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Determinants of Environmental Innovations: New Evidence at the sector Level

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This study carried out an empirical analysis of environmental innovations based on firm-level data from the Technological Innovation Panel (i.e. PITEC) 2014 database created by the Spanish Institute of Statistics. The main goal was to explore the determinants of eco-innovation in the primary, secondary, and tertiary sectors. The methodology applied revealed that, although most of the proposed model's determinants are significant for all sectors, the determinants' effects are specific to each sector. Improvements of products and processes, organisational innovations, research and development, and public financial support for innovation activities are the main drivers for eco-innovation in all sectors. However, these determinants' effects significantly vary across sectors. This study's main conclusion is that international competition is quite important for eco-innovation and economic aid programmes are essential to the implementation of eco-innovation measures.

Keywords: Eco-Innovation, Determinants of Environmental Innovation, Discrete Choice Models

Introduction

Although the association between innovation and firms' financial results has already been analysed for a large number of countries and economic activities[1], empirical studies exploring the main determinants of innovation remain scarce[2]. Learning more about the drivers of environmental innovation or eco-innovation is especially important because these can lead to 'win-win' situations with both economic and environmental benefits. This research is necessary because environmental innovations are important to society's well-being, as well as generating competitive advantages for firms and their stakeholders[3,4]. Various empirical studies have been reported in the literature that predominantly analyse the drivers of innovation in industry. However, only recently studies have been conducted in the service sector[5,1]. Therefore, eco-innovation is now seen as an integral aspect of innovation across all sectors and varies across different activities according to their development patterns and objectives[1,6]. In this context, the present research sought to investigate differences in eco-innovation drivers at the sector level in Spain, distinguishing between the primary, secondary and tertiary sectors.

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Conceptual framework

Empirical analyses of the driving forces behind environmental innovations are rare mainly due to difficulties in obtaining adequate environmental innovation indicators and significant determinants[4]. The main determinants discussed in theoretical studies of environmental innovations are largely based on general innovations. Thus, innovative activities are seen as determined by technological push factors on the supply side and pull factors on the demand side[7], as well as institutional and political factors. The main factors in the first group are companies' technological capacity to develop innovations at the product, process and organisational level[4]. The main incentive for engaging in innovation is how well firms can capture their innovations' returns. Market structure, the intensity of competition between companies and businesses' size also play key roles. Concerning the demand side, researchers have emphasised consumers' role in actively seeking out 'green' products. Changes in consumer behaviour appear to indicate that customers' increasing environmental awareness has led to a greater demand for environmentally friendly goods and services[8]. This has forced companies to understand the demand side and adjust their marketing techniques to match this new paradigm. Regarding institutional factors, various determinants include, among others, environmental policies (i.e. regulations and public

funding) and international agreements and treaties. Based on a brief overview of the aforementioned determinants, the following empirical hypotheses were developed for the present study:

H1: Product, process and organisational innovations foster eco-innovation.

H2: Companies belonging to a business group are more likely to boost their eco-innovation.

H3: Company size drives environmental innovations.

H4: Companies improve their attitude towards eco-innovation when facing international competition.

H5: Public financial support for innovation activities triggers eco-innovation.

H6: Research and development (R&D) investment that builds up knowledge capital stock is positively related to eco-innovation.

Methodology

Econometric modelling

This research used a discrete approach to testing the hypotheses listed in the previous section. To meet the study's methodological requirements, the dependent variable – denoted by y_1– was a dichotomous variable. This was given a value of 1 when a firm i's innovation activities were mainly focused on reducing environmental impacts (i.e. eco-innovation), and 0 otherwise. Thus, y_i^* was the latent variable of eco-innovation activity, which depended on a vector of exogenous variables x_i represented by equation (1):

$$y_i^* = x_i' \beta_1 + \varepsilon_i \quad \ldots (1)$$

in which β_1 is a vector of unknown parameters and ε_i is the error term. The probability of having certain discrete values depended on the cut-off points estimated or c as shown in equation (2):

$$y_i = \begin{cases} 1 \; if \; y_i^* > c \\ 0 \; otherwise \end{cases} \quad \ldots (2)$$

Since the outcome was a dichotomous variable, a binomial logit, discrete choice model was developed based on the maximum likelihood estimation method.

Database and descriptive analysis

This article used the Technological Innovation Panel (PITEC) 2014 database, developed by the Spanish Foundation for Science and Technology of Spain's Ministry of Economy and Competitiveness, in collaboration with the Spanish Institute of Statistics. PITEC uses the methodological framework established for Eurostat's Community Innovation Survey and the innovation classification criteria listed in the Oslo Manual (2005)[9], which facilitates comparisons of Spanish data with those of other European Union (EU) countries. Given the present study's primary goal of comparing the determinants of eco-innovative activities in the primary, secondary and tertiary sectors, the companies in the sample were classified by sector according to Portugal's National Economic Activities Classifications for 2009. In total, data for 7,081 companies were analysed, of which 112 belonged to the primary sector, 3,941 to the secondary sector and 3,028 to the tertiary sector. The variables used in the proposed model were taken from the existing literature on innovation activities[4,1]. The variables were selected based on the criteria of economic significance in order to explain more fully eco-innovation in Spanish companies. Data on most of these variables were directly extracted from the PITEC database or were derived by simple mathematical transformations. In addition, some dummy variables were included by converting original categorical variables. The main determinants of eco-innovation were determined as follows. The product innovation, process innovation and organisational innovation variables were created as dummy variables that had a value of 1 when a company had introduced product, process and organisational innovation measures in the previous two years, and 0 otherwise. The structural characteristics of firms were also represented as binary variables except company size and operating years, which were continuous variables created by the number of workers and the years in business as of 2014, respectively. The business group variable was given a value of 1 for companies belonging to a business group, and 0 otherwise. International competition was also a dichotomous variable that captured if firms competed in international markets. Public financing variables 1, 2 and 3 represented whether companies had received financial support (e.g. loans and grants) for technological innovation activities from local or regional governments, from the national government or from the EU, respectively. These variables took a value of 1 in the three mentioned cases, and 0 otherwise. Finally, R&D expenditure per employee was a continuous variable measured in

thousands of euros. Table 1 shows the descriptive statistics for each of the three sectors and the percentage differences obtained for each variable between the primary and tertiary sectors with regard to the secondary sector. Traditionally, the secondary sector has been more likely to invest in innovation measures. Results confirm that investment in product, process and organisational innovations is clearly higher in the industrial sector, with the exception of organisational innovation, which does not present statistically significant differences in relation to the tertiary sector. Another aspect in Table 1 is that the Spanish service sector engages in eco-innovation less than the Spanish industrial sector, whereas the opposite result was obtained for the primary sector. The first finding is quite similar to the results reported by other authors[5], who used the PITEC database for 2009. The second finding is quite interesting since, although the secondary sector presents the highest overall level of R&D investment, primary sector companies outstrip the former sector in terms of eco-innovation (3.46%), leading in this type of activity in relative terms. The largest mean differences in favour of the industrial sector refer to the international competition faced by these companies (from 47.74% to 30.58%) and the number of years the firms have been in operation (from 19.75% to 26.99%). In addition, secondary sector companies are bigger than those in the primary sector, but tertiary sector companies are on average 96.88% larger than industrial companies. These results may be due to differences between the sectors in production processes. Notably, financial support from the EU for technological innovation activities is much greater in the tertiary (156.19%) and primary sectors (48.98%) than in the secondary sector. Finally, the results highlight that R&D spending per employee is far higher in tertiary (160.26%) and primary sector companies (48.98%).

Results and Discussion

The descriptive analysis presented in the previous section indicates some differences between the three sectors in eco-innovation. This section discusses the main determinants of these differences. Table 2 presents the estimated coefficients of the explanatory variables in equation (1), as well as the odds ratios and marginal effects. The remaining tests confirmed the model's high predictive power. For instance, the proportion of cases correctly classified by the discriminant functions (77.86%, 75.87% and 80.95%) indicates a high correlation between that predicted by the model and the observed data. The likelihood ratio chi-square test produced a statistically significant value, which indicates that the determinants together influence the probability of eco-innovation. With the exception of the variable of belonging to a business group in the tertiary sector, all estimated parameters were shown to be positive in the regressions, which implies that most of the determinants drive eco-innovation. Some exceptions were found for the primary sector, in which some estimated coefficients are not statistically significant. However, the significant variables' odds ratios for the primary sector are clearly higher than those for the other two

Table — 1 Descriptive characteristics by economic sector

Variable	*Type*	*Primary sector*		*Industrial sector*		*Service sector*		*Differences (C-B)/B (%)*	*Differences (A-B)/B (%)*
		Mean (A)	*S.D.*	*Mean (B)*	*S.D.*	*Mean (C)*	*S.D.*		
Eco innovation (dependent)	D.	0.359	(0.48)	0.347	(0.48)	0.211	(0.41)	-39.20	3.46
Product innovation	D.	0.252	(0.44)	0.387	(0.49)	0.315	(0.46)	-18.64	-34.94
Process innovation	D.	0.336	(0.47)	0.395	(0.49)	0.332	(0.47)	-15.97	-15.07
Organisational innovation	D.	0.237	(0.43)	0.378	(0.49)	0.383	(0.49)	1.09	-37.48
Business group	D.	0.313	(0.47)	0.427	(0.49)	0.411	(0.49)	-3.66	-26.71
Size (100 workers)	C.	0.812	(1.49)	2.370	(13.38)	4.667	(2.01)	96.88	-65.73
International competition	D.	0.519	(0.50)	0.748	(0.43)	0.391	(0.49)	-47.74	-30.58
Operating years	C.	22.427	(11.01)	30.718	(18.28)	24.650	(23.04)	-19.75	-26.99
Public financing1	D.	0.107	(0.31)	0.115	(0.32)	0.132	(0.34)	14.64	-7.24
Public financing2	D.	0.183	(0.39)	0.156	(0.36)	0.169	(0.38)	8.67	17.57
Public financing3	D.	0.046	(0.21)	0.031	(0.17)	0.079	(0.27)	156.19	48.98
R&D expenditure per employee (1000€)	C.	3.878	(9.04)	2.785	(8.73)	7.249	(24.49)	160.26	39.22
Observations (Firms)		112		3941		3028		-	-

Note: D = dummy; C = continuous. Standard deviation is in parentheses. Source: PITEC 2014

Table 2 — Logits of eco-innovation by economic sectors

Variable	Primary sector			Industrial sector			Services sector		
	βi	*Odds ratio*	*Marginal effect*	*βi*	*Odds ratio*	*Marginal effect*	*βi*	*Odds ratio*	*Marginal effect*
Product innovation	1.0007***	2.7201	0.2350	1.0156*	2.7611	0.2205	0.4614*	1.5863	0.0674
Process innovation	1.4595*	4.3036	0.3355	1.1405*	3.1285	0.2471	0.9451*	2.5730	0.1449
Organisational innovation	0.7774			0.6869*	1.9875	0.1486	0.6864*	1.9866	0.1001
Business group	0.1907			0.2528*	1.2876	0.537	- 0.1977**	0.8206	-0.0267
Size (100 employees)	0.1506			0.0026**	1.0026	0.0006	0.0065*	1.0065	0.0009
International competition	-0.3877			0.3834*	1.4673	0.0776	0.2343**	1.2640	0.0329
Operating years	-0.0098			0.0055*	1.0055	0.0012	0.0003		
Public financing1	1.4986			0.3564*	1.4281	0.0789	0.6843*	1.9825	0.1108
Public financing2	1.5312**	4.6239	0.3624	0.5598*	1.7504	0.1258	0.4820*	1.6193	0.0738
Public financing3	0.0560			1.0185*	2.7691	0.2419	0.4635**	1.5896	0.0725
R&D expenditure per employee (1000€)	0.0880**	1.0920	0.0197	0.0409*	1.0418	0.0086	0.0101**	1.0102	0.0014
Constant	- 2.1443*			- 2.7834*			- 2.6714*		
McFadden's Pseudo R^2		0.3344			0.2659			0.1989	
LR Chi^2 (11)		31.36*			1,506.15*			550.47*	
Correctly classified (%)		77.86			75.87			80.79	
Area under ROC curve		0.8764			0.8413			0.8141	
Observations		112			3941			3028	

Notes: Level of significance: *(1%), **(5%), and ***(10%). The standard errors and covariances are robust for heteroscedasticity. Source: PITEC (2014)

sectors. These differences appear most clearly when their strength is based on the explanatory variables' marginal effects. The largest differences in marginal effects in favour of the primary sector are related to the influence of R&D spending per employee: 1,307.1% and 129.1% higher than in the tertiary and secondary sectors, respectively. This is followed by the influence of financial support from the national government (higher by 391.1% and 188.1%, respectively). Similar results appear regarding product and process innovations, for which marginal effects are also the greatest in the primary sector. Table 3 summarises the main findings regarding the empirical hypotheses tested at the sector level. More specifically, H1 and H5 are partially supported in the primary sector's activities, whereas H6 is clearly accepted for all three sectors. A comparison of the drivers of eco-innovation in the secondary and tertiary sectors revealed that most of the determinants have the strongest marginal effects on industrial companies. The largest differences in favour of the industrial sector are related to spending on R&D per employee (514.3%), financing from EU and the Spanish government (233.7% and 70.5%, respectively) and product innovation measures (227.2%). The differences between the secondary and tertiary sectors are less marked in process and organisational innovations (70.5% and 48.5%, respectively). In addition, the probability of companies focusing on eco-innovation activities is also significantly increased by international competition in the industrial sector (7.7%) and to a lesser extent in the service sector (3.3%). Finally, the effect of operating years in business on the probability of eco-innovation

Table — 3 Empirical hypotheses at sectorial level

	Primary S.	Industrial S.	Services S.
H1:Product, process and organisational innovations breed eco-innovation	P	A	A
H2: Companies belonged to a business group are more likely to boost eco-innovation.		A	R
H3: The size of the company drives environmental innovation		A	A
H4: Companies improve their attitude to eco-innovation due to international competition.		A	A
H5: Public financial support for innovation activities triggers eco-innovation.	P	A	A
H6: R&D investment, which build up knowledge capital stock, is positively related to eco-innovation.	A	A	A

Note: A: Accepted; R: Rejected; P: Partially accepted

activities is only significant for industrial companies, although this determinant's effect is quite small (0.1%). In summary, most of the empirical hypotheses formulated were refuted for secondary and tertiary sector companies, and only partially supported for the primary sector.

Conclusions

This study's goal was to analyse the main drivers of eco-innovation at a sector level in the Spanish economy. Using data provided by PITEC for 2014, a binomial logit, discrete choice model was proposed to test empirical hypotheses derived from the theoretical literature on environmental innovations. These hypotheses sought to answer the following questions: Do environmental innovations have specific drivers as compared to general innovation activities? Do environmental innovations have specific determinants at the sector level? Regarding the first question, the results demonstrate that eco-innovation activities are determined by technological push factors on the supply side and pull factors on the demand side, as well as institutional and political factors. Concerning the second question, the results emphasise that eco-innovation is an integral part of innovation efforts across all sectors, but development patterns vary for different activities in the Spanish economy. On average, although the secondary sector stands out in terms of general innovation activities, primary sector companies implement significantly more eco-innovation activities (35.9%) than the secondary and tertiary sectors do (34.7% and 21.1%, respectively). The results for all sectors suggest that the dependent variable experiences positive increases in the probability of eco-innovation activities when nearly all the explanatory variables included in the proposed model are considered. However, this increased probability is the greatest for primary sector companies. Notably, the differences between the three sectors are quite clearly reflected in the value of the main determinants' marginal effects. The main drivers of eco-innovations in all sectors are improvements in product, process and organisational innovations; R&D investment, which builds up knowledge capital stock; and public financial support for innovation activities. The results also suggest that company size and international competition only foster eco-innovation in the industrial and service sectors. This research's findings could be quite important for designing sector-specific environmental policies in coordination with private instruments such as environmental management systems. The driving forces behind both general and specific innovation measures need to be considered for each sector. This level of coordination could favour the implementation of better environmental practices.

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