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What to do to Improve our Eco-Innovative Aptitudes? An Empirical Study on the Variables Affecting the Environmental Awareness of Firms While Innovating

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ABSTRACT: Eco-innovation is an actual topic as it links two key issues, innovation and sustainability. The environmental respect and innovation are important drivers of competitiveness. Firms are willing to know what to do to improve their eco-innovative capacity. The objective of this paper is to empirically determine what common characteristics have the most environmental oriented innovative firms. We analyze data retrieve from the Spanish Technological Innovation Panel (PITEC) from 7682 Spanish firms using a two step approach. Results show the impact of certain variables in determining the environmental orientation of companies. More specifically, process and product orientation while innovating was reveled as crucial aspects in determining the environmental orientation of firms. Moreover, results showed the lower relative impact of the importance of market, institutional and technical information sources. Based on these results, we can determine which company's behavior has to be promoted to get companies focused on environmental aspects. Important managerial and policy making implications are derived from the study.

Key words: Eco-innovation determinants, PITEC, Spanish innovative firms

INTRODUCTION

The impact on the competitive positioning of companies of environmental proactivity and innovation is high and increases rapidly (Biondi *et al.*, 2002, Esty and Winston, 2006, Da Silva *et al.*, 2009, Pohoryles, 2010). Those joint concepts are known as eco-innovation and are defined as any innovation that reduces environment's damage, but its full understanding is a concept still under review (Hellström, 2007). Eco-innovation is a multidisciplinary field as stated Carrillo-Hermosilla et al. (2010) who compiled several definitions of the concept.

Regarding the eco-innovative behavior, some authors analyzed how the industry's technological level influences the sustainable orientation when innovating (Peiró-Signes *et al.*, 2011), how companies with a higher absorptive capacity or high educated human resources availability are more aware of environment when innovating (Chen and Huang 2009) or how environment affects companies´ marketing strategies (Gázquez-Abad *et al.*, 2011), albeit what to do to promote a companies´ eco-innovative behavior has not been analyzed so far. Laws and regulations both at the national and supranational level, are pushing firms and society and developing this area of interest but, despite the popularity of the sustainability concept and considering the importance of innovation for competitiveness (Porter and Van der Linde, 1995), the study of the drivers of sustainable orientation while innovating is still poorly developed (Segarra-Oña and Peiró-Signes, 2013).

In this study, we analyze the aspects that drive eco-innovative activities. We consider that there is a need to deploy accurate environmental strategies depending on the type of firm to use in a more efficient way the public funds that national governments are deploying as a key part of the sustainable development and the economic growth strategies (Schnitzer, 1995, Berger *et al.*, 2001, Hellström 2007, *Burciu et al.*, 2010, Hipp and Grupp 2011).

Previous authors have studied how eco-innovation positively affects new business´ creation Carrillo-Hermosilla et al. (2010), green companies´ characteristics (Rehfeld *et al.*, 2007, Del Río *et al.*, 2010) or how previous innovative levels positively affect the environmental orientation of companies (Wagner 2008, De Marchi 2011, Segarra-Oña et al. 2011, Cainelli *et al.*, 2011), but until date there is no study classifying companies attending to their environmental orientation when innovating. What type of

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characteristics they have if they are highly oriented or not become a very important issue to better address public policies (Šauer *et al.,* 2012) and also internal strategic decisions when willing to "greener" companies and the economy (Sullivan, 2002).

To this point, in this paper we won´t establish any hypothesis as we want to discover what are the patterns that orientate the environmental innovation on firms, so we will analyze innovation data in an exploratory way with the objective to model the environmental behavior of companies towards the environment when deploying innovative activities.

MATERIALS& METHODS

To analyze the eco-innovative patterns of firms we used data from 7682 companies. While the analysis we deploy in this paper can be tested by empirical data collected from any region of the world, our study is based on information from Spain.

We used data from the Technological Innovation Panel (PITEC) database, which is a statistical instrument for studying the innovation activities of Spanish firms over time. The database is being carried out by the INE (The National Statistics Institute) and counts on advice from a group of university researchers. The variables´ anonymization is necessary in order to avoid the disclosure problem (i.e., the possibility of identifying firms through the data). The anonymization process applied implies to replace the firm-level observations of some quantitative variables and to replace the (4-digit) NACE Codes with a 44-industry breakdown. However, none of the selected variables in the study is affected by the anonymization process. We present in Table 1 the main descriptive characteristics of the sample.

PITEC survey contained several items related to the innovative capacity and orientation of the firms. We chose, attending to theoretical implications, 21 variables (represented in Table 2) to characterize these firms.

Several of these items might represent identical or similar constructs. Therefore, we used Principle Components Analysis (exploratory factor analysis) to develop reliable multiple-item measures for each of the underlying theoretical constructs (Hair *et al.,* 1998).

Three eigenvalues exceeded the generally accepted cutoff value of 1.0 and were therefore retained in the further data analysis. Together, the four retained factors explained approximately 68.82% of the variance in the data. In order to increase the interpretability, we preformed a Varimax rotation on the identified principle components and then we assigned them to the factor on which they had the highest loadings. For the sake of clarity, rotated factor scores lower than 0.6 are not shown (Table 3).

We labeled each of the four factors according to the items that loaded on them. The product orientation while innovating is comprised of four items related to increase or to substitute product range, to increase product quality or to reach grater market share or new markets. The second factor labeled as Process orientation while innovating is comprised of five items, all of which try to breadth of firm actions to increase operational flexibility or production capacity or to reduce labor costs per unit or energy consumption per unit when they are looking for new innovations. Four items related institutional information sources loaded on the third factor. Similarly, we have labeled the forth factor as the importance of the market information sources and it measures the firm's reliance on market information sources for the innovation process.

We must take care to assess the inter-item reliability of the items comprising each scale (Flynn *et al.,* 1990.) Cronbach's α was used to assess inter-item reliability, with α values of 0.70 or higher considered to indicate acceptable reliability for established scales and 0.60 being acceptable for new scales (Nunnally, 1978; Churchill, 1979). Therefore, we concluded that the scales are comprised of reliable items. We also eliminated the items that loaded on multiple factors. Using the above guidelines, a total of 17 items were retained in the analysis as measures for four company characteristics when innovating.

To evaluate environmental orientation of the firm while innovating, we used the variable called Objet11 in the original database that we renamed as EOWI, *Environmental orientation while innovating*. It measures how essential it is for firms to improve their environmental impact while innovating. PITEC database considers the importance of environmental impact improvement by firms when innovating as particularly important (1), important (2), not so important (3), not considered or not important (4). In prior studies (Segarra-Oña and Peiró-Signes, 2013), we realize that discriminating between these four groups is difficult and more accurate classification can be done considering two groups:High or medium environmentally oriented companies and low or not environmentally oriented. Therefore, we transformed the original 4-state variable in a dichotomous variable (1=oriented and 0=not oriented).

Finally, we developed a discriminant model based on the four company characteristics (independent variables) and by assuming that the companies were originally classified into two groups (dependent variable). This allows us to test the effectiveness these

Table 1. Sample characteristics

Industry	Size			Sales (M€)		Investment (Th€)		R&D expediture (Th€)		R&D employees	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Agriculture, forestry and fishing	102	71	109	14	29	663	1601	442	899	9	19
Mining and quarrying	31	113	236	19	41	1780	5062	269	374	5	7
Petroleum industries	2	5630	0	10M	0	1374M	0	24M	0	171	0
Food products, beverages and tobacco	569	200	367	76	164	2114	6105	761	3157	5	10
Textiles	145	69	72	12	17	324	1027	201	331	4	6
Wearing apparel	60	170	354	33	75	929	2680	660	1704	12	34
Leather clothes and footwear	42	83	113	15	27	222	451	334	691	5	8
Wood and cork	69	131	208	22	45	262	761	139	284	4	8
Paper and paper products	78	209	256	83	148	2799	5635	434	973	3	5
Printing and reproduction of recorded media	53	94	148	17	30	650	1524	160	395	2	6
Chemicals	487	98	152	39	98	1103	3630	626	1598	8	12
Pharmaceutical	138	295	359	152	289	3287	6822	7724	19069	34	52
Rubber and plastic products	280	152	411	33	103	6440	43555	513	1766	7	17
Manufacture of other non-metallic mineral products	228	152	240	34	68	1669	5522	403	956	5	10
Basic metals	128	326	559	162	322	3597	9193	1051	2432	11	22
Fabricated metal products	429	101	178	18	39	601	1859	362	1076	5	8
Computer, electronic and optical products	240	86	137	18	54	337	821	964	1788	13	19
Electrical equipment	228	203	565	53	172	1619	6182	1193	3920	12	30
Machinery and equipment	557	88	220	16	44	386	1626	415	1044	7	12
Motor vehicles	223	510	1415	199	769	3481	13946	6939	34472	24	72
Building of ships and boats	16	337	515	138	194	2572	4375	8996	13433	40	57
Manufacture of air and spacecraft	18	745	1044	171	300	7523	12882	24349	43704	169	271
Other transport equipment	28	427	691	137	228	2260	4138	4799	9409	29	51
Furniture	134	81	128	10	18	241	670	189	466	3	7
Other manufacturing	104	83	139	15	31	682	1996	412	925	7	15

Table 1. Sample characteristics

Repair and installation of machinery and equipment	57	70	99	10	16	248	578	170	306	5	9
Electricity and water	59	631	903	477	1052	64513	148192	2972	4900	21	39
Sewerage, waste management and remediation activities	67	864	2721	78	192	4456	13034	357	796	5	9
Construction	223	520	1235	134	368	7738	44429	605	1579	11	27
Wholesale trade	486	736	3767	225	974	4487	32678	580	2778	4	15
Transportation and storage	132	1428	4478	179	499	65903	290433	1484	5448	9	35
Accomodation and food service activities	41	1493	2281	74	103	4145	16946	91	203	1	1
Telecommunications	42	1144	2698	722	1783	55850	135217	38174	96034	36	73
Programming, consultancy and broadcasting activities	497	181	684	21	100	235	914	978	4759	16	55
Other information and froadcasting services	192	155	274	27	108	675	2898	513	1027	7	15
Financial and insurance activities	179	1656	3664	696	1740	97650	491445	3434	11903	15	61
Real state activities	26	115	189	9	14	1279	2662	235	462	3	6
R&d services	265	66	113	5	14	666	1357	4813	13200	52	96
Other services	595	159	508	24	105	1348	10879	741	3151	12	35
Administrative and support service activities	156	1645	4508	70	167	4875	22942	169	392	2	6
Education	38	93	193	5	8	154	365	150	204	5	8
Human health and social work activities	149	756	1750	44	104	2376	6121	472	1209	8	23
Arts, entertainment and recreation	20	302	261	20	45	5335	11843	283	479	1	2
Other services	69	98	259	6	13	353	1238	297	516	4	8

Table 2. Selected variables from PITEC database

PITEC Variables	Function type	Explanation
$SOURCE_i$ (i=1,…,11)	Cat.	Importance of information sources while innovating (internal sources, competitors, clients, universities, scientific journals, …)
$OBJECTIVE_i$ (I=1,..,10)	Cat.	Importance of some objectives (increase market share, increase penetration, cost savings, increase of quality, increase flexibility, increase capacity, energy savings, material savings,…) while innovating

Categorical variables: 1=High; 2=Medium 3= Low 4=Not considered or not important.

Table 3. Factor analysis (Varimax rotated factor scores)

	Factors			
Factor name and items	**Fac1**	**Fac2**	**Fac3**	**Fac4**
Eigenvalue	6.88	2.13	1.69	1.00
Percent Variance Explained	40.45	12.53	9.95	5.89
Product Orientation (A = 0.881)				
Objet4	.836			
Objet3	.822			
Objet1	.807			
Objet5	.715			
Objet2	.622			
Process Orientation (A = 0.883)				
Objet8		.815		
Objet10		.801		
Objet9		.799		
Objet7		.754		
Objet6		.723		
Institutional Information Sources (A = 0.842)				
Fuente7			.881	
Fuente6			.828	
Fuente8			.824	
Fuente5			.617	
Market Information Sources (A = 0.747)				
Fuente4				.726
Fuente2				.717
Fuente3				.650

Total % of variance explained 68,82. KMO 0,902 sig .000

characteristics in classifying firms attending to their environmental orientation while innovating. The discriminant analysis will check if the selected variables can accurately predict the groups attending the environmental orientation of the firm.

Table 4 shows the coefficients for the discriminant function, as well as Wilk's lambda and the mean scores for each of the two groups (Hair *et al.,* 1998). The discriminant function maximizes the differences between the values of the dependent variable, so it differentiates a case into categories of the dependent based on the values on the independents.

RESULTS & DISCUSSION

The discriminant function was statistically significant (see Table 4 part A) based on Wilk's lambda ($p<0.001$). The structure coefficients show the correlations between each independent variable and the discriminant scores associated with a given discriminant function. They are used to describe how closely a variable is related to each function. The coefficient for *process orientation* while innovating was the highest and substantially higher than the other coefficients in the discriminant function. The negative mean value for oriented companies is due to opposite relation between categorical variables (1=high to 4=no relevant) and dichotomous variables (1=Yes; 0=No). Then, highly environmentally oriented firms (EOWI_mod=1) have lower scores (negative scores) than not oriented firms. Consequently, the higher the Process Orientation, the lower the factor score (negative) and, more negative the resulting

Table 4. Standardized canonical discriminant function coefficients and groups means for firms

A. Standardized canonical discriminant function coefficients and group means			
		Function 1	
Scale	Product orientation while innovating	.570	
	Process orientation while innovating	.793	
	Instutitutional Information Sources	.529	
	Market Information Sources	.261	
	Wilks' lambda	0.679 p<0.001	
Mean scores	Group 1	.630	
	Group 2	-.749	
B. Classification results for original cases. Overall accuracy: 75.2%			
Predicted group	Group 1	Group 2	Total
Actual group			
Group 1	**3121 (74.84%)**	1049 (25.16%)	4170
Group 2	854 (24.32%)	**2658 (75.68%)**	3512
Total	3975	3707	7682
C. Classification results for cross-validated cases. Overall accuracy: 75.2%			
Predicted group	Group 1	Group 2	Total
Actual group			
Group 1	**3119 (74.8%)**	1051 (25.2%)	4170
Group 2	854 (24.32%)	**2658 (75.68%)**	3512
Total	3973	3709	7682

Maximum chance criterion= 54.3 %; Proportional chance criterion= 50.36 %; Hair et al. Criterion= 62.9 %

discriminant function will be (as discriminant coefficients are positive). Note that, as all coefficients are positive, the directionality of all the independents is equal, so, a negative value of the discriminant function reflects a highest chance to be environmentally oriented. Then, we can conclude that firms that are Process and/or Product Oriented, and that rely on Market, Institutional or Technical information sources while innovating are more likely to be environmentally oriented.

However, we obtained a statistically significant function, it is also very important the performance of the function in classifying companies into their original groups for calibration and validation samples. We present the classification results based on the discriminant function in Table 4 (part B. Rows show the classification based on the variable EOWI_mod, while columns show the predicted group based on the discriminant function. Correct predictions (in bold) align in the main diagonal, while the other cells represent the misclassified firms.

Taking into account the group sizes, 4170 not oriented (54,3%) and 3512 oriented (45,7%), the proportional chance criterion (50.36%) can be used to assess the predictive accuracy of a discriminant model (Morrison, 1969; Perreault *et al.,* 1979; Huberty, 1984; Hair *et al.,* 1998). We can also compare our model with the maximum chance criterion (probability of being in the group with the largest sample size 54.3 %). However, Hair et al. (1998) recommended that classification accuracy should be at least 25% higher than the proportional chance criterion for a good discriminant model (1.25x 50.36% = 62.9%). In our case, the classification accuracy for the estimated model was 75.2%, which is considerably higher than the suggested threshold of Hair et al. (1998). Further, cross-validation results (Table 4) validated the estimated discriminant model (Hair *et al.,* 1998).

Our model is quite proficient in classifying firms attending to the environmental orientation, which indicates that these variables would be particularly useful to discriminate between high and medium oriented and low or not oriented firms.

CONCLUSION

The aim of this paper was to empirically determine which are the common characteristics that the most environmental oriented innovative firms have. We empirically test the predictive relevance and the impact of certain characteristics in determining the environmental orientation of companies. We collected data from PITEC database which provided conclusions about the characteristics that determine the environmental orientation of the firm. More specifically,

process and product orientation while innovating was reveled as crucial aspects in determining the environmental orientation of the firms. Moreover, results showed the lower relative impact of *the importance of market, institutional and technical information sources*. Then, eco-innovative companies are highly concern about cost reduction, about developing new products and markets, and very influenced by relevant information sources in their innovation process. That is, firms that are concerned about internal and external operational improvement (Zhu et al. 2006, Dekker et al. 2012) and that rely on the information from the competitors, the suppliers and the customers are also more sensitive to introduce environmental innovations.

Based on these results, we can determine which company's behavior has to be promoted to get companies to focus on environmental aspects. The exploratory factor analysis results, the high factor loading and the high reliability scores for the identified factors provide validity for the results presented earlier in this paper and also give confidence in using these scales in future researches for additional analysis. Further, our study serves to model which firm's characteristics determine the environmental orientation of the firm. We consider very encouraging that the model could classify about 75.2% of the responses correctly, highlighting its ability to differentiate extreme orientations. This research confirms previous findings (Segarra-Oña et al. 2011), showing highly polarized positions in environmental aspects.

Overall, we believe that we have managed to address a number of relevant and important issues, which should be of interest for future research. However, there are a number of limitations of our study. We have used direct relations between the constructs and the environmental orientation in our study, while we can expect relations between constructs or indirect effects between constructs and environmental orientation. Future studies should try to deep in the analysis with other techniques such as structural equation modeling to address properly direct and indirect effects of each construct. Another limitation of the study is due to the self limitations of the data. Although results can be extrapolated due to robustness of the statistical analysis, data only comes from Spanish Statistics Department, replicating the study on Europe or more countries as USA in America or South Korea in Asia would give a wider relevance to the results.

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