Low tech	0.5070	(0.5001)	0.4596	(0.4942)	-0.0474***	(0.0115)

Note: comparison of the two samples by the statistical *t-test.*
56.23% of all innovative firms consider reducing environmental impacts is an innovation objective of medium-high importance (on average 2008–2015).
*** significance at 1%
R&D effort in euros per worker, size in number of employees in workers and, the rest of variables are expressed in percentages.

5. Main results

After examining the most relevant characteristics of the firms according to their commitment to the environment, in this section, we present the empirical results that allow us to delve into the role of the main determinants of environmental motivations. Table 4 provides the results of the estimations for all Catalan innovative firms and for different types of eco-innovators (according their size or sector). First, looking at the results for the whole sample, we observe that the relevance of technology push factors is confirmed by the importance of internal innovation capabilities and of information flows from internal and market sources. Regarding internal factors intimately related to technological capabilities, we find strong evidence for the positive influence of internal R&D activities in environmental motivations. This result is similar to the findings of other studies in the Spanish context (Cainelli et al. 2015; Del Río et al. 2015), but contrasts with what has been found, for example, in Germany and France (Horbach 2008; Horbach and Rennings 2013).

Furthermore, cost savings and the introduction of new or relevant organizational innovations are important for environmental motivations. The result indicates that firms can find synergies or complementarities when combining the objectives of environmental and competitiveness or efficiency. Surprisingly, participating in cooperative projects is not significant in triggering eco-innovation motivation. Similarly to us, Horbach et al. (2013) and Cuerva et al. (2014) are not able to confirm a positive relationship between an open innovation strategy and eco-innovation. They found that firms that follow and in-house strategy experience greater environmental innovation.

The positive sign that we find for the variable reflecting the importance given to the entry to new markets, confirms the role of demand pull factor in eco-innovation. This result is similar to those of Horbach (2008) for Germany, Triguero et al. (2013) for European countries.

We can find that the role of public policies in terms of regulations is statistically significant, indicating that the propensity for firms to engage in eco-innovation is strongly dependent on regulations, as also observed by Del Río et al. (2015) and Del Río et al. (2017) for Spain. In contrast, subsidies from public institutions are not relevant for explaining environmental motivations. The result indicates the lack of effectiveness of subsidies as an environmental policy instrument to trigger green innovation. Neither are, subsidies a determinant of eco-innovation in low-tech SMEs in the Castilla-La Mancha regions of Spain (Cuerva et al. 2014) or among SMEs in the 27 EU-Member States (Triguero et al., 2013).

Finally, concerning a firm's characteristics, in line with the findings in the literature our results show that larger manufacturing firms are more likely to design an eco-innovation strategy (Costa-Campi et al. 2015; De Marchi 2012; Del Río et al. 2015). Whereas belonging to a group shows no relationship to being a green firm (Cainelli and Mazzanti 2013; Doran and Ryan 2016).

To explore different types of eco-innovators we split our sample according to their size (small, medium and large) and their technology intensity (high tech and low tech). Some clear features and determinants can be observed in each type of eco-innovators. Environmental regulation is a main driver for all eco-innovator types (except for large firms), whereas other public policies such as subsidies from local, national or EU authorities or cooperation do not seem to encourage any type of eco-innovator.

Despite size having been posited as having a positive influence on the adoption of eco-innovation, little is known about the different behaviour of small, medium and large-sized firms. In regard to firm size, large Catalan firms are only influenced by internal information flows, and the importance of organisational innovations when eco-innovating. In contrast, small and medium firms share more determinants. In particular, internal R&D efforts, regulations, and givig high importance to entering in new markets trigger eco-motivation in small and medium Catalan firms. In addition to these three factors, it is worth highlighting, that for medium firms market sources and cost saving practices also increase the likelihood of being green.

Regarding technology intensity, the environmental regulations and size variables are the main drivers for both eco-innovators types. Whereas internal R&D efforts and cost saving are only drivers for low tech Catalan firms, high tech firms seem to rely more on internal sources of information and demand-pull factors such as entering new markets.

Table 4. Results of the randon probit model. Objective: reduce environmental impacts						
		Size			Sector	
	Whole sample	Small	Medium	Large	High tech	Low tech
Technology push						
Internal R&D effort $_{t-1}$	0.0410***	0.0379**	0.0483**	0.0489	0.0237	0.0618***
	(0.00931)	(0.0130)	(0.0156)	(0.0315)	(0.0131)	(0.0135)
External R&D effort $_{t-1}$	0.00699	0.00949	0.00158	0.0160	0.000130	0.0104
	(0.0103)	(0.0162)	(0.0158)	(0.0297)	(0.0136)	(0.0161)
Internal sources $_{t-1}$	0.168**	0.107	0.180	0.418*	0.171*	0.152
	(0.0618)	(0.0977)	(0.0955)	(0.178)	(0.0866)	(0.0894)
Market sources $_{t-1}$	0.177*	0.140	0.286**	-0.133	0.180	0.145
	(0.0706)	(0.115)	(0.104)	(0.201)	(0.0973)	(0.104)
Institutional sources $_{t-1}$	0.0401	0.146	-0.205	0.346	0.165	-0.0260
	(0.0818)	(0.125)	(0.129)	(0.235)	(0.119)	(0.115)
Other sources $_{t-1}$	-0.0443	-0.118	0.206	-0.317	-0.0313	-0.0419
	(0.0884)	(0.135)	(0.141)	(0.279)	(0.139)	(0.117)
Cooperation $_{t-1}$	-0.0551	-0.164	0.0158	0.146	0.00175	-0.0862
	(0.0662)	(0.117)	(0.0945)	(0.168)	(0.0911)	(0.0981)
Saving $_{t-1}$	0.192**	0.136	0.300**	0.309	0.162	0.243**
	(0.0620)	(0.0988)	(0.0950)	(0.169)	(0.0864)	(0.0901)
Organizational inno. $_{t-1}$	0.136*	0.0824	0.116	0.579***	0.123	0.140
	(0.0577)	(0.0892)	(0.0895)	(0.163)	(0.0810)	(0.0830)
Market pull						
New markets $_{t-1}$	0.274***	0.335**	0.258*	0.189	0.454***	0.0961
	(0.0664)	(0.107)	(0.100)	(0.182)	(0.0945)	(0.0949)
Environmental policies						
Regulation $_{t-1}$	0.540***	0.626***	0.656***	0.106	0.503***	0.600***
	(0.0640)	(0.0993)	(0.100)	(0.175)	(0.0878)	(0.0943)
Subsidies $_{t-1}$	-0.000882	0.0475	0.0170	-0.0788	0.00148	-0.0141
	(0.0653)	(0.112)	(0.0960)	(0.161)	(0.0910)	(0.0950)
Firm characteristics						
Size $_{t-1}$	0.286***				0.313***	0.268***
	(0.0429)				(0.0607)	(0.0610)
Group $_{t-1}$	-0.00782	-0.0593	0.224	-0.242	0.00961	-0.0233
	(0.0941)	(0.155)	(0.125)	(0.319)	(0.131)	(0.136)
Constant	-1.833***	-1.197***	-0.748**	1.548	-2.455***	-1.806***
	(0.252)	(0.320)	(0.279)	(0.863)	(0.559)	(0.316)
lnsig2u	0.520***	0.619***	0.415**	0.387	0.464***	0.581***
	(0.0909)	(0.142)	(0.140)	(0.259)	(0.128)	(0.130)
Observations	6472	2692	2744	1032	3387	3085
Log likelihood	-3054.2	-1322.6	-1294.6	-398.4	-1563.4	-1481.9
Wald test of χ^2	462.3	179.5	216.0	74.93	272.2	204.6
Prob> χ^2	0.000	0.000	0.000	0.000	0.000	0.000

Estimations control for time and industry dummies. Standard errors in parentheses. *, ** and *** correspond to significance levels of 1%, 5% and 10%, respectively.

5.1 Robustness check

To verify the robustness of our results, we ran further regressions with different specifications of our main dependent variables. As mentioned, the eco-innovation motivation variables in the PITEC database are measured using a variable with four values (high, medium, low and null impact). As a sensitivity analysis, we estimated the model when the intermediate answers were also considered. Hence, we ran a model using a random-effects ordered probit regression.

The results, reported in Appendix 4, clearly show that there are hardly any changes regarding the sign and significance of the explanatory variables in the models when using a different specification of the dependent variables, from a dichotomous specification to a multinomial one (four categories). Therefore, the results shown in the previous section are considered to be robust.

6. Concluding remarks

This paper contributes to the empirical literature on the drivers of eco-innovation using a sample of Catalan innovative firms. The study contributes new results related to both the temporal and the geographical dimension of eco-innovation orientation. Our empirical results suggest that regulations, together with the need for efficiency through cost saving or organizational innovations, internal R&D efforts and firm characteristics such as size are the main determinants influencing the environmental innovation strategy.

This analysis carries some important policy implications. First, since eco-innovations are characterized by the double externality problem, public policy still retains a relevant role. Traditional environmental policy, in terms of existing regulations, is effective in the Catalan context in driving eco-innovation orientation. However, the lack of effectiveness of subsidies suggests a change in the current regulatory framework: more stringent regulation is needed, because access to existing subsidies and fiscal incentives does not enhance environmental motivation among Catalan firms. In this sense, local government can continue promoting eco-label strategy or certification about environmental management systems as EMAS or ISO14001 rather than subsidies or tax incentives.

Second, as eco-innovations have both environmental and innovation externality (Rennings 2000), environmental policies can be only one component of the package of instruments needed to promote eco-innovation strategies. Our results suggest that other policy measures such as reinforcing the internal capabilities of firms, or innovation information flows and supporting information campaigns on cost saving and organisational changes, might also be effective in promoting green firm.

Third, although Catalan firms are starting to develop environmental-innovations, their motivation is still very much more oriented towards meeting regulatory requirements, than towards truly sustainable goals. This suggests the need for more education and awareness regarding sustainability, among both firms and for consumers. If green strategies are profitable, firms will be encouraged to adopt voluntary environmental practices, thus reducing the need for regulation to achieve environmental goals.

The analysis presented has provided useful additional results on the drivers of environmental innovations. Nevertheless, it is important to highlight some limitations of the paper addressing these could be the object of fruitful future research. Although PITEC is a valuable data source, and one that has been previously used in analyses of eco-innovation, it was not specifically established to analyse environmental innovation, and consequently variables of interest to us, such as market demand for green products or different environmental policy instruments, are not reported.

In addition, since the relevance of spatial characteristics for innovation activities was recognized by Krugman (1991), the analysis of regional characteristics and location conditions may be especially important. Because of the lack of adequate data, we have limited access to regional factors and location to incorporate into our analysis. It could be interesting to have the opportunity to work with more disaggregated data or to merge different datasets with mixed characteristics (innovation, environmental, local and regional indicators) to explore the drivers of eco-innovation.

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Appendix

Appendix 1. Spanish eco-innovation context

The Eco-Innovation Scoreboard (Eco-IS) is the first tool to assess and illustrate eco-innovation performance across the EU Member States. It aims at capturing the different aspects of eco-innovation by applying 16 indicators grouped into five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. The Eco-Innovation Index shows how well individual Member States perform in different dimensions of eco-innovation compared to the EU average and presents their strengths and weaknesses.

Figure A.1. Eco-Innovation Scoreboard of all 28 EU members in 2015 (Eco-innovation observatory (EIO, 2015).

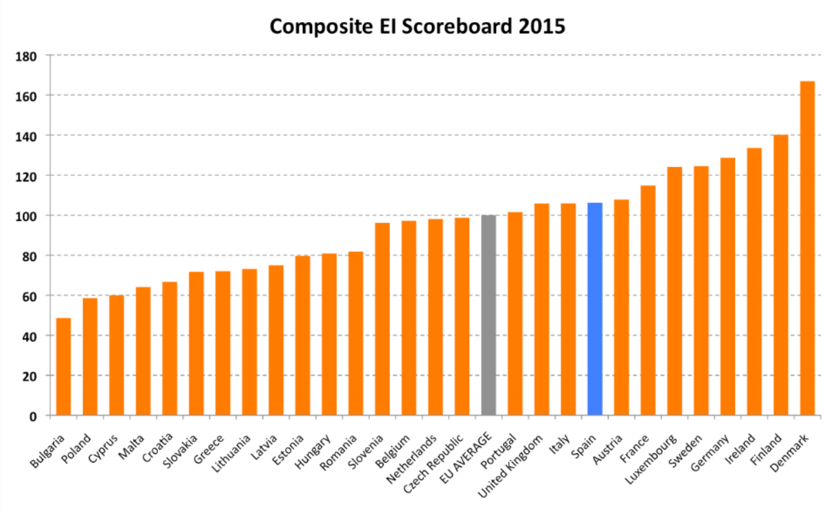
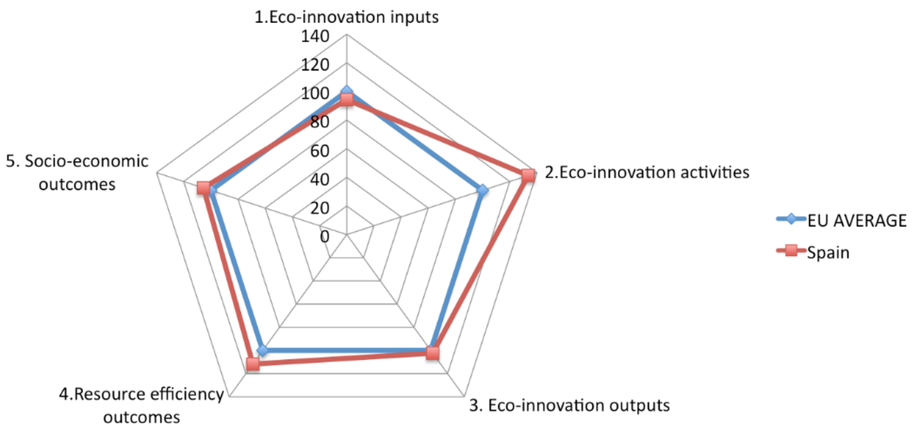


Figure A.2 Spain's Eco-Innovation Scoreboard areas in 2015 (Eco-innovation observatory (EIO, 2015).



Appendix 2. Variables definition

Table A.2. Variable definitions

Dependent variables	
Environmental motivation	Dummy variable that takes a value equal to 1 if the firm considers the objective of innovation “reducing environmental impact” of medium or high importance; 0 if not
Independent variables	
Technology push factors	
Internal R&D effort	Expenditures in internal R&D activities per worker (in logs)
External R&D effort	Expenditures in external R&D activities per worker (in logs)
Cooperation	Dummy variable that takes a value equal to 1 if the firm cooperates with other agents during; 0 if not
Sources of information	Internal sources: dummy variable which takes a value equal to 1 if information from sources within the enterprise or group has high importance; 0 if not Market sources: dummy variable which takes a value equal to 1 if information from suppliers, clients, competitors or private R&D institutions has high importance; 0 if not Institutional sources: dummy variable which takes a value equal to 1 if information from universities, public research organizations or technology centres has high importance; 0 if not Other sources: dummy variable which takes a value equal to 1 if information from conferences, scientific reviews or professional associations has high importance; 0 if not
Cost saving	Dummy variable that takes a value equal to 1 if the firm considers the objectives of innovation “reduce labour costs”, “reduce material costs” or “reduce energy costs” of medium or high importance; 0 if not
Organisational innovations	Dummy variable that takes a value equal to 1 if the firm has introduced organisational innovations (new business practices for how work is organised and new company procedures); 0 if not
Market-pull factors	
New market	Dummy variable that takes a value equal to 1 if the firm considers the objective of innovation “entering new markets” of medium or high importance; 0 if not
Environmental policies	
Regulation	Dummy variable that takes a value equal to 1 if the firm considers the objective of innovation “meet regulatory requirements” of medium or high importance; 0 if not
Subsidies	Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from local, national or EU authorities; 0 if not
Firm characteristics	
Group	Dummy variable that takes a value equal to 1 if the firm belongs to a group; 0 if not
Size	Log of the total number of firm's employees (natural logs)

Appendix 3. Correlation matrix

Table A.3. Correlation matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1.Internal R&D effort	1.000												
2.External R&D effort	0.407*	1.000											
3.Internal sources	0.149*	0.056*	1.000										
4.Market sources	0.129*	0.039*	0.426*	1.000									
5.Institutional sour.	0.216*	0.153*	0.155*	0.209*	1.000								
6.Other sources	0.168*	0.065*	0.248*	0.363*	0.287*	1.000							
7.Cooperation	0.192*	0.166*	0.139*	0.175*	0.358*	0.159*	1.000						
8.Saving	0.001	-0.012	0.127*	0.175*	0.094*	0.121*	0.094*	1.000					
9.Organitzational inn.	0.105*	0.056*	0.138*	0.168*	0.147*	0.189*	0.162*	0.188*	1.000				
10.New markets	0.181*	0.053*	0.335*	0.350*	0.196*	0.314*	0.141*	0.177*	0.157*	1.000			
11.Regulation	0.065*	0.023*	0.174*	0.196*	0.145*	0.210*	0.102*	0.301*	0.210*	0.206*	1.000		
12.Subsidis	0.234*	0.139*	0.117*	0.143*	0.298*	0.126*	0.286*	0.061*	0.126*	0.145*	0.064*	1.000	
13.Size	0.011	0.133*	0.047*	0.038*	0.113*	0.013	0.169*	0.084*	0.093*	0.028*	0.047*	0.099*	1.000
14.Group	0.036*	0.113*	0.059*	0.027*	0.116*	0.025*	0.235*	0.104*	0.102*	-0.009	0.074*	0.100*	0.266*

* significant at 5%

Appendix 4. Robustness check

Table A.4 Results of the random ordered model. Innovation objective: reduce environmental impacts

	Whole sample	Size			Sector	
		Small	Medium	Large	High tech	Low tech
Technology push						
Internal R&D effort $_{t-1}$	0.0705***	0.0633*	0.0880**	0.0795	0.0398	0.107***
	(0.0163)	(0.0259)	(0.0291)	(0.0663)	(0.0252)	(0.0264)
External R&D effort $_{t-1}$	0.0127	0.0169	0.00192	0.0361	0.00106	0.0190
	(0.0180)	(0.0276)	(0.0298)	(0.0552)	(0.0239)	(0.0311)
Internal sources $_{t-1}$	0.301**	0.181	0.335	0.738*	0.309	0.274
	(0.109)	(0.203)	(0.190)	(0.335)	(0.185)	(0.174)
Market sources $_{t-1}$	0.312*	0.275	0.491*	-0.255	0.314	0.260
	(0.124)	(0.216)	(0.193)	(0.397)	(0.186)	(0.195)
Institutional sources $_{t-1}$	0.0723	0.249	-0.347	0.630	0.297	-0.0485
	(0.143)	(0.229)	(0.241)	(0.426)	(0.223)	(0.219)
Other sources $_{t-1}$	-0.0781	-0.209	0.329	-0.606	-0.0782	-0.0664
	(0.155)	(0.246)	(0.285)	(0.368)	(0.263)	(0.221)
Cooperation $_{t-1}$	-0.102	-0.274	0.00999	0.218	-0.00106	-0.161
	(0.116)	(0.225)	(0.185)	(0.335)	(0.168)	(0.199)
Saving $_{t-1}$	0.352**	0.263	0.523**	0.535	0.308	0.437*
	(0.109)	(0.181)	(0.191)	(0.311)	(0.163)	(0.180)
Organizational inno. $_{t-1}$	0.246*	0.133	0.180	1.097***	0.220	0.262
	(0.101)	(0.165)	(0.165)	(0.286)	(0.152)	(0.156)
Market pull						
New markets $_{t-1}$	0.487***	0.590**	0.463*	0.303	0.810***	0.172
	(0.116)	(0.197)	(0.206)	(0.325)	(0.189)	(0.180)
Environmental policies						
Regulation $_{t-1}$	0.971***	1.107***	1.172***	0.183	0.917***	1.064***
	(0.113)	(0.202)	(0.190)	(0.359)	(0.171)	(0.190)
Subsidies $_{t-1}$	0.00795	0.0583	0.0168	-0.120	0.0146	-0.0161
	(0.115)	(0.206)	(0.175)	(0.282)	(0.162)	(0.170)
Firm characteristics						
Size $_{t-1}$	0.499***	0.310	0.432	0.714*	0.550***	0.469***
	(0.0753)	(0.177)	(0.239)	(0.338)	(0.110)	(0.110)
Group $_{t-1}$	-0.00386	-0.174	0.275	-0.555	0.0323	-0.0402
	(0.165)	(0.296)	(0.238)	(0.705)	(0.259)	(0.233)
cut1						
_cons	3.224***	3.047***	3.261**	1.461	4.257***	3.191***
	(0.440)	(0.825)	(1.178)	(2.203)	(0.972)	(0.589)
sigma2_u						
_cons	5.032***	5.614***	4.449***	4.316**	4.754***	5.358***
	(0.475)	(0.892)	(0.694)	(1.313)	(0.695)	(0.773)
Observations	6472	2692	2744	1036	3387	3085
Log likelihood	-3052.6	-1320.1	-1292.7	-394.8	-1562.4	-1481.1
Wald test of χ^2	448.8	179.5	216.2	688.5	254.6	182.6
Prob> χ^2	0.000	0.000	0.000	0.000	0.000	0.000

Estimations control for time and industry dummies. Standard errors in parentheses. *, ** and *** correspond to significance levels of 1%, 5% and 10% respectively.