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DIVERSITY OF ECO-INNOVATIONS: A QUANTITATIVE APPROACH

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Abstract:

Despite a high academic interest in eco-innovation, a clearly defined common understanding of the characteristics of eco-innovations is largely missing. Existing research on this topic is still mostly qualitative, fragmented, difficult to compare or aggregate and generally specialized on certain aspects. Quantitative research is deemed necessary to improve the knowledge base and measurement of essential aspects regarding the characteristics of eco-innovation. The aim of this study is to quantitatively explore the underlying structure of the eco-innovation concept based on the current knowledge of those characteristics and to advance on the quantification of a four-dimensional framework proposed in the past. Industrial small and medium-size enterprises in Spain were asked to quantify a set of variables according to the perceived relevance for the firm of a realized eco-innovation. Factor Analyses were conducted on 197 collected data sets. Our statistical results reveal how the identified characteristics shape an underlying structure of eco-innovations along the 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. The final impact of eco-innovation on the environment goes in tandem with and is usually mediated by considerable impacts at the company level (including internal management and organizational practices) which lead to changes in products and processes. Furthermore, our results stress the critical role played by users and clients' engagement and acceptance and cooperation with other stakeholders in the eco-innovation process. The eco-innovation may entail radical, path-breaking changes in existing relations between the firm and its production network. This article contributes to advance the understanding of the phenomenon by providing a comprehensive view and a common perspective.

Key words: Eco-innovation; Spain; small and medium-size enterprises; dimensions; Factor Analysis.

1. Introduction

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 (Bocken et al., 2014; Boons et al., 2013; Carrillo-Hermosilla et al., 2010; Ghisetti and Rennings, 2014; Klewitz and Hansen, 2013; OECD, 2012; Rennings, 2000). In short, they improve "sustainability performance" (Carrillo-Hermosilla et al., 2010).

Previous studies have advanced our understanding of these sustainability transitions regarding niche and systemic transformation (Adams et al., 2012; Boons and Lüdeke-Freund, 2013; Carrillo-Hermosilla et al., 2010); linear and closed-loop/circular economy models (Braungart et al., 2007) and industrial and business model lock-in/drop-in/breakout (Adams et al., 2012; Boons and Lüdeke-Freund, 2013; Könnölä et al., 2006). Sustainability performance has been studied against absolute and relative contributions to sustainability (eco-efficiency and eco-effectiveness)

(Braungart et al., 2007; Carrillo-Hermosilla et al., 2010), value creation, competition and its integration in (new) business models (Adams et al., 2012; Boons and Lüdeke-Freund, 2013; Ghisetti and Rennings, 2014).

However, despite the aforementioned general and abstract definition of eco-innovation and abundant research (see Del Río et al., 2016a and Xavier et al., 2017 for an overview), 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. This would individually help academia advancing knowledge on the characteristics of eco-innovation, business management to properly administer eco-innovation development and policy makers to properly frame and incentivize it. Furthermore, a common perspective can provide a solid foundation for all parties involved to communicate on equal terms instead of on different understandings. This can facilitate cooperation and finally contribute towards the sustainability transition of economies and societies.

Therefore, the research question is: "*Is there a simple, underlying set of characteristics, that the diversity of eco-innovation has in common?*" 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 groups of characteristics of eco-innovations. To our best knowledge, this study is the first attempt to quantitatively explore the underlying structure of the characteristics of eco-innovation and to cover the aforementioned gap in the literature.

Accordingly, the paper is structured as follows. Section 2 outlines existing eco-innovation frameworks, describes the different dimensions of the guiding framework and justifies its selection. Section 3 describes the methodology being used for the quantification of the previously set conceptual qualitative framework. The results are provided in section 4 and discussed in Section 5. Section 6 concludes with implications, limitations and possible avenues for future research.

2. Theoretical framework

Several authors have suggested eco-innovation frameworks in the past. For instance, Adams et al. (2016, 2012) propose the contexts of organizational optimization and systems building, connecting them by a phase of “step-changing” organizational transformation and three characterizing dimensions. Machiba (2010) puts forward a framework of type, localization and impact. Hansen et al. (2009) come up with a 3D-sustainability innovation cube, crossing types of innovation, effects and life-cycle stages. Carrillo-Hermosilla et al. (2010) propose four dimensions of eco-innovations (design, user, product-service, and governance), describing their detailed characteristics within each dimension while simultaneously providing a comprehensive overview. Numerous studies refer to these frameworks for characterizing eco-innovations (Boons et al., 2013; Boons and Lüdeke-Freund, 2013; Garrido Azevedo et al., 2014; Iñigo and Albareda, 2015; Klewitz and Hansen, 2013). There is clearly a need for a better understanding of the underlying set of characteristics for the phenomenon (Boons and Lüdeke-Freund, 2013; Jakobsen and Clausen, 2016; Kesidou and Demirel, 2012; Roscoe et al., 2016).

This article builds upon the framework proposed by Carrillo-Hermosilla et al. (2010) published in this journal. It 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, providing (or not) empirical evidence for it. 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 will be given in the rest of this section (see Carrillo-Hermosilla et al., 2010 for further details).

2.1. Design dimension

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 (Adams et al., 2012; Bocken et al., 2014; Braungart et al., 2007; Klewitz and Hansen, 2013):

- <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.
- <u>Sub-system change</u>: eco-efficient solutions and the optimization of sub-systems, leading to a reduction of negative environmental impacts.
- <u>System change:</u> It involves the redesign of systems towards eco-effective solutions, remodeling the environmental impacts on the ecosystem and society at large.

2.2. User dimension

The success of any innovation depends on the economic demands in the target market. Additionally, eco-innovations address sustainability issues (Horbach, 2008; Kemp and Foxon, 2007a). 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 (Adams et al., 2012; Boons and Lüdeke-Freund, 2013; Hansen et al., 2009; Rondinelli and London, 2003).

Two subdimensions can be distinguished in this dimension:

- User development: Identification of users that are capable of providing valuable inputs in innovation projects.
- User acceptance: Understanding users' needs and wants enhances the market success of sustainable solutions.

2.3. Product-service dimension

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 (Bocken et al., 2014; Boons and Lüdeke-Freund, 2013; Mont, 2002; Williams, 2007) delivers a "function" to the customer, consisting of combinations of products and services, that are capable of "jointly fulfilling users' needs" (Adams et al., 2016; Goedkoop et al., 1999; Hansen et al., 2009). Supply chain/network perspectives include production, delivery, consumption and disposal (Linton et al., 2007; Schaltegger and Burritt, 2014).

- Product-service deliverable consists of changes in the product/service and value delivered and changes in the perception of the customer relation.
- Product-service process consists of changes in the value-chain process and relations that enable the delivery of the product-service and value capture.

2.4. Governance dimension

Radical and systemic eco-innovation usually takes place beyond firm boundaries (Hansen and Coenen, 2015), highlighting the importance of cooperation with different stakeholders. Sustainable transformations "connect" the firm to society at large (Schaltegger and Wagner, 2011; Van Kleef and Roome, 2007). Overcoming barriers to radical eco-innovations requires major governance innovation in both the private and public sectors (Boons and Lüdeke-Freund, 2013). From a company perspective, governance invites managers to explore the wider role of business in society (Hansen and Spitzeck, 2011), i.e., to renew their relationships with other stakeholders, stressing the importance of collaboration in eco-innovation, especially regarding knowledge (Del Río et al., 2016a, 2016b; Ghisetti et al., 2015).

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.

3. Materials and methods

In this section, details on the steps and research procedures are provided. First, the input variables are defined and their inclusion has been justified, based on a thorough literature review. The questions included in the questionnaire are derived. This was subject to a content adequacy (pre-test of the questionnaire with experts and managers) (3.1). Second, details on the sample universe as well as the process of data gathering are provided (3.2). Finally, details on the statistical technique being used (exploratory Factor Analysis) are given in Section 3.3.

3.1 Definition of input variables

This article builds on previous literature that examines the characteristics of eco-innovations. In a first step, an extensive literature review was conducted with a university search tool indexing EBSCO, ScienceDirect, Web of Science (ISI), JSTOR, Wiley Online, Scopus and Springer Link among others. The terms "eco-innovation", "ecological innovation", "sustainable innovation", "environmental innovation" and "green innovation" were introduced (Hojnik and Ruzzier, 2015; Schiederig et al., 2012). Then, abstracts were screened for "characteristic", "form", "type", "nature" and "class". Relevant contributions were then carefully read and further references included in them were searched. In total, 152 contributions describing characteristics of eco-innovations were identified and used for item generation[1]. All of them were grouped along the aforementioned four dimensions in accordance with the framework. For the purposes of measurement, each characteristic needed to be associated with a quantifiable variable.

3.1.1. Questionnaire design (item generation)

If available, an already existing variable and question were used from previous research. If not available, a variable was created based on the original contributions' concept by using its specific expressions and terms (Tables 1 to 4)[2]. Content adequacy was assessed and confirmed (see 3.1.3).

Table 1. Variables for the design dimension

Variable	Justification	Questions in the survey: What has been the degree of impact of the eco-innovation on…
Material, energy, water and land use savings	Eco-innovations can increase input efficiency for every economic unit produced and delivered (Horbach et al., 2012; Rennings et al., 2006).	…material, energy, water or land use savings?
Reduction of the toxicity of the product or service	Toxic burdens of products and services may emerge as a consequence of the use of toxic inputs, the release of toxic substances during product or service usage or product disposal (Braungart et al., 2007; Horbach et al., 2012).	… reduction of the toxicity of the product or service?
Increased recycling	Recycling allows resources and materials to be part of production and consumption processes until they are physically degraded, i.e., to be part of these processes for a longer time ("downcycling")(Braungart et al., 2007; Hofstra and Huisingh, 2014).	…increase in the possibility of recycling?
Increased product or service life cycle	Eco-innovations may increase the durability and quality of products and services, increasing their life cycles and reducing the pace of replacement or repair (Kammerer, 2009; Kemp and Foxon, 2007b; Klewitz and Hansen, 2013).	…increased product or service life cycle?

[1] Those references are not included in this paper for reasons of space but they can be provided by the authors upon request.
[2] For instance, the first variable is based on the study of Horbach et al. (2012) which use the variables "Reduced material use per unit of output" and "Reduced energy use per unit of output" to describe changes in environmental impacts. Other authors specifically mention natural input resources to include "materials, energy, water and land" (i.e., Hojnik and Ruzzier, 2015). Therefore, the variable contains "material, energy, water and land use savings" and the corresponding question is: "What has been the degree of impact of the eco-innovation on material, energy, water or land use savings?"

Reduction of emissions to air and reduction of wastes to water and soil	Eco-innovations can reduce air emissions and wastes to water and soil (Horbach et al., 2012).	…the reduction of emissions to air/water or residuals?
Greater use of renewable materials	Eco-innovations that use renewable *physical* resources and materials could reduce environmental impacts considerably (Bocken et al., 2014; Kemp and Foxon, 2007b).	…the increase in the use of renewable materials?
Replacement of less sustainable resources and materials	Eco-innovations may completely replace non-sustainable resources and materials, often through redesign of the product-service system (Bocken et al., 2014; Klewitz and Hansen, 2013).	…the replacement of less sustainable resources and materials for more sustainable ones?
Breaking with previous production and delivery processes towards more sustainable solutions	The radicalness of the eco-innovation influences the level of breaking with previous, established productive processes and the corresponding environmental benefit (Cainelli et al., 2015; Rennings, 2000).	…the disruption of previous production and delivery processes towards more sustainable solutions?
Breaking with previous management processes	"New forms of organization" is a type of "Schumpeterian" (eco-)innovation (Kemp and Pearson, 2007). Frequently, eco-innovations in managing processes go in parallel with other eco-innovations in product, service, production process or business models (Kemp and Foxon, 2007a; Kemp and Pearson, 2007).	…discontinuation of previous management processes?
Total or partial redefinition of the business model	Business models influence and are influenced by eco-innovations (Bocken et al., 2014; OECD, 2012).	…total or partial redefinition of the business model?

Table 2. Variables for the user dimension

Variable	**Justification**	**Questions in the survey**
User involvement	Involving clients and users in (eco-) innovation is beneficial (Del Río et al., 2016b; Junquera et al., 2012; Kammerer, 2009) since they can give valuable inputs to identify the innovation potential and improvement and development of new innovations (Carrillo-Hermosilla et al., 2010; Ghisetti et al., 2015; Junquera et al., 2012). Involvement intensity can range from unidirectional communication without feedback or interaction loops to complex iterative interaction on multiple levels (Junquera et al., 2012). Some clients and users are even able to adopt the role of inventors and co-developers (Bogers et al., 2010). Although clients and users usually refer to a third party (external to the firm), they can also be internal. The firm boundary typically acts as a barrier which is mostly resource and capacity related (Teece, 2014) and thus external and internal clients and users need to be considered separately. Moreover, innovation can satisfy needs/demands of existing or new clients/users. The same holds true for eco-innovations (Kemp and Foxon, 2007b; Klewitz and Hansen, 2013).	During the process of creation, development or adoption of the eco-innovation what has been the degree of implication of… …current external users/clients? …current internal users/clients? …potential external users/clients? …potential internal users/clients? …current intermediate agents? …potential intermediate agents?
Anticipation of user acceptance	In order to ensure the commercial success of eco-innovative products and services, the identification of specific client and user needs and desires must be complemented with an anticipation of acceptance of the new value proposition in the market.	During the process of creation, development or adoption of the eco-innovation, what has been the

		degree of anticipating the acceptance of… …current external users/clients? …current internal users/clients? …potential external users/clients? …potential internal users or clients? …current intermediate agents? …potential intermediate agents?

Table 3. Variables for the product-service dimension

Variable	**Justification**	**Question in the survey.** Has the eco-innovation changed the offer of your business…
Change in the business offer through the creation of new products or services	The emerging markets for sustainability lead many businesses to reevaluate the concepts of value and profitability rooted in business models (Kemp and Pearson, 2007; Mont, 2002). New, changed and intensified demand for sustainable solutions creates new demand and opportunities for green product-service deliverables (Goedkoop et al., 1999; Williams, 2007).	…with new products or services?
Change in the business offer through improved products or services	Less radically, traditional and non-sustainable business practices are also subject to increasingly greener corporate agendas and may lead to the improvement of existing product-service deliverables to include broader value considerations such as ecological value (Goedkoop et al., 1999; Tietze and Hansen, 2013).	…with improved products or services?
Change in the business offer by facilitating access to new markets	The creation, delivery and capture of value within business models is realized with the product-service deliverables and is targeted at clients and users in specific markets. In each of these, the underlying industry structure differs, and with it, value perception and corresponding value needs and demands (Demil and Lecocq, 2010; Morris et al., 2005; OECD, 2012). Eco-innovation may facilitate access to new markets.	…by facilitating the entrance into new markets?
Change of the business offer by enhancing the convenience for the clients/users	Innovations change the underlying value-creating technology of products and services. While the innovative firm can benefit in many ways from this value-creating technological innovation, technology does not attribute value to any stakeholder *per se*, but rather through a value proposition inherent in the product-service deliverable (Tongur and Engwall, 2014). Therefore, the eco-innovation may increase the convenience for the clients/users and change the business offer.	…with increased convenience for clients or users?
Change in the business offer by allowing a	The flexibility to (re-)configure, combine existing and create new products and services into ecological product-service deliverables that successfully	…with increased personalization of the

greater customer personalization of the offer	address clients, users and market segments is itself a value proposition, complementing the more "traditional" financial (i.e., profit, turnover) and market-related metrics (i.e., market share) (Demil and Lecocq, 2010; Morris et al., 2005; Tongur and Engwall, 2014).	offer?
Change in the value chain	Eco-innovations reinforce the shift from local and unidimensional optimization to comprehensive life-cycle optimization including and addressing altogether all the steps of the product lifecycle (Linton et al., 2007; Tietze and Hansen, 2013). This might lead to changes in the value network (i.e., new members or changes in the relations with existing members).	Has the eco-innovation changed the value chain of your business by …creating new kinds of relations with current clients or users? …integrating new clients or users? …creating new kinds of relations with current suppliers? …integrating new suppliers? …creating new kinds of relations with other current stakeholders in general? …integrating other stakeholders in general?

Table 4. Variables for the governance dimension

Variable	**Justification**	**Question in the survey**
Frequency and importance of cooperation with different stakeholders	Lock-in effects, industry and organizational inertia are main obstacles for developing radical (new-to-the-market) eco-innovations. In order to overcome such prevailing technological and institutional lock-in and inertia conditions and to achieve a break out of the established trajectories, major inter-organizational governance efforts (i.e., cooperation with other stakeholders) are required (Del Río et al., 2016b; OECD, 2012).	During the process of creation, development or adoption of the eco-innovation, how frequently has your firm cooperated with… …suppliers (of machinery, materials, furniture, components or software)? …clients or users? …competitors? …consultants or private research centers? …universities or public research centers? …regulators and public administration? …scientific conferences, fairs and expositions? …scientific journals and

		technical/commercial publications? …professional industry associations? …non-governmental organizations? During the process of creation, development or adoption of the eco-innovation, how important has been the cooperation with… …suppliers (of machinery, materials, furniture, components or software)? …clients or users during the process of creation, development or adoption of the eco-innovation? …competitors? …consultants or private research centers? …universities or public research centers? …regulators and public administration? …scientific conferences, fairs and expositions? …scientific journals and technical/commercial publications? …professional industry associations? …non-governmental organizations?

3.1.2 Survey method (item-data availability)

The qualitative aspects that the article aims to quantify are not present in any publicly available dataset. This is why a survey directly focusing on those aspects is needed. This study follows a deductive scale development procedure (Churchill, 1979; Fields, 2002; Nunnally, 1978). In short, previous definitions of constructs were identified and guided the questionnaire item generation. Content adequacy was assessed by a cognitive pre-test providing evidence for construct validity. Exploratory Factor Analyses were carried out and internal consistency of scales was assessed with Cornbach's Alpha indicating scale reliability. The resulting factors/constructs have been validated with construct discriminant and convergent validation (Churchill, 1979; Fields, 2002; Nunnally, 1978). Full details are provided below. This technique obviously comes along with certain restrictions, among them the reliance on respondents' perception, quantification issues and biases; yet it is not unusual in eco-innovation research (see, among others, Cuerva et al., 2013; De Marchi, 2012; Horbach, 2014; Kammerer, 2009). The use of a questionnaire and item quantification on a 5-point Likert scale is commonly accepted within the scale development process (Churchill, 1979; Fields, 2002; Nunnally, 1978).

3.1.3 Content adequacy (item pre-testing)

As the generated items are new, content adequacy must be assessed. This was done by pre-testing the questionnaire with 11 academic experts and managers. The academic experts were chosen on the basis of their experience in eco-innovation research, and the business experts were chosen because they work in areas that were targeted by the questionnaire. The feedback they provided helped to improve the formulation of a few questions and assured their clear and unambiguous understanding. Conceptually, evidence for content adequacy was established for the final survey containing 49 questions (Tables 1-4).

3.2 Sample selection and data gathering

The study was specifically targeted at Spanish industrial SMEs. The industrial sector is of special interest in the transition towards more sustainable production patterns because of its historical and current ecological impact, a considerable weight in the economy and as an important source of eco-innovations (Kemp and Foxon, 2007a). SMEs are of special interest in eco-innovation research due to their weight in the production system. They are important candidates for developing and diffusing eco-innovations (Keskin et al., 2013).

2821 firms according to these specifications were identified in the Iberian Balance Sheet Analysis System (SABI) in 2014. They were allocated to one of the four strata according to firm size (number of employees): 1st (50-99), 2nd (100-149), 3rd (150-199) and 4th (200-250). Within these firms, the questionnaires were targeted at qualified staff in areas related to innovation, i.e., innovation managers, R&D managers, etc. In order to obtain their direct contact data, all firms were contacted by telephone. This work was professionally undertaken by a market-research company. It was ensured that the number of obtained contact data in each stratum corresponded with its relative weight. Therefore, all the strata were similarly represented. All participants were then invited by email to participate in the online survey, which took place in May and June 2014.

In total, 638 persons accessed the survey, 430 completed the survey and 197 stated that their firms had developed or adopted an eco-innovation. Full details are provided in Table 5.

The response rates are satisfactory if compared to other surveys with similar set-ups, and in line with the studies of i.e., Kesidou and Demirel (2012) and Horbach et al. (2012). Table 6 summarizes some of the characteristics of the firms in our survey and the eco-innovations developed/adopted by them. Most eco-innovators operate in the B2B market and carry out economic activities abroad (imports or exports). The average firm age is 30 years and the average size is 107 employees. Most firms are public limited companies (60%). New-to-the-firm eco-innovations dominate. Most eco-innovations were developed in-house (42.1%), followed by development with external sources (21.8%). Eco-innovations leading to changes in products/processes dominate with respect to component additions and major changes.

Table 5: 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 characteristics of eco-innovation being obtained	197

Table 6. Details on the final sample (eco-innovators and eco-innovations)

Eco-innovators		
Target market (% of firms)	B2B	65
	B2C	4.6
	Both	27.9
Foreign economic activity (% of firms)	Exports and imports	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	60
	Limited liability companies	39.6
	Cooperatives	0.5
Eco-innovations		
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
	Developed 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.

3.3. Statistical technique: Exploratory Factor Analysis

In order to grasp the *ex-ante* unknown, underlying set of characteristics that the diversity of eco-innovations has in common, an exploratory methodological approach has been chosen. Exploratory approaches make no prior assumptions on data behavior. Exploratory Factor Analyses have shown to be a useful instrument to detect latent underlying factors to empirical observations in order to identify how the variables "group together". It is commonly used by researchers when developing a scale. Similar methodological approaches can be found in the recent eco-innovation literature (Cai and Zhou, 2014; Castellacci and Lie, 2017; Sáez-Martínez et al., 2016).

In accordance with the aim of this study, Exploratory Factor Analyses based on the solution of Principal Components were performed as these allow identifying sets of correlated variables and, thus, reducing the number of variables to a smaller number of factors, maintaining the degree of information of the original variables. Within Factor Analysis techniques, the Principal Component Analysis is the most common and is generally preferred for purposes of data reduction (Di Stefano et al., 2012).

Factor Analyses are affected by missing values. A few missing values for individual unanswered questions were replaced. For multinomial answer choices, replacing missing values with the mode is an adequate, standard procedure. The mode was calculated from within groups of similar firms.

The Factor Analyses were undertaken in two stages. The initial analyses were run with all the variables belonging to a certain dimension. The Eigenvalues for all variables were obtained. If a variable showed a "complex structure" (very high loadings on more than one factor), it was separated from the definitive analyses and kept individually.

The literature suggests that the factors might be related. A priori, the relations between these factors are unknown. Therefore, an oblique rotation type was used (more precisely, a direct oblimin rotation). The correlation matrix was scanned, searching for patterns of relations between variables, especially for non-significant or untypically high correlations.

The sampling adequacy of the variables included in the definitive Factor Analyses was assessed based on different measures: Bartlett's Test of Sphericity[3], the present partial correlations in the anti-image matrix[4], the measures of sampling adequacy for each particular variable (MSA) and the global sampling adequacy measure of Kaiser-Meyer-Olkin (KMO)[5].

Adequate attention was also given to construct validity and reliability (Churchill, 1979; Fields, 2002; Nunnally, 1978). Construct validity was assessed via factor loadings which, in all cases, were significantly above the minimum value of 0.40 (Hair et al., 1998), suggesting construct convergent validity. No present factor cross-loadings indicated construct discriminant validity. The reliability of scales was measured with Cronbach's alpha. Nunnally's (1978) recommended cut-off value of 0.60 was exceeded without exception. In fact, all Cronbach's Alphas are above 0.8, except one (0.771),

[3] Bartlett's Test of Sphericity checks whether the correlation matrix is significantly different from the identity matrix. If this is the case, then the overall correlations between variables are significantly different from zero.

[4] The partial correlations are displayed as off-diagonal elements. If the variables share common factors, then the partial correlations are small.

[5] The measures of sampling adequacy (MSA) for individual variables, and the Kaiser-Meyer-Olkin (KMO) for the set of variables, compare simple (zero-order) correlations and partial correlations between items, while eliminating the influence from other items. Values close to 1 indicate that the patterns of correlation are compact, resulting in potentially reliable factors. Values close to 0 indicate large diffusion and potentially unreliable factors (Cerny and Kaiser, 1977). Thus, it is a measure of appropriateness of the data for factor analyses.

being classified as "good" (Nunnally, 1978) and fully complying with other recommendations (see Peterson, 1994, for review). For full details, see Tables 7-10.

4. Results

4.1. The design dimension

For the design dimension, a Factor Analysis was conducted on 10 variables. In an initial analysis, the Eigenvalues were obtained for each factor. Since one variable showed complex structures, it was separated from the analysis and kept individually. For the remaining variables, the Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis[6]. The results of the Factor Analysis (Table 7) suggested that 4 factors should be maintained. Combined, they explained 74.1% of the variance. The variable "Reduction of the toxicity of the product or service" was separated and maintained as an individual variable.

Table 7. Factor loadings after rotation for the design dimension

Design Dimension What has been the degree of impact of the eco-innovation on...	**N**	**Mean**	**SD**	**Factor** 1	2	3	4	**Communalities**
...material, energy, water or land use savings?	196	2.43	1.215			0.932		0.902
... increase in the possibility of recycling?	193	3.19	1.486	0.502				0.574
... increased product or service life cycle?	196	3.78	1.358	0.697				0.579
...reduction of emissions in air, water or reduction of residuals?	195	2.32	1.285				1.005	0.989
... increase in the use of renewable materials?	194	3.75	1.324	0.943				0.795
... abandonment of resources and materials in favour of more sustainable resources and materials?	195	3.61	1.382	0.788				0.638
... discontinuation of previous production and delivery processes towards more sustainable solutions?	196	3.68	1.348		0.861			0.684
...discontinuation of previous management processes?	196	4.13	1.083		0.853			0.768
... total or partial redefinition of the business model?	196	4.31	1.038		0.814			0.739
... reduction of the toxicity of the product or service?	195	3.50	1.487					
Eigenvalue				3.568	1.338	0.933	0.830	
% of Variance				39.641	14.869	10.363	9.225	
Cronbach's Alpha				0.771	0.800			

[6] KMO = 0.797 (0.8 is "meritorious" according to Hutcheson and Sofroniou, 1999) and all KMO values were above 0.642, which is above the acceptable limit of 0.5 (Field, 2013).

Notes: Scale 1 to 5 (indicating, respectively, to a large, fair, moderate, small and zero extent). Loadings lower than 0.4 are not shown. Explained total variance = 74.099 per cent; KMO = 0.797; Bartlett's test of Sphericity Approx. Chi-Square = 517.185, df = 36; p = 0.000. Cronbach's Alpha calculated for the Likert scale defined by the items that principally load on each factor.

The design dimension is made up of 5 factors that refer to impacts on the input composition of the product, service or a combination of both, impact on the firm's processes, impact on (direct) savings, various types of emissions and toxicity.

Factors 1, 3, 4 and the initially excluded variable "impact on toxicity" refer explicitly to the environmental impacts of the eco-innovation and not to changes in the internal management practices of the company. Factor 1 represents the eco-innovation's impact on the input composition of the product/service (substitution of more sustainable alternatives for traditional input resources and materials, higher recycling and a longer useful product life-cycle). The emphasis is on product composition rather than on processes. Factor 3 represents direct environmental savings from the eco-innovation (input side), including reductions in the use of physical input materials, energy, water and land use, which may not be intentional but a side-effect (i.e., Antonioli et al., 2013; Machiba, 2010). But, in contrast to factor 1, it specifically addresses firm competitiveness through increased efficiency and corresponding cost reductions. Factor 4 (impact of the eco-innovation on reductions of air emissions and waste water) also refers explicitly to environmental impacts but, in contrast to factor 3, to the "output side". It reflects the literature's proposition of "low-hanging fruit" eco-innovations that are achievable without requiring accompanying changes in products, services or processes (i.e., Braungart et al., 2007; Klewitz and Hansen, 2013).

In contrast, factor 2 represents the impact of the eco-innovation on the firm's organisational changes and processes, including effects on production and delivery processes that turn "greener" as a result, changes in management processes and a redefinition of the firm's business model. The main feature of this factor is its emphasis on the rupture with the previous management processes due to the eco-innovation.

4.2. The user dimension

For the user dimension, a Factor Analysis was conducted on 10 variables. Two of the original 12 variables were removed due to the low response rates resulting in low informational value and, thus, potential statistical difficulties. Eigenvalues were obtained for each factor. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis[7]. The results of the Factor Analysis (Table 8) suggest that there are three factors, which explain 76.8% of the variance.

Table 8. Factor loadings after rotation for the user dimension

User Dimension		N	Mean	SD	Factor 1	Factor 2	Factor 3	Communalities
During the process of creation, development or adoption of the eco-innovation, what has been the degree of implication of...	...current external users or clients?	197	3.67	1.324	0.869			0.752
	...current internal users or clients?	197	2.74	1.306		0.910		0.729
	...potential external users or clients?	195	3.85	1.283	0.912			0.794
	...potential internal users or clients?	194	3.63	1.281		0.681		0.746
	...current intermediate agents?	194	3.40	1.273			0.704	0.787
During the process of creation, development or adoption of the eco-innovation, what has been the degree of anticipating the acceptance of...	...current external users or clients?	194	3.35	1.418	0.716			0.772
	...current internal users or clients?	194	3.00	1.308		0.793		0.788
	... potential external users or clients?	194	3.60	1.317	0.771			0.779
	...potential internal users or clients?	194	3.54	1.312		0.662		0.729
	...current intermediate agents?	193	3.57	1.322			0.712	0.801
	Eigenvalue				5.656	1.238	0.784	
	% of Variance				56.560	12.377	7.837	
	Cronbach's Alpha				0.905	0.847	0.834	

Notes: Scale 1 to 5 (indicating, respectively, to a large, fair, moderate, small and zero extent). Loadings less than 0.4 are not shown. Total variance explained = 76.774 per cent; KMO = 0.773; Bartlett's test of Sphericity Approx. Chi-Square = 1393.198, df = 45; p = 0.000. Cronbach's Alpha calculated for the Likert scale defined by the items that principally load on each factor.

The results confirm the role of users and customers (factors 1 and 2) and intermediaries (factor 3) in eco-innovation. Factors 1 and 2 stress the relevance of user involvement in eco-innovation. This can refer to internal or external users and clients. And it may refer to their implication in the eco-innovation process or to the

[7] KMO = 0.773 ("middling" according to Hutcheson and Sofroniou, 1999) and all KMO values were above 0.705, which is well above the acceptable limit of 0.5 (Field, 2013).

anticipation by the eco-innovator of the acceptance of the eco-innovation by these actors. Similarly, factor 3 emphasises the role of the involvement of one specific actor (intermediaries) in eco-innovation, as well as anticipating their acceptance.

4.3 The product-service dimension

For this dimension, a Factor Analysis was conducted on 11 variables. Two of the original 11 variables from the questionnaire measured changes in the value chain induced by the eco-innovation, specifically with regard to “other”, previously unspecified stakeholders. However, there were few unspecified stakeholders and, thus, the corresponding variables were removed. One variable showed complex structures and was kept individually. For the remaining 8 variables, Eigenvalues were obtained for each factor in the data. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis[8]. The results of the Factor Analysis (Table 9) suggested that 3 factors should be maintained (87.5% of the variance).

Table 9. Factor loadings after rotation for the product-service dimension

Product-Service Dimension		N	Mean	SD	Factor			Communalities
					1	2	3	
Has the eco-innovation changed the offer of your business…	…with improved products or services?	197	3.25	1.427			0.954	0.868
	…by facilitating the entrance into new markets?	196	3.65	1.379	0.829			0.862
	…with increased convenience for clients or users?	195	3.34	1.400			0.899	0.878
	...with increased personalization of the offer?	196	3.73	1.342			0.583	0.809
Has the eco-innovation changed the value chain of your business…	…by creating new kinds of relations with current clients or users?	196	3.67	1.315	0.863			0.883
	… by integrating new clients or users?	196	3.71	1.306	0.991			0.942
	…by creating new kinds of relations with current suppliers?	196	3.57	1.241		0.710		0.840
	… by integrating new suppliers?	195	3.54	1.249		0.990		0.919
Has the eco-innovation changed the offer of your business	…with new products or services?	197	3.62	1.422				
	Eigenvalue				5.728	0.804	0.469	
	% of Variance				71.602	10.047	5.864	
	Cronbach’s Alpha				0.944	0.838	0.903	

Notes: Scale 1 to 5 (indicating, respectively, to a large, fair, moderate, small and zero extent). Loadings less than 0.4 are not shown. Total variance explained = 87.514 per cent; KMO = 0.900; Bartlett’s test of Sphericity Approx. Chi-Square = 1447.506, df = 28; p = 0.000. Cronbach’s Alpha calculated for the Likert scale defined by the items that principally load on each factor.

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[8] KMO = 0.9 (“marvellous” according to Hutcheson and Sofroniou, 1999) and all KMO values were above 0.846, which is above the acceptable limit of 0.5 (Field, 2013).

The three factors of this dimension are related to the two subdimensions of this dimension (change in the product-service deliverable and product-service process). It stresses the "revenue side" of the competitive advantage of firms, in contrast to the "cost side" which is present in the first dimension. The generation of eco-innovations largely depends on the benefits received by the innovator. Successful innovations must provide higher value (or reduce costs) and, ultimately, either increase revenues from existing customers or attract new customers.

Factor 1 represents major changes in the firms' product offer and the value chains (with respect to clients/users) as a result of the eco-innovation, including entry into new markets, new clients and new relationships with existing clients. Factor 2 specifically covers relations with suppliers. It includes changes in the relationships with existing suppliers and new suppliers. Factor 3 groups variables that represent incremental advances caused by the eco-innovation with improved products/services, major personalization of the offer and a greater convenience for the use of the product/service.

4.4. The governance dimension

For the governance dimension, a Factor Analysis was conducted on 20 variables. Two variables showed high correlations between themselves and very low correlations with the other variables (none above 0.3). They were separated from the analyses and maintained individually. For the remaining 18 variables, Eigenvalues were obtained for all factors. The Kaiser-Meyer-Olkin measure verified the sampling adequacy[9]. The results of the Factor Analysis (Table 10) suggested that 6 factors should be maintained (82.3% of the variance).

Table 10. Factor loadings after rotation for the governance dimension.

Governance Dimension		N	Mean	SD	Factor						Comm-unalities
					1	2	3	4	5	6	
During the process of creation, development or adoption of the eco-	...clients or users?	196	2.78	1.131				0.894			0.873
	...competitors?	197	3.65	0.634			0.671				0.726
	...consultants or private research centers?	197	3.01	1.027		0.878					0.719

[9] KMO = 0.715 ("Middling" according to Hutcheson and Sofroniou, 1999). All KMO values were above 0.660, and the acceptable limit of 0.5 (Field, 2013).

innovation, how frequently has your firm cooperated with...	...universities or public research centers?	197	3.36	0.935		0.685					0.732
	... regulators and public administration?	195	3.35	0.948						-0.925	0.912
	... scientific conferences, fairs and expositions?	197	3.26	0.998	0.659						0.762
	...scientific journals and technical/commercial publications?	197	3.31	0.898	0.865						0.847
	... professional industry associations?	195	3.45	0.862			0.682				0.762
	... non-governmental organizations?	197	3.75	0.603					-0.899		0.905
	...suppliers	197	2.05	1.096							
During the process of creation, development or adoption of the eco-innovation, how important has been the cooperation with...	...clients or users?	196	2.64	1.242				0.904			0.863
	...competitors?	197	3.63	0.721			0.743				0.735
	...consultants or private research centers?	197	2.90	1.141		0.865					0.827
	...universities or public research centers?	197	3.28	1.044		0.696					0.808
	...regulators and public administration?	195	3.28	1.044						-0.920	0.910
	...scientific conferences, fairs and expositions?	197	3.27	0.975	0.641						0.740
	...scientific journals and technical/commercial publications?	197	3.28	0.930	0.847						0.827
	...professional industry associations?	195	3.41	0.928			0.728				0.796
	... non-governmental organizations?	197	3.75	0.593					-0.934		0.908
	...suppliers?	196	1.93	1.126							
	Eigenvalue				7.372	1.954	1.623	1.506	1.231	1.126	
	% of Variance				40.954	10.853	9.014	8.368	6.837	6.255	
	Cronbach's Alpha				0.895	0.863	0.835	0.939	0.974	0.962	

Notes: Scale 1 to 5 (indicating, respectively, to a large, fair, moderate, small and zero extent). Loadings less than 0.4 are not shown. Total variance explained = 82.281 per cent; KMO = 0.715; Bartlett's test of Sphericity Approx. Chi-Square = 4152.462, df = 153; p = 0.000. Cronbach's Alpha calculated for the Likert scale defined by the items that principally load on each factor.

The results of the Factor Analysis stress the relevance of the frequency and importance of cooperation with different stakeholders: cooperation engagement on conferences, exhibitions and fairs and scientific, technical or commercial publications (factor 1), cooperation with consulting and private research firms and with universities and public research centres (factor 2), with competitors and industry associations (factor 3), with clients (factor 4), with NGOs (factor 5) and with regulators (factor 6). In addition to the 6-factor solution, 2 individual variables (frequency and importance of cooperation with suppliers) were maintained as they were not correlated with other variables. Their high mutual correlation caused the two variables to form one factor in the initial Factor Analyses.

5. Discussion

Most discussions on eco-innovation have focused on their drivers/barriers as well as on their radical/incremental nature and their potential contribution to a transition to environmentally sustainable production and consumption patterns. The results of this article suggest that eco-innovations are not (only) characterized by their environmental impacts, but also by other aspects. In fact, the final impact of eco-innovation on the environment goes in tandem with and is usually mediated by considerable impacts at the company level, including changes in the business offer, in the structure of the firm, in the firm supply chain and in the type and degree of involvement and interaction with other stakeholders. Useful eco-innovation frameworks should be inclusive of the different characteristics featuring eco-innovations beyond the narrow focus on their environmental impacts and drivers/barriers.

Our results show that, indeed, eco-innovations involve a combination of characteristics belonging to the four dimensions proposed by Carrillo-Hermosilla et al. (2010), which play a significant role in understanding their multi-faceted nature and diversity. Although the design dimension has received most attention in the past, the other dimensions are also very relevant to explain the phenomenon of eco-innovation. This article reveals that the multitude of previously identified characteristics of eco-innovations belongs to an underlying structure made up by the four dimensions and the different factors within them.

In particular, the *design dimension* stresses the relevance of the impact of eco-innovations on processes, products and organizational changes. From the environmental point of view, the emphasis is both on a reduction of inputs (especially on materials, but also on energy and water) and outputs (emissions). However, as mentioned above, the design dimension (and, more specifically, factor 2) also stresses the relevance of the impact of eco-innovation on "company variables". More specifically, our findings suggest that eco-innovations have a direct effect on firms' business models, i.e. changes in operative processes facilitate those "upward" shifts towards more sustainable business models. This focus on the impacts of the eco-innovation on the firm is in contrast to the previous literature, which has put the emphasis on the environmental impacts in this dimension (see Table 1) and/or the radicalness of technological changes (see Carrillo-Hermosilla et al., 2010). Interestingly, our results show that company variables mediate the relationship between the eco-innovations and the environmental impacts. It does also show the importance of "around company" variables, i.e., the productive (supply chain) and user/client environment surrounding the firm and its influence on the success of the eco-innovation.

Our results regarding the *user dimension* suggest the relevance of both the degree of actual involvement during development or adoption processes of this group and anticipated acceptance of the final eco-innovation within this group. The relevance of user involvements confirms that user-led eco-innovations and those with a greater market focus have a better chance of market success (Pujari, 2006 and Table 2). Empirical research has shown the importance of users both in eco-innovation (Carrillo-Hermosilla et al., 2010; Del Río et al., 2016a, 2016b) as well as in other types of innovation (see e.g., Luthje et al., 2006; Riggs and Von Hippel, 1994). Some of them adopt the roles of inventors and co-developers (Baldwin et al., 2006).

The anticipation of users' acceptance of the eco-innovation is an interesting second element in this dimension. As with other innovations, the market orientation of eco-innovations is a critical aspect in their successful diffusion. Thus, in order to encourage their penetration, it is important to create links between their environmental protection attribute and other critical factors of competitive products/services such as style, design, price and performance. If the eco-innovations can easily be embedded in existing lifestyles routines and production processes, user acceptance is easier to obtain (Kemp, 1994).

Since both the actual involvement and anticipated acceptance by users and clients can be included in the same factor, this indicates that these two tasks are closely tied together, i.e. they might work in tandem. In other words, the implication in "co-development" processes goes hand in hand with anticipating market acceptance within each group. This is in contrast to the literature, which usually separates both aspects (see, e.g., Carrillo-Hermosilla et al., 2010). The current involvement/acceptance of clients/users is as important as the anticipation of their involvement/acceptance. The user dimension also highlights the role of intermediaries in eco-innovation and, particularly, the involvement of current intermediaries and the anticipation of the acceptance of these intermediaries. Intermediaries can play a main role in eco-innovation by assisting firms. They can provide external impulse, motivation, advice and other specific support, often by acting as an agent or broker between two or more parties (Klewitz et al 2012).

Regarding the *product-service dimension*, our results suggest that the eco-innovation may entail either radical, path-breaking changes in existing relations between the firm and its production network (including new or existing clients, users and suppliers) or business-as-usual, incremental improvements in the product offer and value chain. This indicates that providing higher value for existing customers and attracting new customers is a must for successful eco-innovations. Again, this stresses the focus on the necessary market orientation of the eco-innovations, which is also emphasised by the user dimension, either by fulfilling the needs in existing markets or opening new markets.

On the one hand, as suggested by factor 1, the eco-innovation may entail a significant departure from the firms' current sales, a radical departure from the foundations on which the firm sales are based (i.e., firm competitiveness), a rupture with the traditional markets in which the firm is present (new markets) and changes in the value chain (new relationships with customers and new clients). Previous literature often refers to these major changes in the context of business model innovation (i.e., Adams et al. 2016, Klewitz and Hansen, 2013) rooted in systemic eco-innovations (i.e., Tongur and Engwall, 2014). And in fact, this factor is related to the subdimension "product/service process", which refers to changes in the value networks (Könnölä and Unruh, 2007) and would represent the most radical changes within the product-service dimension.

In contrast, the eco-innovation may have minor impacts on the foundations of the firms' competitiveness, i.e., only small changes which improve the offered products for existing customers and markets (e.g., factor 3). It may lead to a refinement, reconfiguration and adjustment of existing processes within existing business models (i.e., Tongur and Engwall, 2014) and the "greening" of existing product-service deliverables (Tietze and Hansen, 2013).

Finally, our findings also indicate that the eco-innovation modifies traditional collaboration models and value creation within the existing value chain (changes in the relationships with existing suppliers and new suppliers, factor 2). This change in the relationships with suppliers as a result of the eco-innovation has not been sufficiently stressed in eco-innovation research.

The results regarding the *governance dimension* confirm the relevance of collaboration in eco-innovation regarding knowledge exchange, as shown by Del Río et al. (2016a, 2016b), Ghisetti et al. (2015) and De Marchi (2012), but they add additional insights. A relevant, remarkable finding is that, for all external cooperation partners, the frequency and importance of cooperation are highly correlated, i.e., very important cooperation takes places on a very frequent basis, and vice versa. These results indicate that as important as the breadth of cooperation is the depth of cooperation and that both breadth and depth are related. Our results indicate that, at least for Spanish industrial SMEs, cooperation is quite stable. Important cooperation persists continuously along the eco-innovation process.

Another insight is that cooperation is not only driven by knowledge exchange, but motivations to engage in cooperation are diverse. Cooperation with competitors and industry associations is rather about forming industry networks and common positions in order to lobby regulators, including standard-setting processes allowing these firms to shape the future development of the industry or market (Tether, 2002). This is especially relevant for SMEs, which don't have enough resources or visibility (Kesidou and Demirel, 2012; Klewitz et al., 2012). Cooperation with NGOs may allow firms to mitigate the pressure on firms to change their behaviour with respect to environmental protection (De Marchi, 2012; Rondinelli and London, 2003). Cooperation with regulators may allow firms to anticipate and react adequately to regulation, but also to engage proactively with regulators in order to influence environmental policy. Cooperation with clients allows firms to detect demand for future product-service deliverables and to anticipate their feasibility and economic success[10]. Cooperation with suppliers facilitates joint innovation, which typically takes place on the basis of products and services delivered by the supplier and used further

[10] The user dimension picks up details on user-producer interactions from a market perspective and is enriched by a firm governance perspective. Hence, user-producer cooperation is an activity taking place on several "levels" between firms and clients/users. This finding is in line with previous research and represents an advance through the identification of these "levels" (Bogers et al., 2010; Junquera et al., 2012; Del Río et al., 2016b).

by the cooperating firm. Strategic supplier-firm cooperation might be a constant source of “traditional” innovations (Tether, 2002), and eco-innovations (De Marchi, 2012).

Finally, our results (and especially the design and product-service dimensions) also indicate that all types of eco-innovations have a role to play in the transition to more sustainable production and consumption patterns. Eco-innovations may entail changes of all types (environmental impacts, internal changes in the firm and changes in the relationships between the firm and its external environment). However some eco-innovations (system changes) would have more relevance in the reduction of environmental impacts and contribution to the sustainable transition than others (end-of-pipe eco-innovations and incremental eco-innovations leading to eco-efficient solutions). Different eco-innovation types entail different degrees of changes in the company and its relationships with the outer environment and will also have different implications for the management of the firm and for public policies aiming to support those eco-innovations.

6. Conclusions

The understanding of the characteristics and particularities of the eco-innovation process is crucial to manage it more efficiently (Xavier et al., 2017, p.2). The analysis of Carrillo-Hermosilla et al. (2010) already suggested that eco-innovations entail a combination of characteristics pertaining to different dimensions. The aim of this article has been to reveal the simple, underlying set of characteristics that the diversity of eco-innovation has in common, in order to reduce the current complexity to characterize eco-innovations, and to build a common perspective on the phenomenon.

The results of this article suggest that eco-innovations are not only characterized by their environmental impacts, but also by other aspects and reveal that the multitude of previously identified characteristics of eco-innovations belongs to an underlying structure. The final impact of eco-innovation on the environment goes in tandem with and it is usually mediated by considerable impacts at the company level (including internal management and organizational practices) which lead to changes in products and processes. Furthermore, our results stress the critical role played by users and clients' engagement and acceptance and the breadth and depth of cooperation with other stakeholders in the eco-innovation process. The eco-innovation may entail radical, path-breaking changes in existing relations between the firm and its value network.

Some policy and managerial implications stem from our research. Some design aspects of eco-innovations are directly related to firm competitiveness. Also, some eco-innovations may fundamentally change the value network and have an impact on value creation. This is especially worth looking at in industries under transformation. Furthermore, our findings stress the focus on the necessary market orientation of the eco-innovations, a lesson for firms willing to eco-innovate. In order to be successful, eco-innovations have to be competitive in the marketplace regardless of their environmental attributes. Another main implication is that facilitating collaboration channels between companies and other actors is effective in triggering eco-innovation and public policy makers can play a critical role in facilitating such cooperation. Cooperation is a complement to the internal innovation capacities and competences of the firm. On the other hand, managers willing to be more eco-innovative and successful should have a clear understanding of users' needs and wants. Assessing market needs is important for market success.

Some limitations of this research are worth mentioning. Although participants have a high degree of relevant knowledge, the measures are self-reported. In addition, the cross-sectional data were collected from a specific target universe, i.e. the results are not fully transferable. Our results are country-specific, since the institutional context (including environmental regulation, environmental awareness and the national system of innovation) is different across different countries. However, these results can certainly be generalized to countries with similar features as Spain. Future investigations should also include countries with different institutional and other characteristics (i.e., large vs. small countries, open vs. closed economies, developing vs. developed countries, countries with a high share of manufacturing vs. services, countries with a large weight of high-technology vs. traditional sectors…).

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