

# A taxonomy of eco-innovation types in firms

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## A taxonomy of eco-innovation types in firms

### ABSTRACT

Eco-innovations, or innovations which reduce the environmental impact of production and consumption activities, are generally considered key in the transition towards more sustainable economies and societies and help mitigate the traditional dichotomy between competitiveness and sustainability. There are different types of eco-innovation, but they are generally considered complementary, and all play a role in sustainable transitions. However, despite abundant research on eco-innovation, a precise conceptualization of eco-innovation types, which takes into account its multifaceted character, is missing. The aim of this paper is to provide a taxonomy of eco-innovation types which takes into account its many different features and dimensions. It draws on a survey of 197 Spanish industrial SMEs which developed or adopted an eco-innovation in the observed period. The statistical analyses (cluster analysis) reveal the existence of five eco-innovation types: systemic, externally driven, continuous improvement, radical (technology-push initiated) and eco-efficient.

**Key words:** Eco-innovation; Cluster Analyses, Spain, small and medium-size enterprises.

### RESUMEN

Las eco-innovaciones, o innovaciones que reducen el impacto ecológico de las actividades de producción y consumo, se consideran generalmente fundamentales en la transición hacia economías y sociedades más sostenibles y contribuyen a mitigar la dicotomía tradicional entre competitividad y sostenibilidad. Existen diferentes tipos de eco-innovación, pero generalmente se consideran complementarios y todos juegan un papel en las transiciones sostenibles. Sin embargo, a pesar de la abundante investigación sobre eco-innovación, falta una conceptualización precisa de los tipos de eco-innovación, que tiene en cuenta su carácter multifacético. El objetivo de este estudio es proporcionar una taxonomía de tipos de eco-innovación que tenga en cuenta sus muchas características y dimensiones diferentes. Se basa en un estudio de 197 PYMEs industriales españolas que desarrollaron o adoptaron una eco-innovación en el período observado. Los análisis estadísticos (análisis de conglomerados) revelan la existencia de cinco tipos de eco-innovación: sistémica, de respuesta a estímulos externos, de mejora continua, radical (iniciada por el impulso de la tecnología) y eco-eficiente.

**Palabras clave:** Eco-innovación; Análisis de conglomerados, España, pequeña y mediana empresa (PYME).

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## 1. Introduction

**E**co-innovations, or innovations which reduce the environmental impact of production and consumption activities, are generally considered key in the transition towards more sustainable economies and societies and help mitigate the traditional dichotomy between competitiveness and sustainability.

On the other hand, it has been acknowledged in the literature that different kinds of eco-innovations contribute differently to sustainable transitions, but that they all may have a (complementary) role to play in this context (Carrillo-Hermosilla et al., 2009).

However, there is no commonly agreed taxonomy of eco-innovation types in the literature.

Different types of eco-innovations and eco-innovators have been mentioned in the literature: e.g. large vs. small eco-innovators (De Marchi, 2012; Del Rio et al., 2017; Kammerer, 2009; Kesidou and Demirel, 2012; Rave et al., 2011; Walz, 2011), new and old ones (Del Rio et al., 2017; Horbach, 2008; Rave et al., 2011; Veugelers, 2012; Wagner, 2007), process vs. product eco-innovation (Belin et al., 2011; Frondel et al., 2008; Rave et al., 2011; Rehfeld et al., 2007; Rennings et al., 2006; Veugelers, 2012) and new-to-the-firm and new-to-the-market eco-innovations (Del Rio et al., 2017; Rave et al., 2011). Their relevance in sustainable transitions is different, but they are often regarded as complementary (Carrillo-Hermosilla et al., 2009). In addition, the drivers of those different types are also likely to be different. Many papers refer to the abstract and generic dichotomy of “radical” vs. “incremental” eco-innovation, a reflection of the general innovation literature. Such distinction takes into account the environmental impacts of the innovation and often the level of rupture with existing products and processes. However, as shown by Carrillo-Hermosilla et al. (2010) and Kiefer et al. (2017), eco-innovations have many aspects or dimensions beyond their distinct impact on the environment, which could contribute to their classification in different “types”.

A novel approach is provided by Carrillo-Hermosilla et al. (2010) and Kiefer et al. (2017), who try to derive the characteristics and dimensions of eco-innovations. Kiefer et al. (2017) quantitatively explore the underlying structure of the eco-innovation concept based on the current knowledge of those characteristics and advance on the quantification of a four-dimensional framework proposed in the past by Carrillo-

Hermosilla et al. (2010). The authors find that the identified characteristics shape an underlying structure of eco-innovations along four dimensions (design, user, product-service and governance). The analysis identifies the factors which make up these dimensions, allowing a characterization of eco-innovations with considerably less complexity. In this paper we draw on these results to derive a taxonomy of eco-innovation types, whose drivers can be analysed in future research.

Therefore, the aim of this paper is to provide a taxonomy of eco-innovation which takes into account its many different features and dimensions. It draws on a survey of 197 Spanish industrial SMEs which developed or adopted an eco-innovation in the observed period. The statistical analyses (cluster analysis) reveal the existence of five eco-innovation types (systemic, externally driven, continuous improvement, radical (technology-push initiated) and eco-efficient).

Accordingly, the paper is structured as follows. The next section provides the theoretical framework. The methodology is described in section 3. The results of the analysis are provided and discussed in section 4. Section 5 concludes.

## 2. Theoretical framework

The theoretical framework is based on the four dimensions of eco-innovation proposed in Carrillo-Hermosilla et al. (2010). The framework proposed by Carrillo-Hermosilla et al. (2010) was chosen among the alternatives, because of its impact on the literature, being cited by numerous researchers (Boons and Lüdeke-Freund, 2013; Ghisetti et al., 2015, 2013; Marzucchi and Montresor, 2017, amongst others) and because the objective of this research was to take our framework to the quantitative level. This empirical advance of the framework is in line with the literatures' call for a better empirical understanding of the phenomenon of eco-innovation (Xavier et al., 2017). As stressed in the recent review of the literature by Xavier et al. (2017), "the understanding of the characteristics and particularities of the eco-innovation process is crucial to manage it more efficiently" (op.cit., p.2).

The four-dimensional framework proposed by Carrillo-Hermosilla et al. (2010) is considered suitable for the purpose of this article. It allows the collection of detailed information within each dimension, while simultaneously providing a clear structure for

the adequate simplification of the many characteristics at stake. A brief description of each dimension is provided in table 1 (see Carrillo-Hermosilla et al., 2010 for further details).

**Table 1. Describing the dimensions of eco-innovation in Carrillo-Hermosilla et al. (2010).**

Dimension	Description
Design	<p>From an environmental perspective, there are two different design rationales to innovations: redesigning human-made systems to reduce their environmental impacts, versus the search for minimization of those impacts. When these two perspectives are combined with the incremental/radical nature of technological change, three different approaches can be proposed to identify the role and impacts of eco-innovations:</p> <ul style="list-style-type: none"> <li>• <u>Component addition</u>: development of additional components to minimize negative impacts without necessarily changing the processes/system that generate those impacts, as with “end-of-pipe” technologies.</li> <li>• <u>Sub-system change</u>: eco-efficient solutions and the optimization of sub-systems, leading to a reduction of negative environmental impacts.</li> <li>• <u>System change</u>: involves the redesign of systems towards eco-effective solutions, remodeling the environmental impacts on the ecosystem and society at large.</li> </ul>
User	<p>The success of any innovation depends on the economic demands in the target market. Additionally, eco-innovations address sustainability issues. Towards this aim, companies can engage in user-producer interactions. But this user-producer interaction perspective should be complemented with the consideration of the influence of market demand on new product development, as stressed by Pujari (2006). Not only do users apply the eco-innovation, but they might also identify future eco-innovation potentials. These interactions can generate a clear understanding of the users’ demands to be addressed by the eco-innovation. Two subdimensions can be distinguished in this dimension:</p> <ul style="list-style-type: none"> <li>• <u>User development</u>: Identification of users that are capable of providing valuable inputs in innovation projects.</li> <li>• <u>User acceptance</u>: Understanding users’ needs and wants enhances the market success of sustainable solutions.</li> </ul>
Product service	<p>To be radical, product-service innovations require a redefinition of the product-service concept and how it is provided to customers. A “product-service system” embedded in sustainable business models delivers a “function” to the customer, consisting of combinations of products and services, that are capable of “jointly fulfilling users’ needs”. Supply chain/network perspectives include production, delivery, consumption and disposal:</p> <ul style="list-style-type: none"> <li>• <u>Product service deliverable</u> consists of changes in the product/service and value delivered and changes in the perception of the customer relation.</li> <li>• <u>Product service process</u> consists of changes in the value-chain process and relations that enable the delivery of the product-service and value capture.</li> </ul>
Governance	<p>Radical and systemic eco-innovation usually takes place beyond firm boundaries, highlighting the importance of cooperation with different stakeholders. Sustainable transformations “connect” the firm to society at large. Overcoming barriers to radical eco-innovations requires major governance innovation in both the private and public sectors. From a company perspective, governance invites managers to explore the wider role of business in society, i.e., to renew their relationships with other stakeholders, stressing the importance of collaboration in eco-innovation, especially regarding knowledge.</p>

Source: Carrillo-Hermosilla et al. (2010).

In short, the different dimensions in the framework of Carrillo-Hermosilla et al. (2010) can be synthesized as follows: The design dimension covers aspects of technological change from an environmental perspective, the user dimension covers the specific demands for sustainability among (potential) users of the eco-innovation, the product service dimension covers the firm's value proposition in the market targeting these user demands and facilitated by techno-environmental change, and the governance dimension describes involved stakeholders and their behavior within the value network. Eco-innovations involve a combination of characteristics belonging to these dimensions, which play a significant role in understanding their multi-faceted nature and diversity.

Kiefer et al. (2017) note that a precise conceptualization of eco-innovation is missing, probably due to its multifaceted character. Different studies refer to different aspects and characteristics of eco-innovations and there is not a commonly shared perspective. Many concepts and variables describing these different aspects exist in previous literature. Efforts for empirical consolidation and systematization have not been attempted so far. Yet, this is much needed, as Academia, business management and public policy for eco-innovation can substantially benefit from the mitigation of the existing complexity with a commonly shared perspective of eco-innovation. Therefore, the research question is: "Do different types of eco-innovation in firms exist? And if so, how are they characterized? And, how can they be differentiated from each other?". The article builds on previous contributions for all variables and questions. The qualitative aspects that the article aims to quantify are not present in any publicly available dataset and, thus, a survey directly focusing on those aspects is needed. Quantitative analyses are realized with the self-collected primary data from a set of eco-innovative Spanish industrial small and medium-size enterprises (SMEs). Results identify distinct types of eco-innovations. To our best knowledge, this study is the first attempt to quantitatively explore different types of eco-innovations that may exist and to cover the aforementioned gap in the literature.

In their study, Kiefer et al. (2017) perform quantitative analyses to reveal the different general characteristics of eco-innovations. The observed eco-innovations are quantified on these characteristics using Factor Analyses based on the solution of Principal Components Analysis (PCA). Based on these findings, Cluster Analyses are performed in order to reveal the different types of eco-innovations realized in the target universe.



They find out that eco-innovations are characterized by 4 dimensions (design, user, product service and governance) and 20 “subdimensions of eco-innovations” that represent their character traits and can be used to jointly and comprehensively describe the phenomenon. These subdimensions include: Purely ecological characteristics (composition of inputs and downcycling); Business processes and model / eco-effectiveness; Savings / eco-efficiency; Environmental impacts from the output side (probably EOP); Reduction of toxicity of the product or service; Involvement and anticipation of the acceptance of internal and external clients/users as well as intermediaries; Radical deviation from current business bases; Relations with suppliers; Incremental advances within existing business models; New products / services; Scientific-academic cooperation; Cooperation with universities and research centers; Cooperation with competitors and industrial organizations; Cooperation with clients; Cooperation with NGOs; Cooperation with regulators; Frequency of cooperation with suppliers and importance of cooperation with suppliers.

However, although Kiefer et al. (2017) identify the set of characteristics and subdimensions of eco-innovation, the authors do not use them to derive different eco-innovation types, i.e., a taxonomy of eco-innovations. This is the aim of this paper, which necessarily draws on the theoretical framework developed in the previous two (Carrillo-Hermosilla et al. 2010 and Kiefer et al. 2017), as well as on their analysis and findings. Based on the idea that eco-innovations with similar character traits belong to the same type of eco-innovation, a cluster analysis with the 20 subdimensions of eco-innovation identified in Kiefer et al. (2017) is carried out in this paper.

### 3. Materials and methods

First, eco-innovations are described using 20 previously identified character traits of eco-innovations belonging to 4 dimensions of eco-innovations (Kiefer et al. 2017, Carrillo-Hermosilla et. al, 2010). Second, according to these character traits, Cluster Analyses reveal the different types of eco-innovations developed by firms in the target universe.

### 3.1. Definition of input variables

Eco-innovations are a multifaceted and diverse phenomenon; their description is not an easy task (Carrillo-Hermosilla et al. 2010). In their study, Kiefer et al. (2017) perform quantitative analyses to reveal the characteristics of eco-innovations. They find out that eco-innovations are characterized on 20 “subdimensions of eco-innovations” that represent their character traits and can be used to jointly and comprehensively describe the phenomenon. This article builds on those findings and adopts the proposed characterization of eco-innovations, resulting in 20 input variables.

### 3.2. Target universe and data gathering

This study is targeted at Spanish industrial small-and-medium sized firms (SME) due to the following reasons.

The industrial sector is very relevant in the transition towards sustainable production and consumption patterns (OECD, 2009) because of its weight in the economy, its relatively high historic and current impacts, both direct and indirect, on the ecological systems. It is indeed a major CO<sub>2</sub> emitter, also due to its high energy, gas and carbon consumption (IEA, 2015). On the other hand, the industry is an innovative sector, mainly with respect to product and processes. It is also an eco-innovative sector (Andersen, 2008; Cheng et al., 2014; Cluzel et al., 2014; Durán-Romero and Urraca-Ruiz, 2015; Franceschini and Pansera, 2015; Kemp and Foxon, 2007; Machiba, 2010; Mondéjar-Jiménez et al., 2014; Nair and Paulose, 2014; Porter and van der Linde, 1995; Rynikiewicz, 2008).

SMEs have recently been subject to an increasing number of studies in eco-innovation, in contrast to the neglect in the past (Bocken et al., 2014; Coad et al., 2016; Cuerva et al., 2013; Klewitz et al., 2012; Klewitz and Hansen, 2013; Marin et al., 2014; Triguero et al., 2015, 2013). Their importance for eco-innovations is recognized, due to their vast numbers (99% of european firms are SMEs (Bocken et al., 2014; EU, 2012)), their mayor role for the creation of employment (2 thirds of private employment is generated by SMEs (Bocken et al., 2014; Brammer et al., 2012; EU, 2012)) and their contribution to the gross national income (Ayyagari et al., 2007; Bocken et al., 2014). Also, SMEs are highly important for eco-innovation development, adoption and diffusion due to some unique characteristics, such as high flexibility, lean structures and informal communication patterns (Keskin et al., 2013). There is abundant research on firm size and (eco-

)innovative behavior (Keskin et al., 2013), yet final consensus on the role of size on eco-innovations has not been reached. It is clear that some SMEs have developed considerable eco-innovations that are very important in the transformation of industries and societies towards sustainability (Aragón-Correa et al., 2008; Klewitz et al., 2012; Paradkar et al., 2015; Sáez-Martínez et al., 2016). This article recurs to the official definition of SMEs by the European Commission in terms of number of employees (European Commission, 2017): SMEs have between 50 and 250 employees.

Spain was chosen because its specific features with respect to other North European countries where eco-innovation studies have been carried out (e.g., Germany and U.K.): a weaker national innovation system (OECD, 2012), lower rigor in applying ecological regulations (Blanke and Chiesa, 2013; Johnstone et al., 2010; Kletzan-Slamanig and Köppl, 2009) and a lower disposition to pay “green” price premiums by consumers (EC, 2011). On the other hand, Spain has some unique features favoring the development and update of eco-innovations (Del Río et al., 2015).<sup>1</sup>

There were 2821 firms with these characteristics in 2014, according to the Iberian Balance Sheet Analysis System (SABI). Questionnaires were targeted at staff close to innovation areas. Therefore, all firms were contacted by telephone and were asked to provide the contact data of such personnel, if existent. This work was professionally undertaken by a market-research company. All identified persons were then invited to the survey via email. The survey was carried out in May and June 2014.

638 persons accessed and 430 completed the survey. 197 firms developed or adopted an eco-innovation in the observed period. This represents a response rate of 28.9% of the contacts, which is satisfactory compared to similar studies (Horbach et al., 2012; Kesidou and Demirel, 2012). The following tables provide details on the procedure and the final sample.

<sup>1</sup> Eco-innovation studies carried out in Spain include Cainelli et al., (2015, 2011), De Marchi (2012), Del Río (2005), Del Río et al (2012) and Mazzanti and Zoboli (2005). In Germany, the following analyses have been undertaken: Belin et al (2009), Frondel et al (2008), Horbach (2014), Kammerer (2009, 2008), Klewitz et al (2012), Rave et al (2011), Reichardt et al (2014) and Rennings and Ziegler (2004). Because of existing differences between these two countries, the results are not transferrable to Spain (Del Río et al., 2015).

**Table 2. Details on the procedure**

	Number
Firms in the target universe	2821
Identified contact persons	2206
Surveys accessed	638
Surveys completed	430
Response rate	28.9% of contacts 22.6% of target universe
Data sets on the characteristics of eco-innovation being obtained	197

Source: own elaboration

**Table 3. Details on the final sample (eco-innovators and eco-innovations)**

<b>Eco-innovators</b>		
Target market (% of firms)	B2B	65.0
	B2C	4.6
	Both	27.9
Foreign economic activity (% of firms)	Imports and exports	71.6
	Exports	13.7
	Imports	4.6
	No foreign activity	10.2
Age (years)	30 (average)	
Size (number of employees)	107 (average)	
Legal form (% of firms)	Public limited companies	59.9
	Limited liability companies	39.6
	Cooperatives	0.5
<b>Eco-innovations</b>		
Degree of novelty for the firm (% of firms)	New to the firm	53.8
	Not new to the firm	39.1
Degree of novelty (% of all firms)	New to the sector	12.7
	Not new to the sector	61.4
Origin of the eco-innovation (% of all eco-innovations)	Developed in-house	42.1
	Development from external sources	21.8
	Adoption from external sources	9.6
	Development in alliance with other firms	8.6
	Outcome of the continuous improvements of a previous innovation	11.2
Type of eco-innovation adopted (% of all eco-innovations)	Component addition	14.7
	Change in product/process*	42.1
	Considerable changes**	31.5

\* Change in products/processes (partial improvement, without large changes in previous products/processes)

\*\* Considerable changes of products/processes in order to avoid environmental damage.

Source: own elaboration

### 3.3. Statistical techniques

Eco-innovation character traits have been comprehensively described by Kiefer et al. (2017). This article recurs to the empirical findings of the authors and uses the 20

characteristics or subdimensions of eco-innovations. The observed eco-innovations are quantified on these characteristics using Factor Analyses based on the solution of Principal Components (PCA), thus replicating the original analyses.

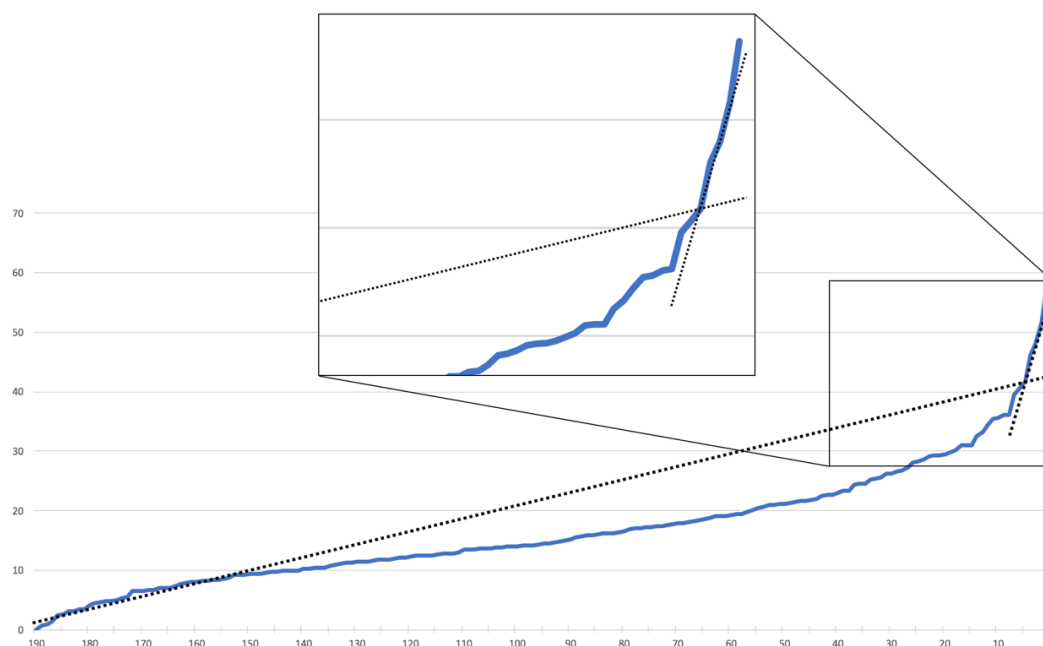
Based on these findings, Cluster Analyses (CA) are performed in order to reveal the different types of eco-innovations carried out in the target universe. Cluster Analyses are adequate for this because they group similar observations as a function of similarity/dissimilarity. These were undertaken in two steps, as it is usual (Castellacci and Lie, 2017; Hair et al., 2010, 1998). In a first step, hierarchical CA were realized with the aim to identify the optimum amount of clusters to retain endogenously. The applied method was “between groups linkage” as it maximizes the distance between different clusters. The Squared Euclidian Distance was chosen as a measure of distance, because it is most common for relativizing or mitigating proximities of extreme cases with great distances between them (Hair et al., 2010, 1998). Variables are standardized with the measure “Z-Score” in order to account for different scale effects (Hair et al., 2010, 1998). Then, the agglomeration schedule and the dendrogram are studied. The inflection (inflexion) points are assessed in order to determine the optimum amount of clusters. As a means of confirmation, a second CA is realized, as it is usual. This time, the “Ward Method” is chosen. It maximizes the variance between different clusters (Hair et al., 2010, 1998). Once the optimum amount of clusters is established, each case is assigned to one with the help of a k-means CA. This method creates k clusters with maximized differentiation (k is known by previous hierarchical CA) and allocates the n cases to them. This is done by minimizing the Squared Euclidian Distance between the observation and the central mean value of the cluster (center or centroid / k-mean). (Hartigan and Wong, 1979; Likas et al., 2011; Wagstaff et al., 2001).

#### 4. Results

Eco-innovations with more similar characteristics belong to the same type of eco-innovation. The CA is carried out with the sub-dimensions of eco-innovation, which are its main characteristics. This allows us to discover the different eco-innovation types that exist according to our data, from which a proposal for the taxonomy of eco-innovation is derived, which in itself constitutes a contribution of this research.

Specifically, turning points are identified after 8, 5 and 3 clusters with the "between-groups linkage" method. After 8 clusters, the coefficient increases considerably from an average value of 0.196 to 3.394. After 5 clusters, the increase is 4,339 and, after 3 clusters, it is 3,641. The agglomeration coefficient and the corresponding number of clusters are shown in a line graph (Figure 1). SPSS does not allow the figure to be produced. Therefore, the data has been exported to Microsoft Excel and the graph has been created manually.

**Figure 1. The conglomeration coefficient as a function of the number of clusters**



Source: own elaboration.

The turning point can be observed as a change of "direction" of the line, also known as the "elbow". It is displayed at the intersection of the two direction lines. The suitability of the selection of 5 clusters is checked visually. This solution maximizes the distance between the different clusters.

In addition, the agglomeration schedule and dendrogram are studied for a CA using the Ward method. Possible solutions would be the creation of 10, 8, 5, 3 and 2 clusters. In

short, the two methods of "between-groups linkage" and Ward produce similar results. The solution of 5 clusters appears to be suitable with both methods.

In the matrix of final cluster centroids, the central values of these are obtained for each factor and variable (e.g., on the characteristics of eco-innovation). The corresponding interpretation is made taking into account that the final cluster centroids represent standardized values, since classification variables (the characteristics of eco-innovation) have been used in a typified way. In other words, they cannot be attributed a specific meaning in terms of the variables themselves. They are interpreted in relative terms and regarding average behavior.

**Table 4. Final cluster centroids in the subdimensions.**

Subdimensions of eco-innovation	Cluster centroids				
	1	2	3	4	5
Purely ecological characteristics (composition of inputs and downcycling)	,413	-,918	-,964	,331	-,156
Business processes and model / eco-effectiveness	,523	-1,007	-1,221	,427	-,203
Savings / eco-efficiency	-,344	-,152	-,463	,188	,241
Environmental impacts from the output side (probably EOP)	,427	-,307	-,614	-,024	,020
Reduction of toxicity of the product or service	,411	-,738	-,402	,232	-,244
Involvement and anticipation of the acceptance of external clients/users	,403	-1,223	-1,381	,688	-,432
Involvement and anticipation of the acceptance of internal clients/users	,587	-,867	-,990	,274	-,139
Involvement and anticipation of the acceptance of intermediaries	,577	-,206	-,481	,337	-,904
Radical deviation from current business bases	,584	-,990	-1,508	,664	-,630
Relations with suppliers	,771	-,791	-1,260	,286	-,312
Incremental advances within existing business models	,547	-,833	-1,399	,630	-,709
New products / services	,629	-,857	-1,385	,647	-,797
Scientific-academic cooperation–	,384	-,613	-,705	,211	-,173
Cooperation with universities and research centers	,247	-1,215	,114	,369	-,439
Cooperation with competitors and industrial organizations	,246	-1,399	,138	,051	,261
Cooperation with clients	,547	-,976	-,984	,398	-,408
Cooperation with NGOs	-,322	1,626	-,095	-,102	-,257
Cooperation with regulators	-,429	1,322	-,046	-,143	,094
Frequency of cooperation with suppliers	1,482	-,548	-,594	-,442	,077
Importance of cooperation with suppliers	1,482	-,445	-,512	-,495	,078



An analysis of the variance (one-way ANOVA) is carried out to confirm that the cluster centroid values (average values of factors and variables) are actually different between the 5 clusters. The analysis of the variance requires a normal distribution and uniformity of variance (Field, 2013; Hair et al., 2010).

The normality tests are performed with the help of the Kolmogorov-Smirnov and Shapiro-Wilk tests that indicate whether a distribution differs significantly from a normal one. The significant results suggest that the data have a non-normal distribution.

The variance homogeneity test is performed by the Levene test, which identifies whether the variances in the distribution of the 5 clusters are significantly different. The results show that the homogeneity of variance is not given for the following variables: Business processes and model / eco-effectiveness; Savings / eco-efficiency; Environmental impacts from the output side (probably EOP); Reduction of toxicity of the product or service; Involvement and anticipation of the acceptance of internal clients/users; Incremental advances within existing business models; New products / services; Scientific-academic cooperation; Cooperation with universities and research centers; Cooperation with competitors and industrial organizations; Cooperation with clients; Cooperation with NGOs; Frequency of cooperation with suppliers; Importance of cooperation with suppliers.

For these reasons, instead of the analysis of variance, a robust analysis of the equality of averages is applied, in particular the Welch and Brown-Forsythe tests (Field, 2013; Hair et al., 2010). It is concluded that the significance in both tests is always given, thus confirming the existence of a significant difference between the centroid values between the clusters in all cases.

### **Systemic eco-innovations**

The results of the CA demonstrate that the eco-innovations of cluster 1 have above-average scores in all subdimensions of the design dimension except for one, namely the change of input materials with environmental benefits in the production, delivery and use phases, a break with business processes and model / eco-effectiveness, as well as environmental impacts from the output (EOP) side. The scores in the eco-efficiency subdimension are below average. There are higher than average scores in all user subdimensions, including external and internal clients and intermediaries. This type of



eco-innovation scores high on the characteristics of changes in the product/service process with a significant deviation from current sales and traditional markets, towards new models of cooperation with suppliers and also to incremental advances in the established product-service system (incremental advances within existing business models). The score in the subdimension of new products and services is one of the highest among all clusters. The subdimensions of governance include high scores in scientific-academic cooperation, interactions with competitors and industry associations and collaboration with clients. The frequency and importance of cooperation with suppliers is the highest overall value observed, well above the average.

This means that the eco-innovations of this cluster are primarily characterized by the environmental benefits that are obtained during the production, delivery and use phases. They represent a rupture with previous business processes and models (eco-effectiveness). In terms of environmental benefit, this type of eco-innovation is very radical and represents a considerable improvement. During its development or adoption, the interactions with external and internal clients are intensive, including anticipating the acceptance of the eco-innovation. The same is true for intermediaries. The eco-innovation comprises the introduction of new products and services, deviates very significantly from the previous bases of business and focuses on new markets and customers. It emerges with the help of a governance focused on technology as well as on the market (competitors and clients) and the value network (suppliers).

For these reasons, the eco-innovations of cluster 1 are highly sustainable, novel and radical in terms of the current business base. They have a clear focus on the market, which is why they are considered to emerge under demand-pull regimes. On the other hand, science-focused governance indicates that technology-push also interferes. As it has been argued earlier in this article, both approaches can be compatible and pursued at the same time. This seems to be the case with this eco-innovation type.

It is concluded that this type of eco-innovation is systemic. 37 "systemic eco-innovations" are grouped together in cluster 1.

### **Externally driven eco-innovations**

Cluster 2 is characterized by below-average scores across the entire design dimension that also includes changes in the composition of product or service inputs (composition

of inputs and downcycling), organizational/productive processes and business model (business processes and model / eco-effectiveness), sustainability from the output side (EOP) and also reduced toxicity. As far as the user subdimensions are concerned, there aren't any noteworthy characteristics regarding the involvement or anticipation of acceptance, either by external or internal clients. Likewise, this type of eco-innovation has scores below the average in the product-service subdimensions. No characteristic regarding the value proposition or delivery stands out. Only among the subdimensions of governance, the cooperation with NGOs and regulators clearly needs to be emphasized as those are the highest scores observed among all eco-innovation types.

Therefore, eco-innovations of this type are undifferentiated in terms of their technological design and value proposition. They arise in the context of interactions with regulators and NGOs. They are considered to be reactive and responsive to specific external pressures or anticipating them. These may be mandatory laws and regulations or environmental pressures from society. This would explain why they do not share a certain type of environmental benefit: reactions depend very much on the product, service or process subject to external pressure and how this impacts on the business and the eco-innovation. This highlights the importance of the two subdimensions of governance. In some cases, eco-innovations developed or adopted under these schemes may be expected to be more of the EOP type, but the results confirm that they are not only associated with it.

The type of eco-innovation in cluster 2 is referred to as "externally driven eco-innovations" (referring to external stimuli) and it is observed 20 times.

### **Continuous improvement eco-innovations**

The eco-innovations of cluster 3 resemble those of the previous cluster with their scores well below the average in all subdimensions of design, user and product-service. In terms of cooperation and the governance dimension, they score below average or average in all subdimensions.

Conceptually, this group of eco-innovations is undifferentiated in terms of ecological and technological characteristics (design subdimensions): obtaining environmental benefit (EOP, eco-efficiency and eco-effectiveness) is nonspecific, so they could all have an influence in this regard. The value proposition and delivery does not change significantly

compared to existing solutions in firms and there is no significant rupture with established business and industrial processes and systems. The development or adoption of such eco-innovations takes place without significant involvement of clients or intermediaries. Also, other aspects of network or cooperation governance do not interfere. For this type of eco-innovations, several characteristics are deduced: they arise as "normal" innovations, i.e., they do not have high levels of novelty nor do they imply a considerable increase in sustainability. They emerge isolated and without any noteworthy interactions. They make no changes to the proposal or processes of value generation. They are developed or adopted without interfering with corporate governance. Therefore, this type of eco-innovations is considered to be the result of continuous improvements without deliberate eco-innovation efforts and the ecological component is a secondary result.

In total, there are 20 "continuous improvement eco-innovations" or "business-as-usual" eco-innovations.

### **Radical and tech-push initiated eco-innovations**

Cluster 4 has high scores in the design subdimensions of purely ecological characteristics (composition of inputs and downcycling) and rupture with previous productive and administrative business processes and models / eco-effectiveness. In addition, it ranks above average in the subdimensions of external clients, intermediaries and, a little bit less, internal clients. As for the subdimensions of product-service, it stands out for its very high score on the radical deviation of the current bases of business, new products and services, as well as incremental changes. The aspect of cooperation with research centers, universities and consultants has a high value within the governance dimension. Cooperation with clients is relatively less important.

In short, this cluster is characterized by high levels of sustainability and technological innovation, as well as radicality in terms of current business bases. This is similar to cluster 1, but there are also clear differences. While cluster 1 has a strong market focus, cluster 4 does not. External cooperation is restricted to universities and research centers (both science and knowledge-related). The score for cooperation with clients is above average, but below the score of cluster 1. For this reason, the eco-innovations of cluster 4 are called radical and technology-push initiated eco-innovations

In total, there are 76 “radical and technology-push initiated” eco-innovations.

### **Eco-efficient eco-innovations**

The eco-innovations of cluster 5 are characterized by their high scores in the subdimension of savings / eco-efficiency in inputs of physical materials, energy, water and land use, as well as in aspects of cooperation with competitors and industrial organizations. The scores in the other subdimensions indicate that the proposed characteristics do not refer to this type of eco-innovation.

It is concluded that this cluster represents eco-innovations focused on input savings, which is a typical approach to eco-efficiency. The environmental benefits of such eco-innovations may not be motivated by sustainability, but by competitiveness. The high scores in cooperation with competitors and other business-related industrial organizations also suggest so. Efficiency is an aspect of competitiveness in markets and industries and the comparison of the company with its close surrounding environment serves to assess its relative competitiveness. Therefore, the type of eco-innovation in cluster 5 is called "eco-efficient eco-innovation", just as the previous literature has proposed. According to the results of the CA, the ecological benefits may be cancelled by an increase in production and consumption potentially induced by a lower cost of the underlying product or service.

37 eco-efficient eco-innovations have been observed.

## **5. Conclusion**

This paper has tried to provide a taxonomy of eco-innovation types which takes into account its many different features and dimensions. Overall, the results show that Spanish SMEs in the industrial sector eco-innovate in multiple ways. The statistical analyses reveal the existence of five eco-innovation types undertaken by Spanish industrial SMEs: systemic, externally driven, continuous improvement, radical and technology-push initiated and eco-efficient.

Systemic eco-innovations are characterized by a high degree of novelty and rupture with existing solutions, as well as by their considerable environmental benefit during the production, delivery and use phases. They emerge with a clear focus on the market,

complemented by a focus on technology. They create a completely new competitive base. They arise from a wide network of cooperations and have transformative effects on this network.

Externally driven eco-innovations are unspecific in their technological characteristics and environmental benefits. They arise in response to external pressures from society or legislation.

Continuous improvement eco-innovations are also nonspecific in terms of their technological characteristics and environmental benefits. They arise from within the SME as a result of day-to-day business activities and are fully compatible with established processes and systems. They represent small advances on existing solutions.

Radical technology-driven eco-innovations are characterized by high levels of technological innovation, a rupture with existing solutions and considerable environmental benefits. They arise from an impulse from science and technological research.

Finally, eco-efficient eco-innovations increase the efficiency of products, services or processes. As a result, there is an environmental benefit.

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