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DRIVERS OF ENVIRONMENTAL INNOVATION IN CLEAN AND DIRTY INDUSTRIES

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EXECUTIVE SUMMARY

Environmental innovation can support the achievement of the Sustainable Development Goals (SDGs) as it is a key enabler for most of them. For environmental innovation to extend its full potential, it is essential that firms and decision makers are able to identify its main drivers.

This study analyzes the factors driving environmental innovation by distinguishing between clean and dirty industries. The variables considered are grouped into three broad categories consisting of environmental policy factors, technology push factors and market pull factors. Moreover, the model also controls for firm heterogeneity through firm's size and exporting activity. Results have been obtained using the PITEC database for the period 2008-2016. The descriptive analysis and the binary logistic regression prove that firms in dirty industries have a higher orientation towards the environmental objective.

Key words: Environmental innovation, environmental policy, technology push, market pull, clean and dirty industries.

La Eco-innovación puede contribuir a la consecución de los Objetivos de Desarrollo Sostenible (ODS), ya que es un implulsor clave para la mayoría de ellos. Para que la eco-innovación despliegue todo su potencial, es esencial que las empresas y los responsables de la toma de decisiones sean capaces de identificar sus principales motores.

Este estudio analiza los factores que impulsan la eco-innovación distinguiendo entre industrias limpias y sucias. Las variables consideradas se agrupan en tres grandes categorías: factores de política medioambiental, factores de impulso tecnológico y factores de atracción del mercado. Además, el modelo también controla la heterogeneidad de las empresas teniendo en cuenta su tamaño y su actividad exportadora. Los resultados se han obtenido utilizando la base de datos PITEC para el período 2008-2016. El análisis descriptivo y la regresión logística binaria demuestran que las empresas en las industrias sucias tienen una mayor orientación hacia el objetivo medioambiental.

Palabras clave: Eco-innovación, política medioambiental, impulso tecnológico, atracción del mercado, industrias limpias y sucias.

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1. INTRODUCTION

The 17 Sustainable Development Goals (SDGs) are at the heart of the 2030 Agenda for Sustainable Development adopted by United Nations in 2015. They are an urgent call for action to address global challenges. Due to the scale and ambition of the goals, innovation has been recognized as critical to the achievement of the SDGs. Indeed, innovation is explicitly mentioned in SDG 9 *"Build resilient infrastructure, promote sustainable and inclusive industrialization and foster innovation"*. Moreover, it is a key enabler for most of the Goals, as these require fundamental changes in the ways in which food, water, welfare, housing, mobility and other goods and services are delivered, distributed, and consumed (UNCTAD, 2021).

In this context, innovations that positively affect the environment play a key role in the achievement of the SDGs as they generate R&D spillovers and positive environmental externalities. Therefore, environmental innovation has become one of main goals of EU policy strategies through the Eco-Innovation Action Plan (EcoAP).

Spain is ranked number 8 in the Eco-Innovation Scoreboard (Eco-IS, 2022) meaning that it is a moderate innovation country. In general terms, it has less customer awareness and a lower level of environmental regulation stringency compared to other European countries.

Several studies confirm that firms are fundamental in the development of eco-innovation as they play an active role in the path to sustainable development and changes in production patterns (Doran and Ryan, 2016; Liao, 2018). Firms set the objectives of environmental innovation through the selection of activities and the extent to which they are developed. However, findings by Horbach (2008) confirm that there are significant differences among industries on the implementation of eco-innovation.

This study aims to analyze the drivers of environmental innovation in Spanish manufacturing firms focusing on the differences between clean and dirty industries. Although the literature about drivers of eco-innovation is abundant, the study of its adoption focusing on differences between clean and dirty industries has not been very covered. Therefore, results of this study can provide interesting conclusions and key insights, which may be useful in the achievement of the SDGs.

Different variables have been considered in this analysis as factors driving environmental innovation. They are grouped into three broad categories: environmental policy factors (which include regulation and subsidies), technology push factors (related to internal and external R&D, as well as market and institutional sources of information) and market pull factors (which refer to the objective of entering new markets or increasing the market share). Moreover, other control factors (namely, size and exporting activity) are also considered to account for firm heterogeneity.

The variables used in the model have been created using data drawn from the Spanish Technological Innovation Panel (PITEC) from years 2008 to 2016. Two databases have been created: one for firms in clean industries and another one for firms in dirty industries. This classification has been done based on the level of pollution and toxins each industry discharges according to the TRI (Toxic Release Inventory) and the EPA (US Environmental Protection Agency).

Conclusions are drawn through a descriptive analysis of the factors and a regression using the binary logistic model in the program SPSS. Results show that there are significant differences between the adoption of environmental innovation in clean and in dirty industries focusing on the objective of having a high or medium orientation towards reducing the energy required per unit of production or the environmental impact.

This study is structured as follows: Section 2 consists of the theoretical background, including the concept of environmental innovation, its drivers, and the determinants for its adoption in clean and dirty industries. Then, Section 3 presents the database, the variables' description and the empirical methods used in the study (including descriptive statistics and the binary logistic regression). The last section presents conclusions and some implications the findings may have.

2. THEORETICAL BACKGROUND

The next section consists of a revision of the existing literature, where the first subsection is devoted to the definition of the concept of innovation and, more specifically of Environmental innovation; then, the second subsection is a revision of the main determinants of eco-innovation considered by the literature; finally, subsection three focuses on the adoption of this environmental innovation in clean and dirty industries

2.1. The Concept of Environmental Innovation

Before focusing on the concept of environmental innovation, it is important to look at the big picture: the concept of innovation itself. According to Siauliai (2013), there are three generally accepted approaches to define innovation.

- First, the work of Joseph Schumpeter, founder of the theory of innovation, has influenced significant theories of innovation and enriched subsequent definitions. According to Schumpeter, innovation is the economic impact of technological change or the use of new combinations of already existing factors of production to solve business problems (Schumpeter, 1982).
- The second approach was given by Twiss (1989), who defined innovation as a process that combines science, economics, technology, and management to achieve novelty and extend from the emergence of the idea to its commercialization in the form of production, exchange, and consumption.
- The third perspective, by Afuah (1998), considers innovation as new knowledge that is incorporated in products, processes, and services. Following this approach, innovation is classified into technological, administrative/organizational, and market innovation.

These definitions reflect the fact that innovation does not exclusively refer to changes in technology. Innovation can also refer to modifications and improvements all through the firms' value chain. Therefore, the term "innovative firm" is used for firms that have incorporated innovations into their operations regardless of their origin (whether they have been internally developed or acquired) or their success (Oslo Manual, 2005).

In addition, it is important to differentiate between two similar concepts: invention and innovation. On the one hand, an invention is a model, idea, or sketch for a new improved device, product, process, or system. On the other hand, innovation in the economic sense, starts with the first commercial transaction (Freeman, 1974, p. 22).

This study focuses on the classical definition of innovation, as published in the Oslo Manual (elaborated by the OECD). Innovation is defined as "*a new or improved product or process (or a combination thereof) that differs significantly from previous ones and that is available to potential users or brought into use by the unit (process).*" (OECD, 2018).

The main change introduced in the third edition of the Oslo Manual is the differentiation of four types of innovation:

- Product innovations are changes in capabilities of goods or services.
- Process innovations are changes in production and delivery methods.
- Organizational innovations are new organizational methods in business practices, workplace organization, and external relations.
- Marketing innovation are changes in design, packaging, promotion, placement, and pricing.

After having presented the concept of innovation, this study focuses on a specific type: Environmental innovation. This has been considered an important driver of economic development over the last years (Constantini et al., 2017 and Arena et al., 2018).

The concept of eco-innovation can be defined following different approaches. Eco-innovation is defined by the OECD as "*the creation of new, or significantly improved, products, processes, organizational structures, marketing methods and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives*." (OECD, 2018, p. 19).

The European Commission defines it as "*changing production and consumption patterns and developing products, services, and technologies to reduce our impact on the environment*" (European Commission, 2009, p. 2).

This concept is also considered as the development of new products, processes, or services that deliver customer and business value but, at the same time, significantly decrease environmental impact (Fussler, C. and James, P, 1996).

Furthermore, Charter, M. and Clark, T. (2007) interpret eco-innovation as a process where sustainability considerations (financial, environmental, and social) are integrated into company systems from idea generation through research and development and commercialization.

As previously mentioned, this study follows the classical typology of innovations in the Oslo Manual published by the OECD, which differentiates between product, process, marketing, and organizational types of innovation. The specific characteristics of each type when applied to environmental innovation are the following:

- Product or service eco-innovation involves the use of eco-friendly materials, eco-friendly packaging, recycling, recovery of products, and eco-labeling (Chen et al., 2006; Chen, 2008).
- Process eco-innovation focuses on the firms' ability to improve already existing processes and develop new ones that save resources and do not pollute (Chen et al., 2006; Chen, 2008).
- Organizational eco-innovation refers to new or significant improvement in practices, business models, methods, relations, and decisions to reduce negative environmental impact (Marcon et al., 2017).
- Marketing eco-innovation involves environmental aspects into product placement, communication, delivery, pricing, or promotion strategies (Marcon et al., 2017).

Evaluating the consequences of the adoption of eco-innovation is key. Diverse studies on the relationship between firms and eco-innovation, emphasize the role of firms in the development of eco-innovation (Doran and Ryan, 2016; Liao, 2018).

In this context of industrial transformation (which implies changes in production and in sustainable development), firms must play an active role according to Vellinga and Herb (1999), and Segarra-Blasco and Jove-Llopis (2019). However, there is variability among firms: some of them limit their action to setting objectives (from a reactive attitude), while others have a proactive attitude, and voluntarily incorporate eco-innovation (Doran and Ryan, 2016; Jove-Llopis and Segarra-Blasco, 2019).

Furthermore, the influence of eco-innovation on economic performance can provide useful insights regarding the use of environmental policies as tools for industrial policy (Dechezlepretre and Sato, 2014). Moreover, as proved by Duchin et al. (1995) eco-innovation can have positive effects on trade and opening to new markets, even if this does not cover all the costs of environmental regulation in terms of foregone profits.

2.2. Drivers for the adoption of Environmental Innovation

Regarding the determinants of environmental innovation, some authors (Belin et al., 2011; Del Río, 2009; Del Río et al., 2015) classify them as internal or external to the firm. Internal factors include existing resources, competences, and capabilities as well as the company's characteristics (for example financial resources, management's commitment with environmental issues, technological capability, etc.) whereas external factors refer to external stakeholders like suppliers, associations and NGOs, environmental authorities, insurance firms, competitors, or clients.

Other approaches consider a geographical point of view. This refers to the effect of national and international drivers of environmental innovation in companies. These drivers include international regulations, sources of funding, the influence of customers in foreign markets or cooperation with international institutions.

Moreover, a theory that has influenced research for a long period of time is the technology push and market pull theory developed by Rehfeld, Rennings and Ziegler (2007). However, when talking more specifically about eco-innovation, it is also necessary to include the role of institutional factors and regulation (Horbach, 2008; Porter and van der Linde, 1995; Rennings, 2000; Rennings et al., 2006). Therefore, the classification elaborated by Horbach (2008), suggests the following factors as drivers of environmental innovation: environmental policy factors, demand side factors and supply side factors.

Furthermore, other authors claim that firms' resources and capabilities are also relevant (Cainelli et al., 2012; Horbach et al., 2012; Triguero et al., 2013). In this sense, to consider these structural characteristics, this study is based on the classification by Horbach (200/) combined with internal and external factors affecting environmental innovation (Del Río et al., 2015), resulting in the following three categories: environmental policy factors, technology push factors and market pull.

2.3. Determinants of Environmental Innovation adoption in clean and dirty industries

Eco-innovation differs from "traditional" innovation in its objectives, externalities and, of course, its drivers. Findings by Horbach (2008) confirm that there are significant differences among industries on the implementation of eco-innovation. Indeed, studies by authors like Mazzanti and Zoboli (2006) show that when considering expenditures on R&D and the adoption of innovative output, sector is more important than size.

Regarding characteristics of clean and dirty industries, on the one hand, a clean industry is defined by Al-Ayouty et al. (2017) as one that uses clean energy and technology to reduce water and air pollution, decrease the quantity of waste generated and minimize chemical risk to improve the efficiency of resources. On the contrary, a dirty industry is for Albrecht (1998), one with the highest level of pollution abatement and control expenditures. However, firms in dirty industries are, in general, more internally oriented towards environmental concerns as they are subject to stricter regulations, institutional pressures and more judged by the public (Berrone et al., 2013).

The implementation of clean technology in dirty industries may have a higher cost and risk associated (Albrecht, 1998). However, as these firms have a bigger polluting potential, it is an incentive to develop innovations that reduce the negative environmental impact as well as the economic costs this implies. Moreover, as firms in dirty industries have a greater environmental footprint, the public is more likely to notice a substantial change towards sustainability.

In addition, dirty industries have a greater need to seize green market opportunities because these are more likely to result in the generation of competitive advantage and potential market success. Indeed, studies by Aragón-Correa and Sharma (2003) show that proactive environmental strategies can lead to competitive advantage. These proactive strategies can be achieved when firms have formal plans to introduce green innovations. Furthermore, firms that are more energy-intensive are more determined to reduce energy consumption (Belin et al., 2011). This means that there is a positive correlation between the sector's energy intensity and the implementation of environmental innovation. Accordingly, firms that pollute more, introduce more abatement measures, which is as a proxy for the introduction of eco-innovation (Frondel et al., 2008).

3. METHODS AND DATA

Section 3 covers the methodology used for this study. The first subsection presents the data collection. Then, Subsection 2 provides a descriptive analysis of the variables, by differentiating between the dependent variable, explanatory variables, and control variables. Finally, the third subsection presents the empirical methods used including, among others, the descriptive analysis, and the regression model.

3.1. Data collection

In this study, data is collected from the Spanish Innovation Panel (PITEC), a database developed by the National Statistics Institute (INE) in coordination with the Foundation for Technological Innovation (FECYT) and the Spanish and Technology Foundation (COTEC) (PITEC, 2007).

The PITEC database uses a standardized questionnaire that replicates the Community Innovation Survey (OECD, 2009). This database is commonly used for innovation studies at the firm level, and more specifically, for eco-innovation studies in the Spanish context. Data are collected annually since 2003. It contains information about companies' characteristics (number of employees, sales, sector, export activity, etc.) and detailed information about their innovation activities such as innovation expenditures, types of output, objectives of the innovation activities, barriers to innovation, training activities, financial support, etc.

The population framework refers to Spanish companies in the national territory according to the Central Directory of Spanish Companies (DIRCE). Regarding the sectoral scope, it covers agricultural, construction, industrial, and service companies (following the NACE-2009 classification). The collection method consists of a mixed system that includes interviews, emails, and telephone.

The main value of this database is thst it provides representative statistics from thousands of firms over the years. This implies that firms are in continuous observation, which allows comparisons, explanations to their behavior, as well as the analysis of tendencies.

This study considers the reference period of 2008-2016 and classifies industries based on the CNAE2009 criterion (Spanish national classification of economic activities), which coincides with the NACE Rev 2 (Statistical classification of economic activities in the European community).

After filtering the sample, the result is a balanced panel that is then divided according to the "industry" factor into two different databases: one for firms in clean industries and another one for firms dirty industries. This classification (available in Table A1 in the Appendix) is done based on the level of pollution and toxins each industry discharges according to the TRI (Toxic Release Inventory) and the EPA (US Environmental Protection Agency).

3.2. Description of the variables

As it has been explained, eco-innovation is a broad concept; therefore, different combinations of variables have been considered in the literature. However, following the objective of this study, the main reference used for the variables' selection is the paper by Jové-Llopis, E. and Segarra-Blasco, A. (2018). Hereunder, a presentation of the main variables included in the model is provided.

3.2.1. Dependent variable: Environmental Innovation

Regarding the dependent variable (what we want to measure in the model), Environmental innovation is measured in the PITEC questionnaire with the question: "*Was the innovative activity carried out in your company oriented towards the following environmental objectives?*"

Among the objectives, those related to the purpose of this study are the following:

- Less energy per unit of production
- Less environmental impact.

As a result, the dependent variable "ECO_INNOVATION" considers these two objectives. It is a dummy variable that takes value 1 if the firm innovation objective has a high or medium orientation towards reducing the energy required per unit of production or the environmental impact. It takes value 0 if the firm's objectives are not related to at least one of these objectives.

Table 1 shows that when looking at the total sample in the database, only 39% of firms have energy reduction as an objective. However, this result varies from clean to dirty industries: The proportion of clean industries with this orientation is significantly lower (27%) than in the case of dirty industries (46%).

Regarding the objective of environmental impact, almost half of the firms in the sample (47%) have an orientation towards it. Again, there are differences between industries, with a lower proportion of firms in clean sectors following the eco-innovative objective.

Table 1: Summary statistics of the dependent variable

ECO_INNOVATION	TOTAL SAMPLE		CLEAN		DIRTY		ANOVA test Difference between dirty and clean industries (P value)
	Mean	Sd	Mean	Sd	Mean	Sd	
ENERGY	0.39	0.488	0.27	0.446	0.46	0.499	0.001
IMPACT	0.47	0.499	0.35	0.477	0.55	0.498	0.001

Source: Own elaboration using SPSS.

3.2.2. Main explanatory variables

As presented in Section 2, explanatory variables are grouped into three types of factors following Horbach (2008) and Del Río et al. (2015): environmental policy factors, technology push factors and market pull factors. In the subsequent paragraphs, a descriptive analysis of the variables included in the study is provided.

Environmental policy factors

Environmental policy factors account for regulation and subsidies. The variable "REGULATION" is a dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards meeting regulatory requirements; 0 if not.

To facilitate the interpretation of our data, a new variable named "SUBSIDIES" was created, which takes value equal to 1 if the firm receives any public financial support for innovation activities from local, national or EU authorities; 0 if not. The variable subsidies results, in turn, from the addition of the following variables: Local subsidies, national subsidies and EU subsidies.

- LOCAL_SUBSIDIES: Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from local authorities; 0 if not.
- NATIONAL_SUBSIDIES: Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from national authorities; 0 if not.
- EU_SUBSIDIES: Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from the EU; 0 if not.

Table 2 shows results for the descriptive analysis of these variables. Regarding regulation, almost half of the firms in the total sample have an innovation objective with a high or medium orientation towards meeting regulatory requirements. However, there are differences between firms in clean industries (with only 37% of them having this regulatory requirement orientation), and firms in dirty industries (where the percentage is significantly higher, reaching 56%).

With respect to the variable SUBSIDIES, Table 2 shows that the percentage of firms that receive any public financial support for innovation activities from local, national or EU authorities is low in every case, ranging from 24% in clean industries to 29% in dirty industries. Nevertheless, the ANOVA test done for the sample shows that the difference is small but significant.

Table 2: Summary statistics of environmental policy variables.

ENVIRONMENTAL_POLICY	TOTAL SAMPLE		CLEAN		DIRTY		ANOVA test Difference between dirty and clean industries (P value)
	Mean	Sd	Mean	Sd	Mean	Sd	
REGULATION	0.49	0.500	0.37	0.484	0.56	0.496	0.001
SUBSIDIES	0.27	0.444	0.24	0.427	0.29	0.455	0.001

Source: Own elaboration using SPSS.

Technology push factors

The second category of explanatory variables is grouped as Technology push factors, which includes the following four variables:

- INTERNAL_R&D: Dummy variable that takes a value equal to 1 if the firm has expenditures in internal R&D; 0 if not.
- EXTERNAL_R&D: Dummy variable that takes a value equal to 1 if the firm has expenditures in external R&D; 0 if not.
- MARKET_SOURCES: Dummy variable that 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 that takes a value equal to 1 if information from universities, public research organizations or technology centers has high importance; 0 if not.

As shown in Table 3, almost half of the firms (44%) have expenditures in internal R&D. This proportion is smaller in the case of external R&D expenditures, with only 20% of firms in the total sample. However, information from suppliers, clients, competitors, or private R&D institutions has high importance for 75% of the firms in the sample and results are similar in the case of clean and dirty industries. Finally, information coming from institutional sources (universities, public research organizations or technology centers) has high importance.

Table 3: Summary statistics of technology push variables.

TECHNOLOGY_PUSH	TOTAL SAMPLE		CLEAN		DIRTY		ANOVA test Difference between dirty and clean industries (P value)
	Mean	Sd	Mean	Sd	Mean	Sd	
INTERNAL_R&D	0.44	0.496	0.34	0.474	0.51	0.500	0.001
EXTERNAL_R&D	0.20	0.400	0.15	0.358	0.24	0.425	0.001
MARKET_SOURCES	0.75	0.430	0.74	0.440	0.76	0.424	0.001
INSTITUTIONAL SOURCES	0.62	0.440	0.60	0.450	0.64	0.420	0.001

Source: Own elaboration using SPSS.

Market pull factors

The third group of explanatory variables includes Market pull factors. It is composed of two different variables: new markets and market share. First, the variable “NEW_MARKET” is a dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards entering new markets; 0 if not. Second, the variable “MARKET_SHARE” is a dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards increasing or maintaining market share; 0 if not.

Results are very similar for both variables (see Table 4), with around 65% of firms in the total sample with a high or medium objective towards entering new markets and maintaining market share. However, there are some differences across sectors, with lower percentages in the case of clean industries (around 60%), compared to values close 70% for dirty industries.

Table 4: Summary statistics of market pull variables.

MARKET_PULL	TOTAL SAMPLE		CLEAN		DIRTY		ANOVA test Difference between dirty and clean industries (P value)
	Mean	Sd	Mean	Sd	Mean	Sd	
NEW_MARKET	0.63	0.482	0.57	0.496	0.67	0.469	0.001
MARKET_SHARE	0.66	0.475	0.60	0.490	0.69	0.462	0.001

Source: Own elaboration using SPSS.

3.2.3. *Control variables*

In this model, control variables have been included to test factors related to firm-level heterogeneity and track relevant effects that could be affecting the variables. Heterogeneity arising from firm industry is already controlled by drawing separate results for clean and dirty industries. Nevertheless, to provide new empirical evidence and obtain complementary information, three additional control variables are included: size, exports, and time.

- SIZE: Dummy variable that takes a value equal to 1 if the firm has more than 250 employees; 0 if not.
- EXPORT: Dummy variable that takes a value equal to 1 if the firm exports to non-EU countries; 0 if not.
- YEARS: Time dummies are included in the analysis so that the estimations obtained control for changes over time from year 2008 to 2016. Results are omitted in the presentation for simplicity.

Table 5 presents the summary statistics for these variables. Regarding the variable “SIZE”, only 22% of the firms in the total sample are large firms (having more than 250 employees). This percentage is higher in the case of clean industries (30% of large firms) than in the case of dirty industries, where only 16% of them are large.

With respect to “EXPORTS”, only 11% of firms in the total sample export to non-EU countries. This proportion is even lower in the case of firms in clean industries, with only 4% of them exporting to non-EU countries (compared to 19% in the case of dirty industries).

Table 5: Summary statistics of control variables.

CONTROL_VARIABLES	TOTAL SAMPLE		CLEAN		DIRTY		ANOVA test Difference between dirty and clean industries (P value)
	Mean	Sd	Mean	Sd	Mean	Sd	
SIZE	0.22	0.415	0.30	0.458	0.16	0.367	0.001
EXPORT	0.11	0.315	0.04	0.201	0.19	0.392	0.001

Source: Own elaboration using SPSS.

Finally, a summary of the variables included in the model, together with their definition, is provided in Table 6:

Table 6: Summary and definition of the variables introduced in the model.

DEPENDENT VARIABLE	
ECO_INNOVATION	
ENERGY	Dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards reducing energy per unit of production; 0 if not.
IMPACT	Dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards reducing environmental impact; 0 if not
EXPLANATORY VARIABLES	
ENVIRONMENTAL_POLICY	
REGULATION	Dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards meet regulatory requirements; 0 if not
LOCAL_SUBSIDIES	Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from local authorities; 0 if not
NATIONAL_SUBSIDIES	Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities national authorities; 0 if not
EU_SUBSIDIES	Dummy variable that takes a value equal to 1 if the firm receives any public financial support for innovation activities from the EU; 0 if not
TECHNOLOGY_PUSH	
INTERNAL_R&D	Dummy variable which takes a value equal to 1 if the firm has expenditures in internal R&D; 0 if not

EXTERNAL_R&D	Dummy variable which takes a value equal to 1 if the firm has expenditures in external R&D; 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 centers has high importance; 0 if not
MARKET_PULL	
NEW_MARKET	Dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards entering new markets; 0 if not
MARKET_SHARE	Dummy variable that takes a value equal to 1 if the firm innovation objective has a high or medium orientation towards increasing or maintaining market share; 0 if not
CONTROL VARIABLES	
SIZE	Dummy variable that takes a value equal to 1 if the firm has more than 250 employees; 0 if not
EXPORT	Dummy variable that takes a value equal to 1 if the firm 1 if the firm exports to non-EU countries; 0 if not
INDUSTRY	Dummy variable that takes a value equal to 1 if the firm belongs to a clean industry; 0 if not
Years	Dummy variables indicating the year to which observations belong to (2008-2013)

Source: Own elaboration.

3.3. Empirical methods

3.3.1 Simple descriptive statistics

The descriptive analysis of the sample shows the following results about the eco-innovative orientation of firms based on different factors. This analysis has been done using the cross tables function in SPSS.

Environmental policy factors

Table 7 shows results for firms' orientation to eco-innovation based on environmental policy factors: regulation and subsidies.

- Regulation: results show that out of the firms that have the objective of meeting regulatory requirements, most of them are oriented to Eco-innovation (82.2% in clean industries and 89.8% in dirty industries).
- Subsidies: regarding subsidies, it is worth mentioning the difference between clean and dirty industries. In the case of clean industries, only 53% of firms that receive any public financial support for innovation activities from local, national or EU authorities have an eco-innovative orientation. However, in the case of dirty industries, this percentage is notably higher: 72.6% of them are oriented to Eco-innovation.

Table 7: Analysis of the eco-innovative orientation of firms based on Environmental policy factors.

	Firms not oriented to Eco-innovation				Firms oriented to Eco-innovation			
	CLEAN		DIRTY		CLEAN		DIRTY	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
REGULATION	1413	17.8	2007	10.2	6537	82.2	17644	89.8
SUBSIDIES	3976	47.0	3739	27.4	4477	53.0	9918	72.6

Source: Own elaboration using SPSS.

Technology push factors

Concerning the relationship between orientation to eco-innovation and technology push factors, Table 8 shows revealing results. The four variables included (internal R&D, external R&D, market sources and institutional sources) behave similarly. In the case of clean industries, around half of the firms that have expenditures in R&D and where information sources are important, are oriented towards innovation. However, in the case of dirty industries, the percentage is remarkably higher: around 75% of them are oriented to eco-innovation.

Table 8: Analysis of the eco-innovative orientation of firms based on Technology push factors.

	Firms not oriented to Eco-innovation				Firms oriented to Eco-innovation			
	CLEAN		DIRTY		CLEAN		DIRTY	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
INTERNAL_R&D	5961	48.6	6761	28.3	6294	51.4	17129	71.7
EXTERNAL_R&D	2365	43.8	2908	26.2	3033	56.2	82802	73.8
MARKET_SOURCES	7772	50.4	7344	28.1	7643	49.6	18760	71.9
INSTITUTIONAL SOURCES	4615	43.5	4103	23.4	5998	56.5	13424	76.6

Source: Own elaboration using SPSS.

Market pull factors

When examining the relationship between market pull factors and eco-innovative orientation, results in Table 9 show that firms having a high or medium orientation towards entering new markets and increasing or maintaining market share behave differently in clean and dirty industries. In the case of clean industries, only around 55% of these firms are oriented to eco-innovation, whereas this percentage increases to almost 75% in the case of dirty industries.

Table 9: Analysis of the eco-innovative orientation of firms based on Market pull factors.

	Firms not oriented to Eco-innovation				Firms oriented to Eco-innovation			
	CLEAN		DIRTY		CLEAN		DIRTY	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
NEW_MARKET	5451	45.3	5991	25.5	6576	54.7	17526	74.5
MARKET_SHARE	5956	46.6	6195	25.6	6815	53.4	17958	74.4

Source: Own elaboration using SPSS.

Control variables

Firm's orientation to eco-innovation based on their characteristics is presented in Table 10. With respect to size, large firms (those having more than 250 employees) are more oriented to eco-innovation in dirty industries (76.2% of large firms in dirty industries are oriented to eco-innovation, compared to 43.8% in clean industries).

Moreover, as for the exporting activity, firms that export to non-EU countries in dirty industries are more likely to be oriented to eco-innovation than firms in clean industries (64.5% compared to a 46.1% of firms exporting to non-EU countries in clean industries).

Table 10: Analysis of the eco-innovative orientation of firms based on firm characteristics.

	Firms not oriented to Eco-innovation				Firms oriented to Eco-innovation			
	CLEAN		DIRTY		CLEAN		DIRTY	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
SIZE	3080	56.2	1501	23.8	2399	43.8	4810	76.2
EXPORT	495	53.9	1491	35.5	423	46.1	2714	64.5

Source: Own elaboration using SPSS.

3.3.2. Binary logistic regression

This subsection presents the model built with the variables that have been explained. Before running the regression model, The Pearson Coefficient is analyzed for the total sample (see Table 11). Correlation values among all variables are generally low to moderate, suggesting there is a low risk of facing collinearity issues or redundancies with this set of variables. This is confirmed by the analysis of the variance inflation factor (Vif) value.

Table 11: Pearson Correlation matrix and Variance Inflation Factor (VIF) for the total sample.

	1	2	3	4	5	6	7	8	9	10	11
1. Eco_Innovation	1										
2. Regulation	0.638**	1									
3. Subsidies	0.159**	0.143**	1								
4. Internal_RD	0.256**	0.270**	0.526**	1							
5. External RD	0.165**	0.162**	0.423**	0.436**	1						
6. Market_sources	0.299**	0.307**	0.173**	0.289**	0.146**	1					
7. Institutional_sources	0.276**	0.260**	0.356**	0.296**	0.318**	0.290**	1				
8. New_market	0.330**	0.345**	0.203**	0.359**	0.168**	0.365**	0.257**	1			
9. Market_share	0.328**	0.351**	0.175**	0.343**	0.162**	0.387**	0.240**	0.691**	1		
10. Size	0.061*	0.046**	-0.008*	-0.046**	-0.050**	0.037**	-0.042**	-0.070**	-0.020**	1	
11. Export	0.086**	0.085**	0.121**	0.199**	0.133**	0.066**	0.050**	0.127**	0.114**	-0.019**	1
VIF		1.248	1.348	1.449	1.234	1.298	1.342	2.058	2.057	1.030	1.032

Source: Own elaboration using SPSS.

With respect to the regression, the model used is the binary logistic regression. This statistical tool is appropriate when the dependent variable is binary (meaning it can only take two values). It allows the identification of important factors that affect the dependent variable as well as the nature of the relationship between them.

Moreover, as estimations for clean and dirty industries are reported separately, it is important to account for inter-sectoral differences. The standard one-tailed z-test is used to compare the regression coefficients between the two industries (Van Beers and Zand, 2013).

Table 12 presents results for the binary logistic regression coefficients for clean and dirty industries (with the standard error included in parenthesis) and z-test to study inter-sectoral differences. Time variables have been included in the analysis to control for differences across years, but results are omitted in the presentation. In addition, the R^2 shows the proportion of the variation explained with the model's inputs.

Table 22: Results of the binary logistic regression for the Eco-innovation variable and Z test for inter-sectoral differences.

	CLEAN	**DIRTY**	**Z test**
REGULATION	2.712*** (0.044)	2.701*** (0.046)	0,173
SUBSIDIES	0.098* (0.051)	0.175*** (0.050)	1,078
INTERNAL R&D	0.176*** (0.051)	0.164*** (0.049)	0,170
EXTERNAL R&D	0.160*** (0.053)	0.093* (0.054)	0,885
MARKET_SOURCES	0.390*** (0.047)	0.577*** (0.051)	2,696**
INSTITUTIONAL_SOURCES	0.493*** (0.058)	0.576*** (0.047)	1,112
NEW_MARKETS	0.454*** (0.058)	0.297*** (0.058)	1,914**
MARKET_SHARE	0.175*** 0.050)	0.313*** (0.059)	1,784**
SIZE	0.220*** (0.091)	0.522*** (0.059)	1.153
EXPORT	0.017 (0.009)	-0.176*** (0.051)	3,727***
Adjusted R^2	44.10%		

*Significance at 1%; **significance at 5%; ***significance at 10%. Standard errors are given in parentheses. Estimations control for years and industry dummies but results are omitted for simplicity. *Source: Own elaboration using SPSS.*

The interpretation of the coefficient estimators shows the following results:

Environmental policy factors

- Regulation: There is a positive and significant correlation between the firms' orientation towards meeting regulatory requirements and meeting eco-innovation objectives. This result is in line with studies that prove that environmental public policies and regulation are essential for eco-innovation (De Marchi, 2012; del Río et al., 2015; Demirel and Kesidou, 2019; Horbach, 2008; Horbach et al., 2013). Other factors can also explain these results, for instance, regulation can compensate for additional costs of eco-innovation through the substitution or better utilization of some materials (Porter and Linde, 1995). Moreover, some types of regulation have the same effect as setting a price for polluting. In this regard, there are studies that prove that the increase of this price can positively affect orientation towards eco-innovation Frondel et al., (2008), Rehfield et al., (2007). However, the effect on eco-innovation is similar in the case of clean and dirty industries and, as confirmed by the z-test, differences across sectors are not significant for this study.

- Subsidies: The reception of any public financial support for innovation activities from local, national or EU authorities is proved to be significant and positively correlated to the firms' orientation to eco-innovation. This is consistent with the results obtained by Horbach et al. (2012), del Río et al. (2015) and De Marchi (2012), who confirm a statistically significant influence. This can be explained by the fact that these subsidies can be used by firms to obtain more resources and information as well as new opportunities to eco-innovate. On the contrary, the lack of subsidies can lead to a waste of money and time if firms try to address environmental issues without the adequate tools (Porter and van der Linde, 1995).

  This reasoning is applicable for every firm regardless of whether it develops its activity in a clean or a dirty industry and this can explain the fact that differences across sectors are significant when looking at the z-test.

Technology push factors

- Internal and External R&D: Expenditures in both, internal and external R&D are positively correlated to the eco-innovative orientation. Results are again significant in the case of both industries, and this coincides with findings by Horbach (2008) about the positive relationship between improving technological capabilities through R&D and being updated on new environmental possibilities. In addition, it has been proved that firms which have innovated in the past are more likely to innovate in the future because of sunk costs in R&D investments (Martínez-Ros and Labeaga, 2009; Peters, 2009; Triguero and Córcoles, 2013).

  It is also worth mentioning that the z-test is not significant, which means that differences across sectors are not relevant. In other words, the existing difference in the value of the coefficients from clean to dirty industries is not significant.

- Market and Institutional sources: These types of sources have a positive relationship with the eco-innovation objectives which is significant. This matches the theory claimed by Cainelli et al. (2015) and Ghisetti et al. (2015) that the more sources or partners a firm can employ, the more likely it is to implement an eco-innovation strategy. This happens because eco-innovation is relatively new, thus, as the study by Horbach (2016) showed, firms must rely more on basic research activities and external sources of information (compared to other well-established innovation fields). Moreover, according to Belin et al. (2011) the new technology that characterizes eco-innovation requires more basic research through these sources. This explains the increase in the need of sources of information to obtain the knowledge required by the multidimensionality of eco-innovation.

  This result is true for clean and dirty industries; however, there are significant differences from one sector to another: according to the z-test, the correlation is stronger in the case of dirty industries, meaning that the effect on eco-innovation is greater than in the case of clean industries. This can be explained because firms' behavior in dirty industries is more likely to be of concern for the rest of society and stakeholders (Shan and Wang, 2019). Therefore, sources of information can play a more important role and create greater value in these industries. In contrast, eco-innovation in clean industries has, in general terms, less importance for the public.

Market pull factors

- New markets and Market share: results show that the more a firm is oriented towards entering new markets and maintaining or increasing market share, the greater the importance of the eco-innovative objective. This relationship is significant and can be explained because demand drives innovative development. More precisely, the consumption of ecological products by proactive consumers is an incentive for the development of new products (Zhang et al., 2020; Demirel and Kesidou, 2019) and the entrance of firms into new markets (Annunziata et al., 2018; Arranz et al., 2020). Firms can take advantage of the opportunities generated in the market by investing in innovation to satisfy unmet needs (Kohli and Jaworski, 1990).

As shown in Horbach, (2008) the main drivers of eco-innovation are customer demand and public pressure. In addition, it has been proved by Triguero et al. (2013) that the increasing market demand for green products and market share, in turn, are important when implementing product or organizational eco-innovation.

It is important to note that there are significant differences regarding behavior in clean and dirty industries. On the one hand, firms' orientation towards maintaining or increasing market share has a greater effect on eco-innovation in the case of clean industries. This can result from the fact that firms in industries which are already considered as clean, may want to leverage customers' environmental awareness as a driver of their strategy through the adoption of clean technologies (Horbach et al., 2012 and Kammerer, 2009) and, therefore, achieve an increase in their market share by differentiating from competitors.

On the other hand, when considering orientation towards entering new markets, the effect on eco-innovation is greater for firms in dirty industries. This may be explained by the fact that on many occasions, firms adopt eco-innovation strategies to satisfy the minimum requirements expected by customers and society Demirel (2012) as well as requirements by regulations (which are more stringent in dirty industries). In line with this, although the relationship is also positive in the case of clean industries, it is significantly less important, and this can happen because sometimes, companies may resist to implement eco-innovative strategies as they fear that customers will not be willing to pay a higher price for green products or services Bianchi and Noci (1998).

Firm characteristics

- Size: the results obtained can be interpreted as follows: the bigger the size of the firm, the more oriented the firm is towards the eco-innovative objectives. Studies by Lu and Beamish (2001) prove that smaller firms have less access to resources. This can explain that large firms have more access to information sources which allow them to eco-innovate and be more concerned with eco-innovation goals (Martínez-Ros and Kunapatarawong, 2019). This is also consistent with the finding of Rave et al. (2011) that eco-innovation is more positively associated with firm size than in the case of non-environmental innovations. They also proved that large firms can more easily create continuous eco-innovation. In addition, a further reason to explain this relationship is that there is a positive correlation between firms' size and the extension of the product's green characteristics Kammerer (2009). The result is significant in the case of both industries but there are no differences across sectors according to the z value (which is not significant).

- Exports: The variable "exports" is more particular. First, the coefficient obtained is not significant in the case of clean industries. This may be explained by the fact that the variation on exports resulting from the eco-innovation objective is much subtler than variation because of other basic factors (Zhang et al., 2022).

  Second, in the case of dirty industries, the relationship is significant but negative, meaning that in dirty industries, the higher the level of firms' exports to non-EU countries, the less oriented they are to eco-innovation. This result opposes to conclusions which claim that firms oriented to international markets are supposed to have more competitors and therefore, carry out some eco-innovations. However, this result coincides with Rehfeld et al. (2007). According to them, most environmentally friendly products target a national or regional niche.

  In the case of exports, differences across sectors are also significant and this result can be justified with the study developed by Horbach (2008) that relates the exporting activity with the sector variable. Some sectors like machinery (included in the clean industries) with high shares of exports are more predisposed to innovate compared to other sectors like agriculture, mining, or energy (which are considered dirty industries). The result may be explained by the fact that more strict environmental standards (as it is the case in dirty industries) lead to less net exports in pollution-intensive industries (Wilson, S. et al., 2002).

  Indeed, studies show that although eco-innovation generates innovation offsets effects and compliance costs effects, on many occasions, these are not enough to compensate for additional compliance costs in these dirty industries with more regulation (Zhang et al., 2022).

4. CONCLUSIONS AND IMPLICATIONS

Environmental innovation is increasingly important in the current context as it is a key enabler for the achievement of the SDGs. In this sense, firms are fundamental for the development of environmental innovation through changes in production patterns. However, there are differences across clean and dirty industries in the adoption and implementation of eco-innovation.

Studies claim that for environmental innovation to extend its full potential, it is essential that firms and decision makers are able to identify its main drivers. As a result, this study has focused on the analysis of the drivers for the adoption of environmental innovation by distinguishing between clean and dirty industries.

The analysis of the total sample shows that all the factors included in the model are relevant for the firms considered in the study but to a different extent. For instance, only 27% of the firms in the total sample receive any public financial support for innovation activities, while 75% of them give high importance to information from suppliers, clients, competitors, or private R&D institutions. However, what is true for all the variables in the study is that the proportion of firms that have each of these factors as part of their strategy is higher in the case of firms in dirty industries compared to firms in clean industries.

Going a step further in the analysis, it can be claimed that out of the firms that do have these factors as part of their strategies, only some of the firms have them with a high or medium orientation towards reducing the energy required per unit of production or the environmental impact. In this regard, one of the main findings of this study is that among the firms that have these factors in their strategy, firms in dirty industries have a higher orientation to the environmental objective for every variable studied.

More specifically, environmental policy factors (regulation and subsidies) are clear drivers of eco-innovation in both, clean and dirty industries. However, the regulation factor shows a higher proportion of firms oriented towards Eco-innovation with respect to subsidies. This may imply that regulation is a more effective environmental policy measure in order to promote eco-innovation. This is confirmed by the binary logistic regression, which proves that regulation has a higher impact on orientation towards the eco-innovative objective.

With respect to technology push factors, the four variables (internal and external R&D and market and institutional sources of information) show similar results, which are not very different across industries. Indeed, differences between clean and dirty industries are only relevant in the case of information coming from market sources. The model shows that market sources are significantly more relevant for firms in dirty industries and this proves that they are more influenced by information coming from suppliers, clients, competitors, or private R&D institutions.

In addition, differences are considerable regarding market pull factors (entering new markets or increasing or maintaining market share). The effect of these objectives is significantly different across industries: The objective of entering new markets is a more important driver of environmental innovation in the case of clean industries, while the objective of increasing or maintaining the market share is significantly more relevant for the adoption of environmental innovation in the case of firms in dirty industries. This implies that the adoption of eco-innovation may be more effective for firms in clean industries that seek to enter new markets, whereas, in the case of firms in dirty industries, is a more interesting strategy for those that seek to maintain or increase their market share.

Finally, when considering firms' characteristics, big firms are more likely to have eco-innovative orientation in dirty industries compared to clean industries, and the same is true for firms that export to countries outside the European Union. However, results for the regression show that an increase in the exporting activity does not have a significant effect on eco-innovation for firms in clean industries. Moreover, it is interesting to remark that out of the variables considered in the study, firms' exporting activity in dirty industries is the only factor that negatively affects the adoption of eco-innovation.

All things considered, it can be claimed that firms in dirty industries are more oriented to environmental innovation according to all the factors analyzed. In this sense, this study also shows that firms in clean industries can do a bigger effort for including the eco-innovative objective as part of their strategy and this, in turn, can be more efficient in the long run, as well as a source of new competitive advantage.

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APPENDIX

Table A1: Industry classification: clean and dirty industries. Source: PITEC database and CNAE2009

CLEAN INDUSTRIES	**DIRTY INDUSTRIES**
Clothing	Agriculture, livestock, fishing
Machinery and equipment	Mining and quarrying
Transport equipment	Food, beverages and tobacco
Other manufacturing activities	Textile
Machinery repair	Leather and footwear
Commerce	Wood and cork
Warehousing	Pulp and paper
Accommodation	Graphic arts and reproduction
Telecommunication	Chemicals
Information technology	Rubber and plastics
Software development	Pharmaceutical
Finance and insurance	Non-metallic mineral products
Real estates	Metallurgy
R&D	Metal
Other activities	Computers and electronics
Administrative services	Electrical products
Education	Vehicles
Social services	Shipbuilding
Arts, recreations and entertainment	Spaceship and airplanes
Other services	Furniture
	Energy and water
	Waste management
	Construction

Source: Own elaboration based on CNAE2009 classification and TRI (Toxic Release Inventory).