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Clustering product innovators: a comparison between conventional and green product innovators

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Abstract: This paper aims at analysing firms implementing new products. Based on a cluster analysis, three types of manufacturers have been identified representing different types of product innovators according to the competitiveness factors important for their business, environmentally sensitive new products, and a performance indicator, such as the share of turnover from new products.

Key words: EMS, Manufacturing companies, Product innovation, Environmental impact, Spain.

1. Introduction

According to the United Nations' approach on sustainable development goals (UN, 2016) a sustainable consumption and production helps to achieve overall development plans, reduces future economic-, environmental- and social costs, strengthens economic competitiveness and reduces poverty. Innovation appears as one possible action in this direction. New products, in general, and new products sensitive towards improving environmental impact, in particular, can make a considerable contribution to the society. Some examples of improved environmental impact refer to: reduction of health risks when in use, extended product lifetime, reduction of energy consumption when in use, reduction of environmental pollution when in use, easier to maintain or to retrofit, and improved recycling, redemption or disposal properties.

Recently, a review specifically focusing on green product innovation published by Dangelico (2016) makes an important contribution by analysing 63 studies in the field. It is affirmed that "with regard to capabilities in common with conventional new product development, it would be interesting for future research to investigate whether there is a difference between GPI development and conventional new product development in terms of relative importance of these capabilities and in terms of their extent of use" Dangelico (2016:574).

The analysis responds not just to an academic goal and a broader scientific call verbalised by Dangelico (2016), but also to a global institutional priority as the Europe 2020 strategy targeting improved environmental impacts and boosted innovation. Moreover, using three countries' data we contribute to other –few– data-driven approaches that combine environmental and innovation policy, translated to companies' daily operations.

2. Objectives

The objective of this exploratory work is to characterise patterns of product innovative manufacturing companies distinguishing between green product innovators (GPI) and conventional product innovators (CPI). For this purpose, we proceed with a cluster classification process. More concretely, we focus our

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analysis on firms that affirm having implemented product innovations in the last three years. We complement this aspect with a further detail, namely product innovators whose new products contemplate an improvement of the environmental impact by either using or disposing of them.

3. Literature review

3.1. Conceptual delimitation and definition of green product innovation

A product innovative firm has been defined as the one that has implemented a new or significantly improved product during the period under review according to the Oslo Manual (OECD & Eurostat, 2005).

Complementing this definition, and for the purpose of this study, green product innovation is defines as the design, production and implementation of new or significantly improved products that have a positive impact on the environment when in use or when disposing of them.

Different authors use a variety of terms to describe new products with environmental implications that are synonyms and combinations of eco, eco-friendly, ecological, green, sustainable, environmental and environmental-friendly with innovation, product innovation, new product (Dangelico, 2016) (Gerstlberger *et al.,* 2014).

“Green product” and “environmental product” are used commonly to describe those that strive to protect or enhance the natural environment by conserving energy and/or resources and reducing or eliminating the use of toxic agents, pollution, and waste (Ottman *et al.,* 2006).

Pujari refers to the action to develop and market new products that address environmental issues. Most of the sustainable innovation in NPD relates to incremental or evolutionary innovation (Pujari, 2006).

Product innovations with environmental implications should fulfil two goals simultaneously, namely improvement of environmental impact and obtaining commercial performance (Gerstlberger *et al.,* 2014).

Holistic approaches to model design should prevail, as the ones advocated by the 6Rs (redesigning, reusing, remanufacturing, recovering, recycling, and reducing) and products with multiple life cycles (Thomé *et al.,* 2016).

3.2. Determinants of green product innovation

Some authors tried to identify if and up to what degree, determinants of product innovation apply to green new product manufacturers. In the case of specific drivers, they also measured their effect (Edison *et al.,* 2013; Keupp *et al.,* 2012).

Other, grouped the factors in internal/external or by nature as technological capabilities, internal integrative capabilities, external integrative capabilities or marketing capabilities (Dangelico, 2016).

4. Methods

Our research is based on data from the European Manufacturing Survey (EMS), 2015 edition. EMS is coordinated by the Fraunhofer Institute for Systems and In-novation Research (ISI, 2017) and it is the largest European survey in manufacturing activities to date. It aims to collect data relative to the modernisation of manufacturing processes and practices. It complements existing innovation surveys by including latest trends among the topics of interest. Further elaborating in this direction, environmental aspects (energy and material saving technologies and practices, energy consumption, their sources and use) have been considered and updated since 2009 and on-going. Our study includes data from EMS Spain, France and Portugal, formed by 194 firms’ responses. The survey was performed on manufacturing firms having at least 20 employees.

Developed jointly by Columbia University and Yale University, the Environ-mental Performance Index (EPI) ranks 180 countries on 20 performance indicators, which track performance and progress on two broad objectives: protection of human health and protection of ecosystem (Hsu and Zomer, 2016). According to the latest edition all three countries are part of the top 10 of the 2016 EPI rankings, Spain ranks 6th with an EPI score of 88.91, Portugal is at position 7 with a score of 88.63, while France situates at the 10th position scoring 88.2 in the ranking where Finland has taken the top spot with the maximum possible score of 90.68. All countries included in the present analysis have high EPI performance

Table 1. Technical details for the Spanish, French and Portuguese subsamples of the European Manufacturing Survey 2015 edition.

Universe:	Spanish, French and Portuguese manufacturing firms with at least 20 employees CNAE 2009; codes from 10 to 33.
Unit of analysis:	Establishment
Sample:	194 firms: (ES) 100; (FR) 61; (PT) 33
Confidence margin:	95%
Variance:	Maximum indetermination p=q=50%
Documentation	Paper (8 pages questionnaire) + Return envelope + Presentation letter
Channel	Postal
Fieldwork:	May to September 2015
Reference period:	2012-2014; 2014
Institution:	Dept. of Business Administration and Product Design, University of Girona – Girona (Spain) University of Lyon, IAE Lyon, Lyon (France) Dept. of Mechanical and Industrial Engineering, Universidade Nova de Lisboa, Caparica (Portugal)
Data base recording and creation:	ES: Outsourced to DAP GmbH – Passau (Germany) FR, PT: institution
Sample distribution:	By size and sector of activity
By 'Green product innovators':	'Conventional product innovators': 55 (ES) 34; (FR) 15; (PT) 6 'Green product innovators': 60 (ES) 23; (FR) 25; (PT) 12

indicators with a better performance than countries in their region (Europe), globally.

Technical details of the utilized subsamples are shown in Table 1.

From the existing distances in a set of variables, groups of cases have been created by a K-means cluster analysis. Variables were the ones in our sample representing the firm's competitive factors significance ranked from 1 (most important) to 6 (less important): 'product price', 'product quality', 'innovative products' and 'customization to customers' demands'. Other two competitive factors variables, 'Adherence to delivery/short delivery times' and 'Service', were not considered to obtain the clusters because they are not strictly linked with product innovation.

According with the obtained clusters of product innovators, a frequencies analysis for variables representing the technological level of firms and product development and manufacturing aspects and innovation drivers are performed. Other descriptive analysis have been elaborated from variables such as companies' personnel distribution and qualification, company size (normalized with logarithms), exportation index and strategic costs as percentage of the turnover in 2014, like energy, payroll or R&D costs.

The group of companies affirming their new products lead to an improvement of their environmental impact during their use or disposal - differentiating them from the rest of conventional product innovators- is called 'green product innovators'. Both groups are analysed separately to compare results and detect differences among clusters, being this the main objective of the present study.

5. Results

The cluster analysis results in three coherent groups of manufacturing establishments distinguishing between product innovators competing by i) customization, ii) price, and iii) innovation, as shown in Figure 1 and Table 2. In these three cases, companies also compete by quality as well, but we label groups with the most relevant competitiveness factor that differentiates among the groups. The differences are also reported according the presence of firms whose new products improve their environmental impact.

Table 2. Product innovators inside each obtained cluster.

	Cluster 1 Customization	Cluster 2 Price	Cluster 3 Innovation
	N	N	N
Conventional	22	19	13
Green	23	15	20
Total	45	34	33

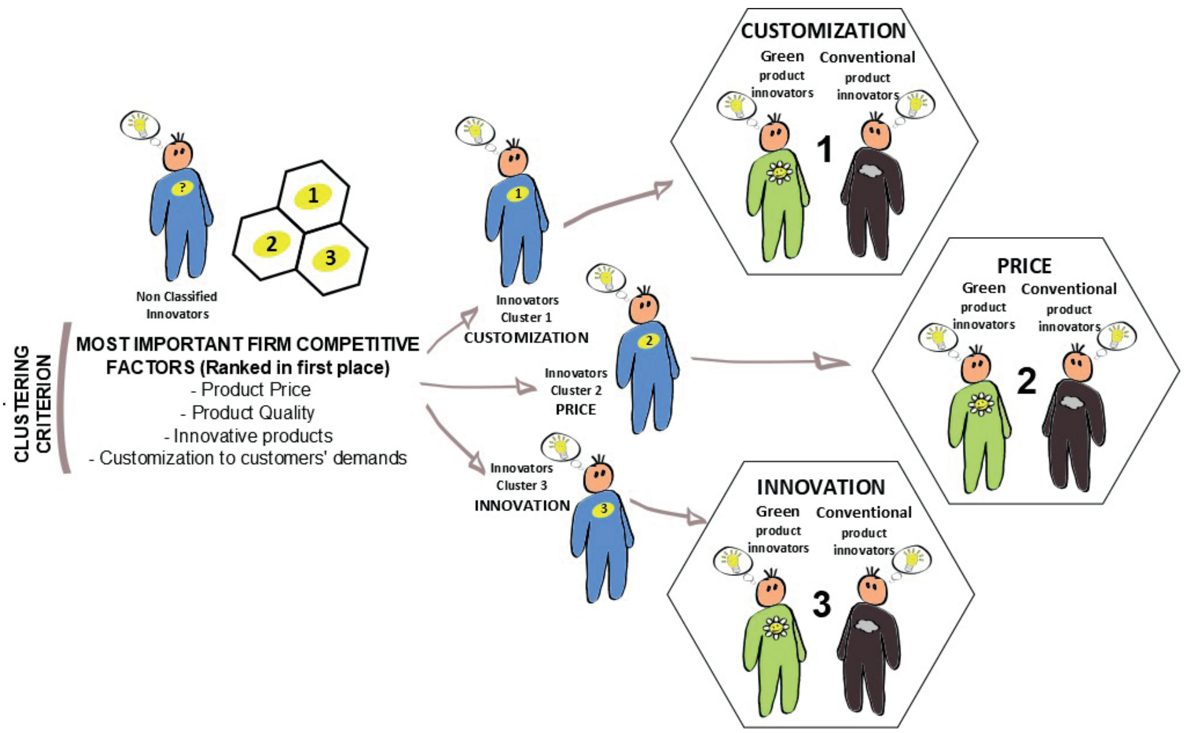

Figure 1. Clustering methodology for product innovators (*Source*: Own elaboration).

5.1. Technological level, product development and product manufacturing characteristics

Table 3 presents a frequency analysis of companies' technological level and product development and manufacturing characteristics for the three clusters, differentiating also between green and non-green/ conventional product innovators.

Technological level refers to the Eurostat aggregation of the manufacturing industry according to technological intensity based on firm's NACE code Rev.2.

It is observable that the majority of product innovative firms competing by innovation are GPI. Likewise, inside the cluster competing by customization, companies are notably more GPI than CPI except in the case of the low technological intensity ones that are clearly more CPI.

Low technological intensity firms competing by price, are 87.5% CPI, and more equilibrated for both groups in the case of Low-med, Med-high and High technological intensity ones.

Regarding the analysed manufacturing characteristics, we obtain the results for product development customization level, manufacturing customization level, batch or lot sizes, and product complexity level. A summary of the most interesting highlights regarding GPI is presented below.

5.1.1. Manufacturing characteristics for product innovators in "Customization" cluster

Inside the cluster of innovators competing by Customization, companies with a high product development customization level are more GPI than CPI. No GPI can be found among manufactures that "make to order", that is the highest manufacturing customization level. The share of GPI increases as the lot/batch sizes decrease being a 78% of the firms in the case of manufacturing unit by unit. Mainly in high but also in low product complexity level the percentage of GPI is higher.

5.1.2. Manufacturing characteristics for product innovators in "Price" cluster

In high product development customization level, the percentage of GPI competing by price is lower than the CPI one (40% *vs*. 60%). Regarding to the manufacturing customization degree, GPI represent a higher percentage in the group of companies that produce with a "make to stock" system. Innovators producing in high lot/batch sizes are, mostly, CPI (66%). The percentage of GPI increases as it increases the product complexity level, being a 55% in the case of companies that produce highly complex products.

5.1.3. Manufacturing characteristics for product innovators in "Innovation" cluster

Product innovative firms competing by innovation that offer a medium or high product development customization level are mostly GPI in a 69% and a 55% respectively. In product manufacturing customization level, CPI represent only a 33% of the companies that assemble to order and no one of them make to stock or make to order. GPI represents the majority of innovators producing big size and unitary lot/batch sizes with a 70% and 88% respectively. In all product complexity degrees, GPI represent the majority of firms inside this cluster with a very similar percentages: 60% for high, 61% for medium and 60% for low complexity.

5.2. Main origins of impulses/ideas for innovation

As it is observed in Table 4 and more easily in Figure 2, some differences between Conventional and Green product innovators appear regarding the

Table 3. Frequency analysis for firms' technological level, development and manufacturing customization, lot size and product complexity.

			Cluster 1 CUSTOMIZATION		Cluster 2 PRICE		Cluster 3 INNOVATION	
			N	[%]Column	N	[%]Column	N	[%]Column
Tech_Level (from NACE rev2)	Low	Conventional	9	64.3 %	7	87.5 %	6	42.9 %
		Green	5	35.7 %	1	12.5 %	8	57.1 %
	Med-low	Conventional	7	41.2 %	6	50.0 %	4	36.4 %
		Green	10	58.8 %	6	50.0 %	7	63.6 %
	Med-high and High	Conventional	6	42.9 %	6	42.9 %	3	37.5 %
		Green	8	57.1 %	8	57.1 %	5	62.5 %
Product development customization level	Low	Conventional	1	100.0 %	1	50.0 %	1	50.0 %
		Green	0	0.0 %	1	50.0 %	1	50.0 %
	Med	Conventional	8	57.1 %	9	52.9 %	4	30.8 %
		Green	6	42.9 %	8	47.1 %	9	69.2 %
	High	Conventional	13	46.4 %	9	60.0 %	8	44.4 %
		Green	15	53.6 %	6	40.0 %	10	55.6 %
Manufacturing customization level	Make to order	Conventional	1	100.0 %	0	0.0 %	0	0.0 %
		Green	0	0.0 %	0	0.0 %	1	100.0 %
	Assemble to order	Conventional	5	45.5 %	3	50.0 %	3	33.3 %
		Green	6	54.5%	3	50.0 %	6	66.7 %
	make to stock	Conventional	2	40.0 %	3	42.9 %	0	0.0 %
		Green	3	60.0 %	4	57.1 %	3	100.0 %
	No production	Conventional	12	46.2 %	13	61.9 %	10	52.6 %
		Green	14	53.8 %	8	38.1 %	9	47.4 %
Batch or lot sizes	Unit	Conventional	2	22.2 %	2	50.0 %	1	12.5 %
		Green	7	77.8%	2	50.0 %	7	87.5 %
	Med size	Conventional	13	52.0 %	9	50.0 %	9	60.0 %
		Green	12	48.0 %	9	50.0 %	6	40.0 %
	Big size	Conventional	7	63.6 %	8	66.7 %	3	30.0 %
		Green	4	36.4 %	4	33.3 %	7	70.0 %
Product complexity level	Low	Conventional	4	44.4 %	2	100.0 %	2	40.0 %
		Green	5	55.6 %	0	0.0 %	3	60.0 %
	Medium	Conventional	14	56.0 %	11	57.9 %	7	38.9 %
		Green	11	44.0 %	8	42.1 %	11	61.1 %
	High	Conventional	4	36.4 %	5	45.5 %	4	40.0 %
		Green	7	63.6 %	6	54.5 %	6	60.0 %

origin of impulses/ideas they declared to use for their innovations. These differences are also particular for every cluster and they could not be appreciated in a general, non-clustered analysis.

Green Product innovators competing by customisation find inspiration for new product development in the R&D/engineering department and the customer service section. Complementary, ideas for NPD also come from the customer/user.

The pattern is partially similar for low cost product innovators who find their main sources of inspiration in the R&D/engineering department, the customer/ user and CEO/management (in decreasing order).

Green Product innovators competing by innovation are mainly inspired by the customer/user followed by the CEO/management and third, in the R&D/ engineering department.

5.3. Companies' characteristics

Since companies' characteristics are important determinants of innovation, it is interesting to observe the results showed in Table 5, Table 6 and Table 7.

5.3.1. Personnel

Closely related to the previous section qualification level of employees is often related to companies' capacity to innovate. The results in Table 5 show that the highest level of qualification is characteristic to cluster of firms following a strategy based on price, followed by those firms differentiating from competitors through innovation, and last the ones focusing on customization. When comparing traditional product innovators to green product innovators, major differences in favour of GPI showing higher or equal values to the other ones, can be observed in the "low cost" category. Differences are minor and do not exceed 0.2 points.

As observed in the previous section both internal to the firm and external sources of ideas/ impulses for innovation can be detected. Focusing the attention on the distribution of employees in the different key functional areas of the firm the analysis shows the following: i) indifferently of the cluster, research & development employees are more numerous in GPIs, ii) Cluster 2 shows differentiated characteristics in the sense that GPIs that belong to this have higher concentration of employees in manufacturing, assembly and other areas, iii) the major difference

Table 4. Frequency analysis for main origins of ideas/impulses for innovation by cluster.

		Cluster 1 CUSTOMIZATION			Cluster 2 PRICE			Cluster 3 INNOVATION		
		N	[%] Share of Companies by cluster	[%] companies by origin of ideas	N	[%] Share of Companies by cluster	[%] companies by origin of ideas	N	[%] Share of Companies by cluster	[%] companies by origin of ideas
R&D / engineering	Conventional	11	32.4 %	20.0 %	15	44.1 %	27.3 %	8	23.5 %	14.5 %
	Green	17	47.2 %	28.3 %	12	33.3 %	20.0 %	7	19.4 %	11.7 %
Production	Conventional	6	37.5 %	10.9 %	7	43.8 %	12.7 %	3	18.8 %	5.5 %
	Green	7	63.6 %	11.7 %	1	9.1 %	1.7 %	3	27.3 %	5.0 %
Customer service	Conventional	5	35.7 %	9.1 %	2	14.3 %	3.6 %	7	50.0 %	12.7 %
	Green	12	50.0 %	20.0 %	5	20.8 %	8.3 %	7	29.2 %	11.7 %
CEO/ management	Conventional	10	43.5 %	18.2 %	8	34.8 %	14.5 %	5	21.7 %	9.1 %
	Green	11	39.3 %	18.3 %	8	28.6 %	13.3 %	9	32.1 %	15.0 %
Customer or user	Conventional	17	48.6 %	30.9 %	8	22.9 %	14.5 %	10	28.6 %	18.2 %
	Green	12	34.3 %	20.0 %	9	25.7 %	15.0 %	14	40.0 %	23.3 %
Supplier	Conventional	2	40.0 %	3.6 %	1	20.0 %	1.8 %	2	40.0 %	3.6 %
	Green	2	50.0 %	3.3 %	0	0.0 %	0.0 %	2	50.0 %	3.3 %
Research institutions, universities	Conventional	0	0.0 %	0.0 %	3	100.0 %	5.5 %	0	0.0 %	0.0 %
	Green	3	50.0 %	5.0 %	2	33.3 %	3.3 %	1	16.7 %	1.7 %
Consultancy	Conventional	1	33.3 %	1.8 %	1	33.3 %	1.8 %	1	33.3 %	1.8 %
	Green	0	0.0 %	0.0 %	1	50.0 %	1.7 %	1	50.0 %	1.7 %

Figure 2. Manufacturing firm's main origin of ideas/impulses for innovation by clusters.

Table 5. Descriptive analysis for the personnel qualification [1-5] by cluster.

		Cluster1 CUSTOMIZATION		Cluster 2 PRICE		Cluster 3 INNOVATION	
		μ	σ	μ	σ	μ	σ
Global Personnel qualification [1-5] 1 for lowest and 5 for highest (PhD and Master)	Conventional	2.6	0.5	3.0	0.6	2.9	0.5
	Green	2.8	0.4	3.1	0.5	2.9	0.6

in percentage points can be observed in Cluster 3, the results showing customer service as the function concentrating more employees in Conventional product innovators than in GPIs (22.3 *vs*. 10.3).

5.3.2. Size, costs and economic parameters

The results for GPI and CPI regarding different variables representing company size, costs and economic performance are showed in Table 7.

The differential of turnover as a basic financial performance indicator does not show any significant difference between GPI and CPI. The same similarities between green and conventional innovators appear in variables as number of employees, payroll costs or relative percentage of energy costs for all the clusters.

The most outstanding results appear in the cluster of firms following a strategy based on price regarding

Table 6. Descriptive analysis for the personnel distribution inside each company areas in % by cluster.

		Cluster1 CUSTOMIZATION		Cluster 2 PRICE		Cluster 3 INNOVATION	
		μ	σ	μ	σ	μ	σ
Research & Development	Conventional	3.7	3.9	6.9	6.6	3.8	5.7
	Green	6.3	4.6	7.4	5.3	5.4	7.7
Configuration, design	Conventional	3.8	5.9	7.3	8.1	3.0	3.4
	Green	8.5	8.9	4.2	7.0	4.6	4.9
Manufacturing and assembly	Conventional	69.8	16.9	57.9	22.3	61.6	28.6
	Green	61.0	14.9	65.3	12.0	58.7	19.5
Customer service	Conventional	3.3	4.3	7.8	8.1	22.2	32.2
	Green	6.0	5.0	6.6	4.6	10.3	9.8
Other	Conventional	20.7	14.1	22.3	14.7	15.5	11.5
	Green	19.3	11.7	22.7	23.3	20.6	12.4

Main differences

Table 7. Descriptive analysis for company size, strategic costs and exportation by cluster.

		Cluster1 CUSTOMIZATION		Cluster 2 PRICE		Cluster 3 INNOVATION	
		μ	σ	μ	σ	μ	σ
Ln (Annual turnover 2014)	Conventional	3.4	1.4	3.3	1.5	3.1	1.6
	Green	3.1	1.3	3.7	2.2	2.9	1.2
Ln (Number of employees 2014)	Conventional	4.9	1.1	4.4	1.0	4.2	1.8
	Green	4.3	1.0	5.2	1.5	4.5	1.1
% of R&D relative to incomes 2014	Conventional	3.0	4.0	8.8	8.2	3.3	4.9
	Green	2.9	2.6	4.9	5.4	4.0	3.7
Payroll costs as % of turnover 2014	Conventional	20.8	7.7	23.0	12.6	22.9	17.1
	Green	23.1	11.1	25.3	16.0	24.5	12.2
% Products sold abroad	Conventional	44.1	30.7	48.1	37.0	45.2	29.1
	Green	41.4	30.0	63.0	23.2	40.4	32.2
Total energy costs as % of turnover 2014	Conventional	2.9	4.2	3.2	2.5	6.6	10.8
	Green	4.5	7.8	4.0	3.5	3.8	4.0

Main differences

variables representing relative R&D expenditures and exportation.

In this cluster, we can observe GPI declare, in average, less percentage of R&D expenditures relative to incomes than CPI. On the other hand, GPI declare they sell more percentage of products abroad than CPI.

6. Conclusions

The paper provides recent objective data regarding product innovation and sustainability in Southwestern European manufacturing firms.

Introducing clusters, hidden aspects that differentiate green product innovators from conventional ones it can be observed. These differences can not be seen in an overall analysis.

Describing and differentiating both groups of GPI and CPI, our findings could be insights for policy makers to identify drivers and factors that impulse this type of desirable innovations or barriers that difficult their emergence.

It could be informative for manufacturing practitioners in terms of characteristics and opportunities of green new product innovation.

7. Contribution

The present work aims to complement previous descriptive analysis on product innovation and sustainability in manufacturing firms using the same methodology (Pons *et al.,*, 2013; Palčič *et al.,*, 2013; Pons *et al.,*, 2017), but adding a layer of complexity achieved by the cluster analysis as well as presenting recent data on a topic situated at the intersection of two crucial societal issues, namely environment and innovation.

While manufacturers can find greening opportunities in both process and products, the product option remains one of the most perceived and visible alternative for stakeholders, being that the backbone of the present contribution.

8. Future research

The study could be expanded to 10 countries evaluating country effects. It would be interesting to observe if different environmental policies, regulations or green cultures affects to the results.

A more sophisticated analysis of performance (environmental and economic) in relation to these GPI should be made in the future.

In the framework of a wider sample, it could be possible to compute a variable capturing different degrees of greenness considering, for example, the extent of implementation of green product innovations.

Models testing relationships between drivers/ barriers, company characteristics and green product innovation and/or performance, have to be further studied.

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