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Eco-innovation: Spanish service and manufacturing firms

Elisenda Jové-Llopis
Agustí Segarra-Blasco

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Departament d'Economia
www.fcee.urv.es/departaments/economia/public_html/index.html
Universitat Rovira i Virgili
Facultat d'Economia i Empresa
Av. de la Universitat, 1
43204 Reus
Tel.: +34 977 759 811
Fax: +34 977 758 907
Email: sde@urv.cat

CREIP
www.urv.cat/creip
Universitat Rovira i Virgili
Departament d'Economia
Av. de la Universitat, 1
43204 Reus
Tel.: +34 977 758 936
Email: creip@urv.cat

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Eco-innovation: Spanish service and manufacturing firms

Elisenda Jové-Llopis and Agustí Segarra-Blasco (§)

Abstract:

The drivers for the adoption of an eco-innovation strategy have been widely explored in the recent literature but, to date, most of these studies have been carried out on manufacturing industries. Hence, this paper investigates the similarities and differences between service and manufacturing firms, distinguishing between the high-tech and low-tech sectors. Using panel data of 4,535 Spanish firms for the period 2008—2014, we specify a dynamic probit model with sample selection. In line with other contributions in the literature, our results confirm the importance of regulatory stimulus to eco-innovation, mainly in form of demand-pull and, especially, in terms of demand push (subsidies) for sectors with low technology intensities. Institutional sources of information seem to be a more important driver for services firms with high technology intensity, whereas manufacturing firms rely more on internal or other sources of information. Furthermore, we find that eco-innovation is highly persistent at the firm level in both sectors and at both technology intensities. Hence, past eco-innovation behaviour is clearly more decisive in explaining the current state of eco-innovation orientation.

Keywords: eco-innovation strategy, environmental innovation, service sector, manufacturing sector, green strategy, Spain

JEL Classification Numbers: O31. Q55

(§) Research Group of Industry and Territory

Department of Economics – CREIP, Universitat Rovira i Virgili

Av. Universitat, 1; 43204 – Reus, Spain Tel. + 34 977 759 816 Fax + 34 977 300 661

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1. INTRODUCTION

In developed countries, there is an increasing political and social awareness of the need to promote a European Union agenda based on smart, suitable, and inclusive growth (Europe 2020). This has led to a widespread consensus that eco-innovation plays a key role which, consequently, has become an important aim of the major EU policy strategies (OECD 2011; EEA 2014). For instance, within the framework of the Europe 2020 agenda, the European Commission launched a specific program, the Eco-Innovation Action Plan (EcoAP), with the aim of ensuring environment sustainability through innovation.

In response to pressures for a sustainable environment, a growing interest in improving the understanding of innovation processes aimed at sustainability has emerged between researchers and policy makers. In particular, eco-innovation is characterized by the so-called double externality providing, on the one hand, the typical R&D spillovers and, on the other, the reduction of environmental externalities (Rennings 2000). Hence, over the past decade, many empirical papers have devoted attention on the drivers of eco-innovation, (Horbach 2008; Carrillo-Hermosilla et al. 2009; del Río et al. 2011; Triguero et al. 2013; Srholec 2014; Díaz-García et al. 2015; Ghisetti et al. 2015; Hojnik and Ruzzier 2015; Horbach 2016).

Because of the higher environmental impact of manufacturing, most eco-innovation studies have been focused on the role played by these sectors. Such studies primarily rely on an econometric analysis of cross-sectional data (De Marchi 2012; Horbach et al. 2013; Cuerva et al. 2014; del Río et al. 2015b; Cainelli et al. 2015). But, service firms account for 60–70% of GDP in most OECD countries and the Spanish compound annual growth rate of CO_2 levels in service firms increased by 2% over the period 2008–2013 (while manufacturing firms reduced by 6%).[1] Despite this, service sectors have not received

[1] Source: EUROSTAT (2013).

comparable attention, as del Río et al. (2016) highlighted in their recent review of firm-level determinants to eco-innovation.[2]

Hence, the main purpose of this study is to analyse the drivers influencing the adoption of an eco-innovation strategy in Spanish services and manufacturing firms with respect to firms not oriented towards eco-innovation. To carry out the econometric analyses we use panel data drawn from the Spanish Technological Innovation Panel (PITEC), a dataset that comprises some waves of the Community Innovation Survey. Using an extensive sample of 4,535 Spanish services and manufacturing firms for the period 2008–2014, we applied a dynamic probit model controlling for sample selection. Our results confirm the importance of regulatory stimulus to eco-innovation mainly in form of demand-pull and, especially, in terms of demand push (subsidies) for sectors with low technology intensities. Institutional sources of information seem to be a more important driver for services firms with high technology intensity, whereas manufacturing firms rely more on internal or other sources of information. Furthermore, we find that eco-innovation is highly persistent at the firm level in both sector and at both technology intensities.

This paper makes several contributions. First, as del Río et al. (2016) and Díaz-García et al. (2015) pointed out in their recent literature review on eco-innovation, analysis of the main drivers of eco-innovation in sectors, other than manufacturing firms, is almost nonexistent. Hence, we contribute to the existing body of literature on eco-innovations by exanimating the similarities and differences between service and manufacturing firms with different technology intensity (including high-tech and low-tech sectors) in the Spanish context. Second, the literature has strongly relied on German data (Rennings et al. 2006; Horbach 2008; Horbach et al. 2012; Horbach 2014) and few papers have focused

[2] One exception is Cainelli and Mazzanti (2013) which explores the manufacturing-services interlinks in environmental terms for more than 8,000 Italian services firms using the cross-sectional database CIS (2008).

on Southern Europe countries.[3] We consider Spain, a moderate innovation country ranked number 9 in the Eco-Innovation Scoreboard (Eco-IS 2015)[4], but one with both a relatively low level of environmental regulation stringency and a low customer awareness, as compared to European countries such as Netherlands, Finland and Germany, of the need to pay more for green as opposed to other products. The specific Spanish characteristics which distinguish it from other European countries make this analysis well worthwhile. Finally, the econometric analysis on the eco-innovation literature has been mainly based on small and cross-sectional samples (Petruzzelli et al. 2011; Horbach et al. 2012; Cainelli and Mazzanti 2013; Horbach et al. 2013; Triguero et al. 2013; Cuerva et al. 2014; Horbach 2016), while there is almost no use of panel data.[5] We take advantage of a large panel database for Spanish firms (PITEC) that allows us to analyse the dynamic character of eco-innovation strategy and to control for non-observable heterogeneity. In addition, the panel data allows us to examine persistence and path dependence in eco-innovation, topic not previously addressed in the literature on drivers of eco-innovation strategy.[6]

The remainder of the paper is structured as follows. Section 2 consists of a literature review. Section 3 presents the database, the variables and some descriptive statistics.

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[3] For some exceptions that analyse the driver of eco-innovation in manufacturing sector in Southern Europe countries, see: Cainelli et al. (2012) for the Italian context and del Río et al. (2015), Cuerva et al. (2014) and Cainelli et al. (2015) for Spanish context.

[4] The Eco-Innovation Scoreboard (Eco-IS) is the first tool to assess and illustrate eco-innovation performance across the EU Member States. The scoreboard aims at capturing the different aspects of eco-innovation by applying 16 indicators grouped into five thematic areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes.

[5] Few contributions using panel data exist, but they have some peculiarities: 1) Some used industry as a level of analysis instead of firm level as in our study. We find the seminal contribution from Jaffe and Palmer (1997) empirically investigating the relationship between innovation and regulation policy using panel data for US manufacturing sector for the period 1976–1991 and del Río et al. (2011) working with twelve Spanish industrial sectors, i.e., 84 observations for the period 2000–2006; 2) Others had a different analytical focus, such as Sáez-Martínez et al. (2016) investigating the technological trajectory of 212 young firms in Spain for the period 2001–2011.

[6] See some exceptions: Sáez-Martínez et al. (2016) and Horbach (2008).

Section 4 contains the econometric methodology. Section 5 shows our main findings. The last section presents our conclusions and the consequent policy implications.

2. DRIVERS FOR ECO-INNOVATION STRATEGY

2.1 Eco-innovation: definition and specificities

Defining eco-innovation is not a simple task, several definitions exist in the literature (Carrillo-Hermosilla et al. 2010; Díaz-García et al. 2015; Hojnik and Ruzzier 2015). In an EU-funded research project called "Measuring Eco-Innovation" (MEI), eco-innovation was defined by Kemp and Pearson (2007) as the: "*production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*".

In general, these innovations differ from more general innovations in that eco-innovations result in both economic and environmental benefits, hence the positive environmental impact of innovation is the core element of its definition (Carrillo-Hermosilla et al. 2009). From these definitions, it follows that eco-innovation can be part of any economic activity and it is neither sector- nor technology-specific. In addition, it can be intentional or not and relatively novel or significant compared to conventional technologies.

Then, a crucial question that environmental innovation scholars deal with is whether those eco-innovations, increasingly the aim of the major EU policy strategies, can be treated as normal innovations or whether there is a need for specific management and policy approaches to foster them. Until now, the literature has mainly focused on two aspects that differentiate eco-innovations from general innovations with regard their externalities and drivers.

The main specificity of eco-innovation is found in what is known as the "double externality problem" (Rennings 2000). Eco-innovation is characterized by the common positive externalities (knowledge spillovers and imitation) produced by innovation activities plus the environmental externalities generated. The second specificity, derived by the market-failure generated by the two externalities, is the need for greater public intervention, known as "regulatory push/pull effect" (Rennings 2000).

2.2 Drivers of eco-innovation

Some theoretical approaches are used in the literature to explain the main determinants of adopting an eco-innovation strategy.[7] Due to the particularities of eco-innovation highlighted above, some researchers have accepted that general innovation theory which includes technology push and demand factors as the main drivers of innovation is not enough to explore the decision to design an eco-innovation strategy. Hence, numerous studies emphasize that general innovation theory has to be extended with respect to the analysis of the role of regulatory and institutional factors (Porter and Linde 1995; Jaffe and Palmer 1997; Rennings 2000; Rennings et al. 2006; Horbach 2008). In particular, Horbach (2008) proposes the main elements of the environmental innovation theory that include demand side, supply side and environmental policy influences as drivers of eco-innovations.[8]

The determinants of eco-innovation are also based on the resource-based view (RBV). This theory argues that firms are heterogeneous, that is each firm has specific set of resources and capabilities that have been developed over the time and that these must be valuable, rare, imperfectly imitable and non-substitutable to become a competitive advantage (Barney 1991). Resource-based theory highlights the importance of internal resources of the firms; in contrast, more recently, the evolutionary perspective emphasizes the importance of innovation systems, the dynamic interaction between different actors and the internal and external factors influencing the innovation process (Nelson and Winter 1982).

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[7] It is worth mentioning that there is not a theoretical framework consensus in the literature, consequently each approach underlines some drivers and rejects others (Hojnik and Ruzzier 2015; del Río et al. 2016). The different approaches are not mutually incompatible and should be combined.

[8] This theoretical background in examining the drivers of eco-innovation has recently been adopted by other researchers (Horbach et al. 2012; Triguero et al. 2013; Cuerva et al. 2014; Doran and Ryan 2016).

Furthermore, taking into account the resource-based and evolutionary perspective approaches some researchers have categorized the drivers of eco-innovation as internal and external factors (Carrillo-Hermosilla et al. 2009; del Río 2009; Demirel and Kesidou 2011; Cainelli et al. 2015; Sáez-Martínez et al. 2016). Factors internal to the firm refer to internal resources such as technological capabilities, qualified employees or financial resources. Meanwhile, external factors refer to a firm's interaction with other agents through cooperation, collaboration, networks and market relations.

Recently, some researchers also integrate the extended view of stakeholders on eco-innovation (Sarkis et al. 2010; Tang and Tang 2012; Tyl et al. 2015). Stakeholder theory underlines that in order to survive and grow firms must take into account the impact and the role of different groups of stakeholders (Kassinis and Vafeas 2006; Carrillo-Hermosilla et al. 2010). In particular, internal stakeholders (managers and employees) and external stakeholders (customers, society, policy makers, and non-governmental organisations) are considered.

Similarly to the Horbach (2008) classification, we examine the drivers of eco-innovation strategy from the perspective of the supply side, demand side, environmental policy, as well as the firms' structural characteristics.

Technology push factors

The first group of factors for designing an eco-innovation strategy, technology push factors, are linked to the development of technological capabilities. The most important factors to build up such technological capabilities are investment in R&D and having qualified employees (Horbach 2008; Mazzanti and Zoboli 2009; Horbach et al. 2012; Horbach et al. 2013; Cainelli et al. 2015). Using a sample of German firms, Horbach (2008) shows that the improvement of technological capabilities measured in terms of R&D and high qualification of employees is a key determinant in favouring eco-innovations.

Nevertheless, the empirical evidence on the importance of internal R&D in fostering the introduction of an eco-innovation strategy is not conclusive. Based on an extensive sample of Spanish manufacturing firms, Cainelli et al. (2015) find that the presence of an R&D structure is positively and highly correlated with the introduction of eco-innovations. A similar positive relationship is found by Cuerva et al. (2014) for a sample of Spanish low tech firms. However, they find that technological capabilities such as R&D and human capital foster more intensity in conventional innovation rather than in green innovation. On the contrary, findings from studies in France and Germany show a negative relationship between internal R&D and eco-innovation, internal R&D is then not being the most important source of eco-innovation (Horbach et al. 2013).

These differences are also present in relation to qualification of employees. High qualified employees is not significant in introducing an eco-innovation strategy in the Spanish context (Cainelli et al. 2015), however it is positive and significant in the German context (Horbach 2008). In addition, training personnel positively supports the introduction of eco-innovation strategy in Southern Europe countries such as Spain or Italy (Cainelli et al. 2012; Cainelli et al. 2015).

H1: Internal technological capabilities promote eco-innovators to a greater extent than general innovators.

The high development of the innovation capacities of a firm (accumulation of human capital and available knowledge) may lead to further innovation success in the future. Following the seminal paper of Malerba et al. (1997) an increasing number of empirical publications devoted great attention to analysing the role of persistence in the general innovation literature, in other words, firms which innovate once have a higher probability of innovating again in subsequent periods (Martínez-Ros and Labeaga 2009; Peters 2009; Triguero and Córcoles 2013; Deschryvere 2014). This path dependency is known in the literature as “innovation breeds innovation” (Baumol 2002), and constitutes an important unexplored area in eco-innovation strategy. An exception is the Horbach (2008) paper that use German sample data to show that being innovative in the past increases the probability of being eco-innovative in the present or the future; that is, path dependences also occur in the green innovation process.

More recently, Sáez-Martínez et al. (2016) use a panel data on 212 young Spanish firms to explore whether, and to what extent, a firm's technological trajectory is a driver of eco-innovation. Their results show that only market-oriented innovators engage significantly more in eco-innovation and that path dependence occurs in the development of eco-innovation (a highly development of innovation capacity leads to additional green-innovation in the future).

H2: Eco past decisions, investments and behaviour help to explain current eco-innovation orientation.

Regarding external sources and cooperation, the literature stresses that eco-innovations are often more prone to cooperation and the search for new knowledge than are general innovations. This is because eco-innovations are characterized by high a level of uncertainty, novelty and the need to go beyond firm's core competences (see Horbach (2008) for Germany, Horbach et al. (2013) for Germany and France, Triguero et al. (2013) for 27 European countries, Mazzanti and Zoboli (2009) for Northern Italy and De Marchi (2012) and Cainelli et al. (2015) for Spain). In this, regard, a higher uncertainty for carrying out an eco-innovation strategy implies a high propensity to rely on external sources and partners. For instance, De Marchi (2012) and Triguero et al. (2013) show that cooperation with public research institutes and universities becomes more relevant for eco-innovators than for other innovators. Similarly, Cainelli et al. (2015) argue that the more types of partners a firm cooperates with, the greater the likelihood that the firm designs an eco-innovation strategy.

H3: Eco-innovation oriented firms require more external sources and cooperation with other partners than do general innovators.

Market-pull factors

The second set of drivers is related to market-pull factors. There is no strong empirical evidence that market pull supports eco-innovation (del Río et al. 2016). Some studies show that the expectation of a future demand, created by environmentally conscious customers, triggers investments in environmental innovation. In particular, Horbach (2008) shows that, for a panel data of German firms, customer demand and public pressure are the key drivers of eco-innovations. Similarly, Wagner (2008) shows that market research on green products has a positive effect on a firm's propensity to carry out eco-innovations, since such research is likely to lead to a better understanding of profitable demand for eco-product innovations as well as to identifying eco-oriented customer segments. More recently, using a sample of 27 European countries, Triguero et al. (2013) find that increasing market demand for green products and market share are also relevant to implementing product or organizational eco-innovation. Regardless, in countries with low environmental awareness and low willingness to pay more for environmentally friendly products a market pull effect will be very low or not expected.[9] For instance, using a sample of 3,341 Spanish manufacturing firms, del Río et al. (2015b) argue that demand-pull from the market is not perceptible and is not a driver either for eco-product innovation or for eco-process innovation.

H4: Market pull promotes eco-innovations to a lower extent than general innovations.

Regulatory pull and push factors

The last category of drivers, known as regulatory pull and push factors, is linked to the double externality problem and the role of public policies in fostering eco-innovations. In many empirical studies, regulations have been identified as an important driver of eco-innovation (see the seminal contribution of Jaffe and Palmer (1997), one of the earliest empirical studies at the industry level in the US context or, more recently, in the European setting, Horbach et al. (2012) for Germany, Horbach et al. (2013) for Germany and France; del Río et al. (2015b) for Spain, or Horbach (2016) for 19 different European countries). Hence, environmental regulation is highly relevant motivations for eco-innovations, a result that has also been postulated by the famous Porter-hypothesis (Porter and Linde 1995).[10]

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[9] According to the Special Eurobarometer (European Commission 2011; European Commission 2014), Spain has improved its ranking in regard to willingness-to-pay more for eco-products, but it still ranks below the EU average. For instance, in Special Eurobarometer survey 2011, 60% of Spanish citizens agree that they would be ready to buy environmentally friendly products even if they cost a little bit more while in Special Eurobarometer survey 2014 this proportion had risen to 73%. However, the respective percentages in other countries are higher than in Spain: Sweden (89%, 94%), Denmark (81%, 87%), Germany (76%, 80%), Romania (65%, 75%).

[10] The Porter-hypothesis postulates that well-designed environmental regulation stimulates innovation and may lead to a win-win situation where pollution is reduced and a firm’s future profits are increased (Porter and Linde 1995).

However, the impact of supply push instruments like subsidies on eco-innovation is not always clear in the literature. Horbach et al. (2012) and Horbach (2008), both for a Germany sample, find a positive and statistically significant influence of subsides on eco-innovation. Similar results are recently found by del Río et al. (2015a) and De Marchi (2012) in the Spanish context. Nevertheless, this variable does not seem to be especially important for eco-innovation either in Horbach et al. (2013), using a sample from the Community Innovation Survey (CIS 4) for France and Germany, or in Triguero et al. (2013) for 27 European countries. More recent, Horbach (2016) shows that regulation activities and environmentally related subsidies seem to be more important for the Eastern countries than they are for the Western European countries.

H5: Eco-innovation oriented firms depend on the public policies to a greater extent than do general innovators.

3. DATABASE, VARIABLES AND DESCRIPTIVE STATISTICS

3.1 Database

The analysis is based on firm level data from the Technological Innovation Panel (PITEC). [11] PITEC is a panel survey based on the Community Innovation Survey (CIS) framework, enabling us to compare our results with previous empirical results on similar datasets. In addition, it is one of the most used datasets in innovation studies and has recently been applied to studying eco-innovations (Cainelli et al. 2015; del Río et al. 2015a; Horbach 2016). The main advantage of the CIS dataset is that it contains detailed information on innovation behaviour at firm level thus allowing comparison between eco-

[11] More information on the dataset is available at the FECYT website: http://icono.fecyt.es/PITEC/Paginas/descarga_bbdd.aspx.

innovators and non-eco-innovators[12] rather than just analysing eco-innovators.[13] Such information is essential to this study. However, the CIS data has several constraints. One of its limitations is the subjective nature of many of the questions addressed to the firm's management or those responsible for R&D departments. Nevertheless, Mairesse and Mohnen (2005) provide evidence that the subjective measures of innovation surveys tend to be consistent with more objective measures of innovation, such as the probability of holding a patent and the share in sales of products protected by patents. Second, the CIS is a cross-sectional dataset; in contrast, PITEC is characterized by its time dimension. It has panel data for the period 2003–2014 making it possible to analyse long-term relationships between variables and to control for standard econometric issues, such as unobserved heterogeneity and simultaneity problems that are hard to detect in simple cross-sectional data or time series (Baltagi 2008).

Our final database selection was subject to a process of filtering. The main filters were as follows: 1) the data referred the period 2008–2014, because eco-innovation motivation questions were not included in the survey until 2008; 2) firms from the manufacturing and service sectors (high and low tech sectors) were analysed; 3) firms that reported confidentiality issues, mergers, employment incidents and so on were not incorporated in

[12] It is worth mentioning that the CIS questionnaire is not specifically designed to investigate eco-innovation, for that reason several interesting variables are not reported (e.g. market demand for green product or different environmental policy instruments). However, a separate module on eco-innovation was introduced only for the CIS 2008 survey. Unfortunately, Spain does not include this environmental module. The PITEC survey includes information on the objectives pursued by firms' innovation activities and on their importance. Among these objectives, three can be strongly linked to the environmental orientation of the firm: the reduction of environmental impacts, the decrease in energy consumption per unit produced and the improvement in health and safety aspects. In our analysis, these questions are used to distinguish between eco-innovation oriented firms and non-eco-innovation oriented firms.

[13] The literature on firm-level determinants of eco-innovate is abundant (Rennings et al. 2006; Wagner 2008; Kesidou and Demirel 2012; Cainelli and Mazzanti 2013; Triguero et al. 2013). In contrast, only recently have studies focused on driver to eco-innovation versus normal innovation using firm-level data (Cainelli et al. 2015; del Río et al. 2015a).

the sample. After all filtering, our empirical analysis is based on a panel of 4,535 Spanish firms for the period 2008–2014; of these 3,201 firms belong to the manufacturing sector and 1,334 firms to the service sector.

3.2 Variables

In this study, we consider eco-innovation as the dependent variable. Although the PITEC database is not specifically designed to examine environmental innovations, in 2008, the panel survey introduces a new question asking firms for the first-time what goals they were pursuing when they introduced innovation into products or processes, thus offering the possibility of making an independent analysis of eco-innovation orientation.[14] In this set of objectives, there are three that can be strongly linked to the environmental orientation of the firm: the reduction in environmental impacts, the decrease in energy consumption per unit produced and the improvement in health and safety aspects. Hence, we use a subjective measure of the motivational nature of the innovation from the survey to build our dependent variable (*eco-inn*) and differentiate firms that carry out eco-innovations than those firms that do not, an approach that has already been used in other studies on eco-innovation (Horbach 2008; De Marchi 2012; del Río et al. 2015b; Sáez-Martínez et al. 2016). Firms were asked to evaluate the importance of these three objectives on a Likert scale of 1 to 4, where 1 represents "high importance", 2 represents "intermediate importance", 3 represents "low importance" and 4 represents "factor not experienced". We have transformed these three-categorical variables into a single binary variable that is equal to 1 when a firm considers any one of the three objectives to have high importance and equal to 0 when the importance is intermediate, low, or not experienced.[15]

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[14] In 2008 the survey introduces the following question: *"Innovation activities carried out in your firm could be oriented to different objectives, how important were each of the following objectives for your innovation activities during the three last years?"* In total 16 objectives were asked.

[15] We evaluate the internal consistency of our grouping by computing Cronbach's alpha value. The Cronbach alpha for the *eco-inn* variable is 0.85, indicating an acceptable level of internal consistency.

Regarding the independent variables[16], we introduced a set of variables that the existing empirical literature lists as determinants of product and process eco-innovation orientation in capturing factors related to: (1) technology-push factors, (2) market-pull factors, (3) regulatory factors, and finally, (4) a set of firm characteristics (see Horbach 2008; Triguero et al. 2013; Díaz-García et al. 2015; Hojnik and Ruzzier 2015 among others).

To test the role of technological factors in adopting an eco-innovation strategy, the variables *R&D effort* and *training* are included. The first one measures the total expenditures on innovation activities per employee as a proxy for the stock of technological competences and the second one is a dummy variable, which indicates whether a firm invests in training its employees to develop technological innovations.

Then, to explore further differences as to whether eco-innovators rely on more partners for cooperation, we include a dummy variable *cooperation* indicating whether a firm reported having cooperated on innovation with other partners. In addition, the nature of their sources of information is recoded in four dummy variables: 1) whether the firm considers important the information from sources within the enterprise or group (i*nternal sources*), 2) from suppliers, clients, competitors or private R&D institutions (*market sources*), 3) from universities, public research organizations or technology centres (i*nstitutional sources*), and, 4) from conferences, scientific reviews or professional associations (*other sources*).

The demand-side set of factors includes two innovation objectives indicating an entry to the new markets (*new markets*) and an increase in market share *(market share).*

Concerning the environmental policy influences, regulation and subsidies policy measures are captured. *Regulation* measures how important is the fulfilment of environmental government regulations or standards for firms wishing to eco-innovate.

[16] Appendix 1 summarises the list of variables and their definition.

Subsidies indicates whether the firm has received public funds at regional, national or EU level.

The econometric analysis also includes a set of firm characteristics factors such as firm size (*lnsize*), measuring the number of employees in natural logs, whether the firm belongs to a group (*group*) and the propensity of firm to export (*export*).

3.3 Descriptive statistics

The sample used in the econometric analysis includes 4,535 Spanish firms of which 3,201 firms belong to the manufacturing sector (44.32% of those firms are classified as manufacturing with high technological intensity and the other 55.67% as manufacturing with low technological intensity) and 1,334 firms belong to the service sector (47.32% are high knowledge intensive services and the 52.78% are other KIS). Among the innovators, which represent the 68.71% of the firms in the sample, almost one-third of firms design an eco-innovation strategy.

In Table 2, we analyse the distribution of eco and non-eco innovators by industry. The comparative analysis points out the existence of industry heterogeneity. It seems that manufacturing firms are more likely to design an eco-innovation orientation than are knowledge intensive industries where just a minority are represented. That could be because manufacturing firms are usually subject to stricter environmental regulation and economic instruments than are service sectors (Cainelli and Mazzanti 2013).

Table 2
Eco-innovators, non-eco-innovators and non-innovators by sectors and technological intensity (2014)

	Total no. of firms	% of eco-innovator	% of other innovator	% of non-innovator
Manufacturing firms	3,201	32.02%	39.08%	28.90%
High tech	1,419	35.24%	41.30%	23.47%
Low tech	1,782	29.46%	37.32%	33.22%
Services firms	1,334	18.37%	44.60%	37.03%
High KIS	630	17.94%	51.11%	30.95%
Other HKIS	704	18.75%	38.78%	42.47%
Total firms	4,535	1,270	1,846	1,419

Source: PITEC database, own calculation

Regarding technological intensities, low tech manufacturing such as textile, woods or food and beverages are less likely to eco-innovate as compare to high tech manufacturing. In contrast, other knowledge intensive service firms tend to be slightly more eco-innovators than high KIS.

In Table 3, we analyse the main characteristics between Spanish eco-innovators, other innovators and non-innovative firms. The comparison highlights the following characteristics:

- Eco-innovation firms are larger, more often to belong a group and have more exposure to international competition;
- Firms that design an eco-innovation strategy seem to invest more in R&D activities, cooperate more and rely more on external sources of innovation (mainly in internal and market sources);
- Due to the double externality problem of eco-innovation pointed out in the literature, the regulatory pull and push effect seems to be highly relevant for eco-innovators firm rather than for their counterparts;
- Regarding eco-innovation strategy across sectors, there is a significant difference in the composition. It seems that manufacturing firms, both high tech and low tech, are more likely to introduce an eco-oriented strategy. In contrast, the services firms group represents just a minority.

Table 3
Descriptive statistics for eco-innovators, non-eco-innovators and non-innovators (mean values and standard deviation in brackets)

Variable	Eco-innovator	Other innovator	Non-innovator
Technology-push factors			
R&D effort	12014.9	8873.6	4077.9
	(54908.8)	(33697.4)	(19069.2)
Training	0.2373	0.1682	0.0169
	(0.4254)	(0.3740)	(0.1291)
Internal sources	0.7517	0.5826	0.2031
	(0.4320)	(0.4931)	(0.4023)
Market sources	0.6271	0.4398	0.1435
	(0.4835)	(0.4963)	(0.3506)
Institutional sources	0.2410	0.1368	0.0824
	(0.4277)	(0.3436)	(0.2750)
Other sources	0.2541	0.1409	0.0566
	(0.4354)	(0.3479)	(0.2310)
Cooperation	0.5139	0.3857	0.1159

	(0.4998)	(0.4867)	(0.3201)
Market pull factors			
New market	0.5540	0.3350	0.1200
	(0.4970)	(0.4720)	(0.3250)
Market share	0.5790	0.3356	0.1126
	(0.4937)	(0.4722)	(0.3161)
Environmental policy			
Regulation	0.6589	0.0807	0.0817
	(0.4740)	(0.2724)	(0.2740)
Subsidies	0.5033	0.3974	0.1744
	(0.5000)	(0.4893)	(0.3795)
Firm characteristics			
Size	361.33	254.6	238.5
	(1275.4)	(1088.5)	(498.6)
Group	0.5526	0.4640	0.4890
	(0.4972)	(0.4987)	(0.4999)
Export	0.3265	0.2748	0.2151
	(0.3295)	(0.3208)	(0.3036)
High tech manufactures	0.3983	0.3103	0.2095
	(0.4895)	(0.4626)	(0.4070)
Low tech manufactures	0.4201	0.3665	0.4129
	(0.4936)	(0.4818)	(0.4923)
High KIS	0.0830	0.1736	0.1380
	(0.2758)	(0.3787)	(0.3450)
Other KIS	0.0985	0.1493	0.2394
	(0.0985)	(0.3564)	(0.4267)
Observations	9,289	15,142	7,314

Source: PITEC database, own calculation

Table 4 shows the descriptive statistics of firms having an eco-innovation orientation among both sectors and technological intensities. The main characteristics can be summarised in the following aspects:

- Eco-innovation manufacturing firms seem to rely more on demand pull policies instruments such as regulation (67.40%). In contrast, we find that services firms, especially high KIS (76.24%), are more oriented to supply push environmental regulations such as subsidies[17];
- Manufacturing firms are less prone to invest in R&D and to cooperate in R&D projects than are services firms;

[17] It is worth mentioning that the subsidies variable indicates if a firm receives public financial support for innovation activities from local or regional authorities. Our data base does not allow distinguishing if this public support is focused on eco-innovations activities.

- In general, when we compare the sources of the innovation between sectors we can see that there are not significant differences among internal and market sources of information. Both sources are the most important for both sectors and intensities. However, services firms also give higher importance to institutional and other types of sources of information than manufacturing firms.

Table 4
Descriptive statistics eco-innovation strategy by sector and intensity (mean values and standard deviation in brackets)

	Manufacturing firms			**Services firms**		
Variable	**Total**	**High tech**	**Low tech**	**Total**	**High KIS**	**Low KIS**
Technology-push factors						
R&D effort	7584.6	9550.7	5720.7	31993.2	52992.4	14299.1
	(15539.9)	(15363.3)	(15478.4)	(122644.3)	(170052.5)	(51794.5)
Training	0.2158	0.2424	0.1906	0.3058	0.3670	0.3071
	(0.4114)	(0.4286)	(0.3928)	(0.4719)	(0.4823)	(0.4615)
Internal sources	0.7490	0.7808	0.7189	0.7639	0.7782	0.7519
	(0.4335)	(0.4137)	(0.4495)	(0.4247)	(0.4157)	(0.4321)
Market sources	0.6233	0.6310	0.6159	0.6423	0.6783	0.6163
	(0.4845)	(0.4825)	(0.4864)	(0.4787)	(0.4674)	(0.4865)
Institutional sources	0.2179	0.2151	0.2205	0.3451	0.4617	0.2469
	(0.4128)	(0.4109)	(0.4147)	(0.4755)	(0.4988)	(0.4314)
Other sources	0.2313	0.2494	0.2141	0.3570	0.4448	0.2830
	(0.4217)	(0.4327)	(0.4103)	(0.4792)	(0.4972)	(0.4507)
Cooperation	0.4854	0.5070	0.4650	0.6423	0.7341	0.5650
	(0.4998)	(0.5000)	(0.4988)	(0.4794)	(0.4420)	(0.4960)
Market pull factors						
New market	0.5696	0.5835	0.5564	0.4839	0.5642	0.4163
	(0.4951)	(0.4930)	(0.4968)	(0.4998)	(0.4961)	(0.4932)
Market share	0.6039	0.6235	0.5874	0.4667	0.48507	0.4563
	(0.4891)	(0.4851)	(0.4923)	(0.4990)	(0.5001)	(0.4979)
Environmental policy						
Regulation	0.6740	0.7118	0.6382	0.5907	0.5992	0.5836
	(0.4687)	(0.4529)	(0.4805)	(0.4918)	(0.4903)	(0.4932)
Subsidies	0.4781	0.4891	0.4675	0.6174	0.7624	0.4950
	(0.4995)	(0.4999)	(0.4990)	(0.4861)	(0.4257)	(0.5002)
Firm characteristics						
Size	290.6	326.0	257.1	680.1	398.2	917.63
	(802.8)	(956.3)	(621.5)	(2436.8)	(01311.8)	(3060.5)
Group	0.5703	0.5943	0.5475	0.4733	0.3904	0.5431
	(0.4950)	(0.4910)	(0.4977)	(0.4994)	(0.4881)	(0.4984)
Export	0.3720	0.4152	0.3310	0.1212	0.1483	0.1047
	(0.3278)	(0.3354)	(0.3151)	(0.2490)	(0.2604)	(0.2379)
High tech	0.4866			0.4573		
	(0.4998)			(0.4893)		
Low tech	0.5134			0.5427		
	(0.4998)			(0.4983)		
Observations	7,603	3,700	3,903	1,686	771	915

Source: PITEC database, own calculation

- Services firms with an eco-innovation orientation are larger, less often belong to a group and have less exposure to international competition than do manufacturing firms.

4. ECONOMETRIC METHODOLOGY

In order to model the dynamic process of designing an eco-innovation strategy for Spanish services and manufacturing firms between 2008–2014 we apply a dynamic probit model correcting by sample selection arising from the exclusion of non-innovative firms from the analysis (Heckman 1979). This methodology is based on a two-step procedure: the first stage equation -selection equation- estimates the probability that a firm will become a technological innovator and the second stage equation -outcome equation- estimates the probability that an innovative firm also orientates its strategy in environmental concerns. In addition, to investigate persistence in eco-innovation we follow a dynamic approach in the analysis based on the Wooldridge (2005) correction that accounts for the initial conditions of the dependent variables.

Innovation decision (selection equation):

$$Innovative_{it}^{*} = \beta_{11} innovative_{it-1} + \beta_{12} X_{it-1} + \beta_{13} Z_{it-1} + \varepsilon_{1it} \qquad \text{Eq. [1]}$$

$$innovative_{it} = 1 \; if \; innovative_{it}^{*} > 0, \qquad 0 \; otherwise$$

Eco-innovation orientation (outcome equation):

$$eco - inn_{it}^{*} = \beta_{21} eco - inn_{it-1} + \beta_{22} Y_{it-1} + \beta_{23} Z_{it-1} + \varepsilon_{2it} \qquad \text{Eq. [2]}$$

$$eco - inn_{it} = 1 \; if \; eco - inn_{it}^{*} > 0, \qquad 0 \; otherwise$$

Equation (1) estimates the probability that a firm innovates depending on a set of determinants related by the current literature.[18] $Innovative_{it}$ is a binary variable that takes the value 1 if firm *i* introduce a technological innovation between *t* and *t-2*. As explanatory variables (X), which are specifics in this equation we include the innovation input such as whether the firm invests in internal R&D or external R&D, the different

[18] See for instance: Vega-Jurado et al. (2008); Segarra-Blasco (2010); Hashi and Stojčić (2013) and Mate-Sanchez-Val and Harris (2014).

sources of information for innovation activities (internal, market, institutional and other sources), whether the firm cooperates or not with other agents and whether the firm receives public funds at regional, national or EU level.

Equation (2) measures the probability of designing an eco-innovation strategy. $Eco\text{-}inn_{it}$ is a binary variable that takes the value 1 if firm i introduce an eco-innovation between t and $t\text{-}2$. $Eco - inn_{it}^{*}$, the second latent variable, may be observed only when $innovate_{it}^{*}$ is equal to 1. As explanatory variables (Y), which are specifics in this equation, we include regulatory factors captured by the variables regulation and subsidies, technology push factors such as R&D effort, whether the firms' employees attended training specifically aimed at developing technological innovations, whether a firm reported having cooperated on innovation with other partners and the different sources of information for innovation activities (internal, market, institutional and other sources). And for the market market-pull factors we consider two innovation objectives indicating an entry to the new markets and an increase in market share.

In addition, both equations include different common sets of control variables (Z). We introduce firm characteristics such as firm size, whether the firm belongs to a group and whether the firm exports. In addition, we include industry and time dummies to control differences in the probability of being an innovator and an eco-innovator oriented across sector and over time. Finally, ε_{it} is the idiosyncratic error term. In the regression analyses, explanatory variables are lagged one-period to overcome those endogeneity problems deriving from reverse causality.

With respect to error terms, Eqs. (1) and (2) might contain some commonly omitted variables such as financial constraints, environmental managerial awareness, or organizational culture and therefore the correlation term ρ between ε_{1it} and ε_{2it} might not be equal to zero. In fact, our estimation of the parameter ρ is highly significant in all the models, justifying the choice of using a section bias model. Using models that do not consider the exclusion of non-innovative firms from the analysis would have led to biased results.

5. RESULTS

In this section, we present estimation results from the dynamic probit model correcting by sample selection for each sector and technology intensity. Table 5 reports both the selection equation, capturing the factors explaining the introduction of product or process innovations (eco or not eco), and the outcome equation, reporting the factors correlated with eco-innovation orientation propensity compared to other innovators, while controlling for potential bias arising from the exclusion of non-innovative firms from the analysis.

In both manufacturing and services firms, there is a weak relationship between technology push factors and a firm's likelihood of developing an eco-innovation orientation (Hypothesis 1). As far as the R&D efforts are concerned, the results suggest that eco-oriented innovators do not differ from non-eco-oriented innovators in terms of expenditures on innovation activities per worker in either sector or in technology intensity. This agrees with Horbach (2008) and De Marchi (2012) both for a manufacturing sample and Cainelli and Mazzanti (2013) for Italian services firms. The relevance of technology push factors is confirmed mainly in the manufacturing firms by the importance of training employees as seen in Cainelli et al. (2015). However, this variable is only significant for low-tech manufacturing firms.

In terms of eco path dependence, the empirical analysis reveals that past eco-innovation behaviour is an important driver of current eco-innovation status, providing support for Hypothesis 2. The coefficients of the lagged dependent variables are positive and significant for both sectors and technology intensities revealing that engaging in eco-innovation orientation during the previous year have a positive effect on the probability of being a green innovator in the current year. These results are in line with the scant literature on eco-innovation persistence. Two exceptions are Horbach (2008) and Sáez-Martínez et al. (2016) who show that being innovative in the past increases the probability of being eco-innovative in the current or future periods.

Results on cooperation and external sources are less straightforward; support for Hypothesis 3 is mixed. Regarding the impact of the role of cooperation, similarly to del Río et al. (2015a) for Spain and Horbach (2008) for Germany, we find the role of participating in cooperative projects in eco-innovators with high technology intensity more relevant compared to general innovators. Similar to us, Cuerva et al. (2014) are not able to confirm a positive relationship between cooperation with other partners and eco-innovation performance in low tech manufacturing industries using data of Spanish food and beverage sector. In addition, when we look at the service firms, in contrast with Cainelli and Mazzanti (2013), we do not find that cooperation is especially important for promoting eco-innovation.

Concerning sources of information, the results are in sharp contrast between the two sectors. In manufacturing firms, it seems, that even though eco-innovation activities rely more on internal sources of information, other sources such as conferences, scientific reviews or professional associations remain very important. In contrast, high knowledge intensive service firms use more institutional information coming from universities, public research organizations or technology centers.

The statically significant and positive sign of the variables reflecting the importance given to the maintaining or increasing market share and entry to new markets confirms the role of demand-pull factors in eco-innovation (Hypothesis 4). Our results concur with those of Horbach et al. (2013), who examined German and French data, Veugelers (2012), who investigated data for Flanders and Triguero et al. (2013) who examined 27 European countries,. However, they contrast with those of del Río et al. (2015a) who find little evidence for these factors in Spain. The growing environmental awareness among Spanish customers in recent years could be one of the reasons for our positive result (European Commission 2014). However, neither variable is significant for the group of service firms. Thus, we confirm Hypothesis 4 only in the case of manufacturing firms.

In line with other contributions in the literature our results show that regulation and environmental public policies are crucial to eco-innovation (Horbach 2008; Demirel and Kesidou 2011; De Marchi 2012; Veugelers 2012; Horbach et al. 2013; Borghesi et al. 2015; del Río et al. 2015b). Looking first at the regulatory variable, we note that the existing regulation is a positive and significant driver for Spanish firms to eco-innovate in both sectors and at both technology intensities. The relevance of subsidies in eco-innovation is also positive and statistically significant in triggering eco-innovation orientation, but this only between manufacturing and services firms with low levels of technological intensities. Our results contrast somewhat with those of Cuerva et al. (2014), who conclude that public subsidies are not relevant for explaining the green innovation among low-tech firms (food and beverage sector).

Finally, concerning a firm's characteristics, in line with the findings in the literature (Carrillo-Hermosilla et al. 2009; Hojnik and Ruzzier 2015; del Río et al. 2016), oour results show that larger firms are more likely to design an eco-innovation strategy (De Marchi 2012; Cuerva et al. 2014; del Río et al. 2015a). Belonging to a group shows no relationship to being a green firm in any sector or at any technology intensity (del Río et al. 2015a; Doran and Ryan 2016). Finally, we find that firms that sell their products in foreign markets are more likely to eco-innovate, but this variable is only positive and statistically significant for the whole manufacturing sample and high-tech manufacturing firms.

In relation to the likelihood of innovating (selection equation), our results suggest that this depends closely on investments in internal and external R&D and participation in cooperative projects. The econometric analysis also reveals that past innovation is determinant of the current innovative situation (Clausen et al. 2012; Triguero and Córcoles 2013). Public funds seem to be important in introducing technological innovations, but mainly for manufacturing and services firms with low technological intensity. Internal and market sources of information are the most important sources for innovation activities across both sectors. However, institutional sources of information show a negative and statistically significant impact in innovation in manufacturing firms. Finally, the largest firms are the more prone to innovate in services firm with high and low technology intensities.

Table 5
Heckprobit estimation of the probability of innovating and the probability to design an eco-innovation strategy-

	Manufacturing			Services		
Variables	TOTAL	HTM	LTM	TOTAL	HKIS	OHKIS
	Probability of designing an eco-innovation strategy					
Persistence						
Eco-innovation $_{t-1}$	1.4093***	1.4041***	1.4179***	1.5890***	1.6556***	1.5304***
	(0.030)	(0.043)	(0.042)	(0.057)	(0.087)	(0.077)
Initial conditions						
Eco-innovation	0.2854***	0.3316***	0.2466***	0.2793***	0.4372***	0.1662**
	(0.027)	(0.040)	(0.037)	(0.057)	(0.090)	(0.075)

Technology-push factors						
R&D effort $_{t-1}$	1.75e-06**	1.58e-06	1.93e-06*	1.55e-06***	1.42e-06**	3.63e-06**
	(8.63e-07)	(1.14e-06)	(1.25e-06)	(6.06e-07)	(6.75e-07)	(1.38e-06)
Training $_{t-1}$	0.0744**	0.0620	0.0799*	-0.0383	-0.0761	0.0047
	(0.032)	(0.044)	(0.046)	(0.050)	(0.073)	(0.070)
Cooperation $_{t-1}$	0.0440	0.1234***	-0.0288	-0.0337	-0.0346	-0.0398
	(0.027)	(0.040)	(0.038)	(0.052)	(0.082)	(0.069)
Internal sources $_{t-1}$	0.0604**	-0.0513	0.1449***	0.0290	-0.0026	0.0506
	(0.026)	(0.040)	(0.035)	(0.051)	(0.075)	(0.068)
Market sources $_{t-1}$	0.0349	0.0038	0.0590*	0.0376	0.0021	0.0856
	(0.025)	(0.037)	(0.035)	(0.048)	(0.072)	(0.064)
Institutional sources $_{t-1}$	0.0546	-0.0142	0.1072**	0.1517***	0.2187***	0.0565
	(0.034)	(0.050)	(0.046)	(0.058)	(0.080)	(0.084)
Other sources $_{t-1}$	0.0721**	0.0696	0.0742	0.0094	-0.0451	0.0473
	(0.033)	(0.047)	(0.048)	(0.055)	(0.079)	(0.077)
Market pull factors						
New market $_{t-1}$	0.0523*	0.0901**	0.0264	0.0598	0.0679	0.0397
	(0.029)	(0.041)	(0.040)	(0.054)	(0.077)	(0.080)
Market share $_{t-1}$	0.0898***	0.1061**	0.0743*	0.0351	0.0540	0.0355
	(0.028)	(0.041)	(0.040)	(0.054)	(0.078)	(0.078)
Environmental policy						
Regulation $_{t-1}$	0.2393***	0.3099***	0.1695***	0.2991***	0.2192**	0.3421***
	(0.029)	(0.042)	(0.042)	(0.058)	(0.091)	(0.078)
Subsidies $_{t-1}$	0.0498*	0.0351	0.0762**	0.0750	-0.0040	0.1286*
	(0.02)	(0.039)	(0.036)	(0.054)	(0.083)	(0.073)
Firm characteristics						
Size $_{t-1}$	0.0793***	0.0772***	0.0778***	0.0319**	0.0433*	0.0312
	(0.012)	(0.018)	(0.016)	(0.016)	(0.025)	(0.021)
Group $_{t-1}$	0.0205	0.0579	-0.0048	0.0066	-0.0777	0.0601
	(0.028)	(0.042)	(0.037)	(0.049)	(0.075)	(0.066)
Export $_{t-1}$	0.0754**	0.1325**	0.0240	-0.0712	-0.1296	0.0035
	(0.038)	(0.055)	(0.054)	(0.089)	(0.125)	(0.130)
Constant	-1.7621***	-1.8178***	-1.6939***	-1.7352***	-1.2963***	-1.7177***
	(0.166)	(0.183)	(0.188)	(0.204)	(0.167)	(0.222)
			Probability of innovate			
Persistence						
Innovative $_{t-1}$	1.9678***	1.9667***	1.9657***	1.9241***	1.9840***	1.8555***
	(0.035)	(0.055)	(0.045)	(0.049)	(0.075)	(0.066)
Initial condition						
Innovative	0.2087***	0.2723***	0.1733***	0.1563***	0.0769	0.1490**
	(0.037)	(0.060)	(0.047)	(0.051)	(0.082)	(0.069)
Internal R&D effort $_{t-1}$	0.0608***	0.0521***	0.0670***	0.0465***	0.0637***	0.3727***
	(0.004)	(0.006)	(0.005)	(0.007)	(0.010)	(0.061)
External R&D effort $_{t-1}$	0.0124**	0.0039	0.0207***	0.0141*	0.0097	0.2095***
	(0.005)	(0.007)	(0.007)	(0.007)	(0.010)	(0.064)
Cooperation $_{t-1}$	0.1272***	0.1761***	0.0801*	0.1539***	0.1392*	-0.0521
	(0.035)	(0.054)	(0.047)	(0.050)	(0.074)	(0.092)
Internal sources $_{t-1}$	0.2136***	0.1814***	0.2329***	0.2445***	0.0979	0.1637*
	(0.029)	(0.045)	(0.039)	(0.045)	(0.068)	(0.088)
Market sources $_{t-1}$	0.1234***	0.1034**	0.1421***	0.1978***	0.1784***	0.0608***
	(0.030)	(0.046)	(0.041)	(0.046)	(0.066)	(0.020)
Institutional sources $_{t-1}$	-0.1144**	-0.1007	-0.1293**	-0.0652	-0.0735	-0.0169
	(0.044)	(0.068)	(0.059)	(0.063)	(0.088)	(0.058)
Other sources $_{t-1}$	0.0755	0.0639	0.0982	0.1329**	0.1304	-0.0205
	(0.044)	(0.062)	(0.063)	(0.061)	(0.085)	(0.132)
Size $_{t-1}$	0.0223	0.0414*	0.0129	0.0643***	0.0688***	0.1490**
	(0.013)	(0.022)	(0.017)	(0.015)	(0.024)	(0.069)
Group $_{t-1}$	-0.0242	-0.0618	-0.0079	-0.0823*	-0.1553**	0.3727***
	(0.031)	(0.052)	(0.040)	(0.044)	(0.068)	(0.061)
Export $_{t-1}$	0.0658	0.1755***	-0.0123	-0.1034	-0.1728	0.2095***
	(0.044)	(0.068)	(0.058)	(0.086)	(0.116)	(0.064)
Subsidies $_{t-1}$	0.1105***	0.0966*	0.1166**	0.0318	0.1003	-0.0387
	(0.034)	(0.051)	(0.049)	(0.057)	(0.081)	(0.081)

Constant	-1.6714***	-1.7763***	-1.6973***	-1.7141***	-1.9871***	-1.7328***
	(0.228)	(0.239)	(0.210)	(0.149)	(0.164)	(0.167)
ρ	0.5134***	0.5631***	0.4160***	0.46360***	0.46373**	0.4785***
	(0.056)	(0.100)	(0.0570)	(0.070)	(0.126)	(0085)
Wald test of χ	13162.05	2957.81	10390.52	2004.63	1062.68	947.46
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Censored obs.	4,086	1,386	2,700	2,439	898	1,541
Uncensored obs.	15,120	7,128	7,992	5,565	2,882	2,683
Observations	19,206	8,514	10,692	8,004	3,780	4,224

Estimations control for time and industry dummies. Robust standard errors in parentheses. *, ** and *** correspond to significance levels of 1, 5 and 10 %

6. CONCLUDING REMARKS

The paper explores the determinants of designing an eco-innovation strategy in a Spanish context. We investigated the similarities and differences between Spanish service and manufacturing firms with diverse technological intensity, especially the high-tech and low-tech sectors. Furthermore, to overcome at least some of the limitations of earlier studies, which have used mainly cross-sectional databases, the empirical analysis carried out in this paper is based on the Technological Innovation Panel (PITEC), a panel data of 4.535 Spanish firms that covers the period 2008—2014.

The availability of longitudinal, firm-level panel data allows us to consider the dynamic features of eco-innovation orientation and focus on the roles of persistence and individual unobserved heterogeneity of firms, a topic that has received great attention in the general innovation literature but which is still unexplored in the eco-innovation context. In estimating the dependence of past eco-innovation performance and the drivers of eco-innovation, we use a dynamic probit model controlling for possible selection sample selection where we introduce lagged dependent variables as explanatory terms to control for the initial conditions and unobserved heterogeneity (Wooldridge 2005).

When we explore the empirical evidence, some stylized facts at firm and sectoral level emerge. At firm level, the profile of Spanish firms setting up eco-innovation strategies is that, in comparison to their counterparts, they are larger in terms of sales or workers, more often belong to a group, participate more in international markets, invest more intensively in R&D activities, and cooperate more with external partners in R&D projects. Our results are in line with previous empirical studies carried out from different samples of Spanish firms (De Marchi 2012; Cuerva et al. 2014; del Río et al. 2015a). However, when we consider those firms that design eco-innovation strategies at sectorial level, we find that manufacturing firms are more likely to carry out eco-oriented strategies than are services firms. In general, manufacturing and services firms seem to rely more on demand pull policies, such as regulation rather than supply push environmental regulations, such as subsidies.

The econometric analyses performed suggest that there is a weak support for Hypothesis 1 that technology push factors, measured in terms of expenditures on innovation activities per worker, are trigger an eco-innovation orientation in both manufacturing and services firms (Horbach 2008; De Marchi 2012; Cainelli and Mazzanti 2013).The relevance of technology push factors is confirmed mainly in the low-tech manufacturing firms by the importance of training employees as seen in Cainelli et al. (2015).

In addition, we find that eco-innovation is highly persistent at the firm level in both sectors and intensity technologies. Eco-innovation strategies are path dependence and persistence occurs when a firm that has followed an eco-innovation orientation in the current year engages in eco-innovation activates again in next period. Our empirical results reveal that past eco-innovation behaviour is an important driver for current eco-innovation status, thus confirming our previously proposed Hypothesis 2.

However, the roles of cooperation in R&D projects and external sources are less direct, and thus support for Hypothesis 3 is mixed. Regarding the impact of the R&D cooperation with external partners, similarly to del Río et al. (2015a) for Spain and Horbach (2008) for Germany, we find the role of participating in R&D cooperative projects in eco-innovators with high technology intensity more relevant compared with general innovators. Regarding the sources of information, the results differ between the two sectors. In manufacturing firms, it seems that, even though eco-innovation activities rely more on more on internal or other sources of innovation to eco-innovation, instead services firms, especially knowledge intensive ones, give more importance to collaboration with research institutes, agencies, and universities.

Moreover, regarding the demand push factors our results indicate that they are a distinctive determinant for Spanish manufacturing firms to promote eco-innovation orientation. Thus, we confirm Hypothesis 4 only in the case of manufacturing firms.

Finally, in line with the existing literature, our empirical results confirm the importance of regulatory stimulus to eco-innovation mainly in form of demand pull (regulations) in both sectors and especially in terms of demand push (subsidies) for sector with low technology intensities (Hypothesis 5).

This analysis carries an important policy implication. Our results have shown that firms from different industries have different attitudes toward eco-innovation orientation. Since eco-innovation is neither a sector- nor a technology-specific phenomenon, it is important that environmental policies are correctly designed and targeted. Thus, for policy-makers, this study emphasizes the drivers of eco-innovation in the service sector with different technology intensity. First, since eco-innovations are characterized by the double externality problem, public policy still retains a relevant role. Traditional environmental policy, in terms of existing regulations, is effective in the Spanish context in driving eco-innovation orientation in all the sectors and technology intensities examined in this paper, whereas governments grants are a significant trigger only in sectors with low technology intensity. Hence, public policies should also reward eco-oriented firms in the form of tax incentives, grants or subsidies as eco-innovations show high a level of uncertainty, novelty and face some specific financial difficulties.

Second, given that we cannot rely either on the market-pull factor or on cooperation as a main driver to eco-innovate in services firms, there is an important role for public polices in triggering an eco-innovation orientation. The role of governments in promoting eco-innovation concerns, not only new regulatory or economic instruments, but also the facilitation of partnerships and the encouragement cooperation.

Third, as mentioned above, our analysis shows a high persistence in eco-innovation orientation. The results are of considerable interest for any public policy targeting innovation and eco-innovation. Government agencies or other institutions could provide incentives to engage in eco-innovation activities, but stability in eco-innovation activities over time is required to produce persistent and stable eco-innovators. Such a policy measure would promote competition and improve performance and would help non-eco-firms or occasional performers.

To sum up, the complex policy challenge based on support for eco-innovation requires a coordinated approach, one which simultaneously integrates innovation, research and environmental policy. Thus, the promotion of eco-innovation requires a balanced strategy that combines different policy tools. However, fostering an eco-innovation orientation not only consists in applying specific instruments, also requires a policy framework that is well defined, stable over the years and based on consistent economic and environmental criteria (Economic Commission for Europe (UNECE) 2011). Spain's relatively low level of R&D intensity (in particular with regard to government environmental and energy R&D investments), the low proportion of R&D personnel and researchers in the workforce, and the lack of organisation and collaboration at institutional and governance levels all constitute barriers for eco-innovation (Observatory 2015).

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APPENDIX

Appendix 1. Variable definitions

Table A.1

Variable definitions

Dependent variables	
Eco-inn	Dummy variable which takes the value 1 if the firm has introduced an innovation with high importance of reducing environmental impact, reducing energy consumption per unit produced or improving health and safety aspects; 0 if not

Innovative	Dummy variable which takes the value 1 if the firm has introduced technological innovations or non-technological innovations; 0 if not
Independent variables	
Environmental policy	
Regulation	Dummy variable that takes a value equal to 1 if the firm gives high importance to compliance with environmental, health and safety regulations as an aim of innovation activity; 0 if not
Subsidies	Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities; 0 if not
Technology push factors	
R&D effort	Expenditures in R&D activities per worker (in logs)
Training	Dummy variable that takes a value equal to 1 if firm invests in training expenditure for innovation activities; 0 if not
Cooperation	Dummy variable that takes a value equal to 1 if the firm cooperates with other agents during; 0 if not
Sources of information	*Internal sources*: dummy variable which takes a value equal to 1 if information from sources within the enterprise or group has high importance; 0 if not *Market sources:* dummy variable which takes a value equal to 1 if information from suppliers, clients, competitors or private R&D institutions has high importance; 0 if not *Institutional sources:* dummy variable which takes a value equal to 1 if information from universities, public research organizations or technology centres has high importance; 0 if not *Other sources*: dummy variable which takes a value equal to 1 if information from conferences, scientific reviews or professional associations has high importance; 0 if not
Market-pull factors	
New market	Dummy variable that takes a value equal to 1 if the firm innovation objective is highly oriented to entering new markets; 0 if not
Market share	Dummy variable that takes a value equal to 1 if the firm innovation objective is highly oriented to increasing or maintaining market share; 0 if not
Firm characteristics	
Size	Log of the total number of firm's employees (natural logs)
Group	Dummy variable that takes a value equal to 1 if the firm belongs to a group; 0 if not
Export	Exports as a percentage of total sales
Internal R&D	Dummy variable which takes a value equal to 1 if the firm invests in internal R&D; 0 if not
External R&D	Dummy variable which takes a value equal to 1 if the firm invests in external R&D; 0 if not
High tech manufacture and high KIS	Dummy variables which take the value equal 1 if the firm belongs to a high-tech manufacturing sector or to a high knowledge intensive service; 0 if not