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Drivers to increase eco-efficiencies in Uruguay, Peru, and Panama

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ABSTRACT

Scarce evidence postulates the drivers of eco-innovation in Latin American Countries. This paper aims to contribute empirically to the literature on drivers of eco-efficiencies in this region. We use the last year available in the new LAIS dataset -Latin American Innovation Survey- and apply multivariate probit models. Results show that drivers in this region can be divided into three groups: *common, frequent, and occasional*. The first one includes market and regulatory factors which affect the three countries; frequent drivers are some technological push drivers whose influence is substantial although only in some countries; and the last one refers to those drivers that have a sporadic effect on eco-efficiencies, such as training and cooperation. Differences also are found distinguishing by type of innovation -product and process, radical and incremental- and by efficiencies -energy, material, and environmental-.

1. Introduction

In current years, eco-efficiencies are becoming key factors in the global economic agenda, due to the need for a combination of environmental, business, and economic objectives (OECD, 2018a; 2021). In this context, innovation allows firms to gain green competitive advantages and be more eco-efficient (Cai and Li, 2018; Colombelli et al., 2021; Jänicke, 2012). The International Energy Agency (IEA) considers innovation as an engine of new technologies for obtaining clean energy and for combating climate change. In fact, innovations and eco-efficiencies are elements of the IEA's Global Energy and Climate Model (International Energy Agency - IEA, 2022). This IEA model fits within the Sustainable Development Goals (SDGs) developed by the United Nations. Specifically, it connects four of them: the analysis of efficiency gains (SDG7 -Affordable and Clean Energy- and SDG12 -Sustainable Consumption and Production-) with the introduction of green innovations (SDG9 -Industry, Innovation, and Infrastructure-) to combat climate change (SDG13 -Climate Action-) (Alola et al., 2021; Bisaga et al., 2021; Chen et al., 2023).

Indeed, the concept of eco-innovation that emerged in the late 1990s is defined as the increase of eco-efficiency (energy, material, and environmental) in the production process explained by introducing green products or processes (Kemp and Arundel, 1998). Several definitions of eco-innovation have emerged since then. Specifically, the contribution of Kemp and Pearson (2007) defines eco-innovation 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" (Kemp and Pearson, 2007: p.7).

Another of the most relevant definitions is that of Carrillo-Hermosilla et al. (2009, 2010) who postulate that "Eco-innovation refers to the introduction of innovation that improves environmental performance" (Carrillo-Hermosilla et al., 2009: p.8).

These important definitions consider that the introduction of eco-innovations reduces the energy and material resources, as well as, the environmental impact of the production process (Cagno et al., 2015; Costa-Campi et al., 2015a, 2015b; Rexhäuser and Löschel, 2015). Therefore the introduction of eco-innovation can minimize the environmental effects -negative effect- or it could generate a benefit to the environment -positive effect- (Carrillo-Hermosilla et al., 2009, 2010).

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Both effects produce eco-efficiencies,[1] and therefore a link between eco-innovation and eco-efficiencies could be proposed.

In this regard, the literature on eco-innovation has been analysing which are the drivers that could increase eco-efficiency gains, following different theoretical approaches, such as: the economics of innovation or the resource-based view of the firm (RBV) (Del Río et al., 2016a; Kiefer et al., 2019). The latter is of particular relevance (Cainelli et al., 2015; Del Río et al., 2016a; Kiefer et al., 2019), because it has indicated how the heterogeneity of resources and capabilities that firms have are key in determining the drivers of eco-innovation.

Illustrative findings are shown in some works, such as in Cuerva et al. (2014), De Marchi (2012), Del Río et al. (2017), Horbach (2008), Horbach et al. (2012) and Triguero et al. (2013), among others. These authors have classified the eco-innovation determinants into three groups according to the contribution of Horbach (2008): *technological push, market pull and regulatory push-pull factors*. However, the analysis of these eco-innovation factors has been developed mainly in high-income economies, specifically in European countries: Germany (Horbach, 2008; Horbach et al., 2012; Ketata et al., 2014), France (Li-Ying et al., 2018; Mothe et al., 2018), and Spain (Del Río et al., 2017; Jové-Llopis and Segarra-Blasco, 2018; Marzucchi and Montresor, 2017).

There are only a few contributions of eco-innovation drivers in other economies not classified as high-income (Cai and Li, 2018; Cai and Zhou, 2014; Chen et al., 2017; Da Silva Rabêlo and De Azevedo Melo, 2018; Fernández, 2022; Fernández et al., 2021; Galbreath et al., 2021; Geng et al., 2021; Keshminder and Del Río, 2019; Liao and Zhu, 2022; Mady et al., 2022; Sanchez-Henriquez and Pavez, 2021; Sanni, 2018; Shao et al., 2022; Ying et al., 2022; Yu et al., 2016; Yu et al., 2019), although the RBV theoretical model has indicated the relevance of differences in firm characteristics and resources (Kiefer et al., 2019). These studies highlight the role of market pull and regulatory push-pull factors as drivers of eco-innovations (Fernández et al., 2021; Liao and Zhu, 2022; Sanni, 2018; Cainelli et al., 2020; Doran and Ryan, 2016). However, there are still some doubts regarding the technological push drivers. In this sense, innovation systems play a relevant role in addressing barriers to eco-innovation (Arranz et al., 2019). Nevertheless, these economies present weak innovation systems and higher costs of innovation (De Marchi, 2012; Dutrénit et al., 2019), and therefore, their eco-innovative performance could be adversely affected. The authors postulate that other innovation expenditures and collaborations with partners, alliances and networks could facilitate the introduction of eco-innovations in these countries (Arranz et al., 2019; Cai and Li, 2018; De Marchi, 2012; Diez-Martínez et al., 2022; Fernández et al., 2021).

In this sense, the main objective of this paper is to add some empirical evidence on the drivers of energy and other green efficiencies[2] in three Latin American Countries: Uruguay, Peru and Panama. Indeed, there have been various calls for papers on this issue in Del Río et al. (2016b), Du and Li (2019), Fernández et al. (2021), and Ying et al. (2022), where these authors recognize the need for a specific analysis of eco-innovation drivers in other regions (Han and Chen, 2021). In the words of Del Río et al. (2016b, p.2167) *"a middle-income and a developing country perspective are missing"*. Moreover, Cai and Zhou (2014) also indicate the need to consider different levels of efficiencies (energy, material, or environmental efficiencies).

Specifically, three would be the main research questions of this work. On the one hand, we test the drivers of eco-innovation in three Latin-American countries, answering our first research question (RQ1): *What are the drivers of eco-efficiencies in Uruguay, Peru, and Panama?* On the other hand, we examine whether there are differences between the drivers considering various types of innovation (product, process, incremental, and radical innovations). Therefore, the second research question would be as follows (RQ2): *Are drivers in these countries different when we consider several types of innovations?* Finally, we test whether there are differences in drivers when we contemplate different types of efficiency (energy, material, and environmental). Thus, research question number three would be (RQ3): *Are drivers in these countries different when we examine several efficiencies: energy, material and environmental efficiencies?*

This paper fills these gaps by analysing the drivers in Uruguay, Peru, and Panama. These countries are considered weak in innovation terms (Dutrénit et al., 2019)[3] but well-positioned according to the green aspects.[4] At the same time, those countries are developing actions to obtain efficiencies gains (SDGs 7, 12) using innovations for combating Climate Change (SDGs 9 and 13).

Applying multivariate probit analysis, we identify drivers distinguishing by product, process, incremental and radical innovations and considering three efficiencies: energy, material, and environmental. To that end, the Latin American Innovation Survey (LAIS) at the firm level[5] developed by the Inter-American Development Bank, is used (Canêdo-Pinheiro et al., 2022; Chavez, 2022; Crespi et al., 2022; Vargas, 2022). Results show as drivers in Latin American Countries could be divided into *common, frequent,* and *occasional*. The *common* drivers include those aspects related to the market pull and the regulatory push-pull factors, which affect all countries and practically all types of eco-efficiencies considered. *Frequent* factors include internal R&D, non-R&D embodied, non-R&D disembodied, and breadth. These drivers substantially influence the different types of eco-efficiencies, but only in some countries. Furthermore, the *occasional* drivers, training and cooperation, have a sporadic influence on eco-efficiencies in the region. Finally, we find differences in drivers considering the type of innovation, and similarities in energy and material efficiencies.

The main contributions of this work are threefold. First, we add empirical evidence analysing eco-innovation in three Latin American countries. Secondly, this study distinguishes between different types of innovation (product, process, incremental, and radical innovations), and efficiencies (energy, material and environmental). Finally, this research contributes to the development of a framework of drivers of eco-efficiencies in middle-income countries, considering different groups: common, frequent, and occasional.

Finally, the paper is organized as follows. The next section analyses the drivers of eco-efficiencies in Latin America establishing our set of hypotheses. The third section describes the data and methodology. Section 4 explains the main results and, finally, Section 5 draws the conclusions and the main policy implications.

2. Hypotheses development

Most studies analysing the drivers of eco-innovation are carried out in high-income economies (Horbach et al., 2012; Li-Ying et al., 2018; Marzucchi and Montresor, 2017). However, the latest studies in the field indicate that factors explaining the development of eco-efficiencies are

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[1] Although eco-efficiencies have too many definitions (Levidow et al., 2016; Mavi et al., 2019). It has been tested that eco-innovations and eco-efficiencies are joint roads for firms and countries (Mavi et al., 2019). For that reason, we use the concepts of eco-innovation and eco-efficiency indistinctly in the paper.

[2] Other green efficiencies here refer to material and environmental efficiency. As can be observed in Fig. 1 the term efficiencies include: energy, material, and environmental efficiency. This classification would be used throughout the paper.

[3] The countries are included in the category of laggard innovation countries according to the Global Innovation Index (GII): the positions of these countries are Uruguay in 64th place, Peru in 65th, and Panama in 81st position.

[4] In the ecological sustainability category included in the GII, the position of the countries analysed are the following: Uruguay in 46th position, Peru in 51st position, and Panama in 29th place.

[5] The analysis at the firm level is a keystone to achieving the eco-efficiencies targets because firms are responsible for a considerable share of energy and material consumption (Cagno et al., 2015).

context-dependent (Fernández et al., 2021; Ying et al., 2022) and, therefore, more analyses considering middle-income economies are needed (Del Río et al., 2016a).

Eco-efficiency drivers can be internal and external to the firm (Del Río et al., 2016a; Doran and Ryan, 2016; Frigon et al., 2020; Kiefer et al., 2019). These drivers have traditionally been classified into three main groups: *technological push, market pull*, and *regulatory push/pull* (Cuerva et al., 2014; De Marchi, 2012; Del Río et al., 2017; Horbach, 2008; Triguero et al., 2013).

Regarding *technological push factors,* the literature argues that the resources and capabilities of the firms are crucial for the development of eco-innovations.

Focusing on R&D expenditures, R&D as well as other innovation expenditures, affect positively eco-efficiencies gains in high-income economies (Cainelli et al., 2015; Horbach, 2008; Triguero et al., 2018). However, empirical evidence of middle-income economies agrees that internal and external R&D have a limited effect on the development of eco-innovations due to the higher expenditure in R&D needed with a long-term orientation (De Marchi, 2012; Fernández et al., 2021). Therefore, meeting such conditions in these countries is difficult because firms cannot attract abundant financial resources and are oriented toward cost minimization (Arranz et al., 2019; Ying et al., 2022). This scarcity of resources for R&D investment is undoubtedly a key characteristic of these markets that impedes the development of eco-innovations, due to that firms in these markets cannot afford the standard expenditures required to develop them (Baskaran and Mehta, 2016; Ying et al., 2022). Thus, not all firms in middle-income economies have sufficient funds (R&D expenditures – *Internal* or *External R&D*) to pursue eco-innovations. In addition, it must be considered how the structure of demand could affect R&D decisions. In these countries, final consumers tend to focus on the price, being eco-efficiency products more expensive. Furthermore, the literature points out that firms in countries with lower levels of development trade internationally between themselves more intensively than firms in high-income countries (Dahi and Demir, 2008). This is because they offer products that are more affordable and easier to imitate, so due to the scarcity of financial resources of these companies and the demand they face, it is common for them to look for alternatives to internal and external R&D.

Therefore, the current framework of eco-innovations has limited application for analysing how resource-constrained firms increase energy and other green efficiencies. In such firms, both internal and external R&D expenditures are lower. Particularly, in the Latin American region, the relationship between innovation and internal and external R&D is not well established (Crespi and Zuniga, 2012). General innovation outputs are based mainly on other innovation expenditures, such as the imitation or transfer of technology or innovation expenditure in engineering, design, and training, (Álvarez et al., 2010; Benavente, 2006). Accordingly, activities related to investment in machinery, equipment, and training are more widespread than R&D expenditures (Cassiolato and Lastres, 2000; Dutrénit et al., 2019).

Given the above, the analysis of the relationship between eco-efficiencies and external and internal R&D in the Latin American region has contradictory evidence. Fernández et al. (2021) show as R&D intensity is not a factor that explains the development of eco-innovations using a sample of Chilean firms. However, considering external R&D, De Jesús Pacheco et al. (2018) have noted that it affects positively the development of eco-innovations in a sample of Brazilian firms, while Fernández et al. (2021) found mixed evidence for these external expenditures. According to the previous background, we hypothesize that:

H1. Internal R&D is not a driver of eco-efficiencies in Latin American firms.

H2. External R&D is not a driver of eco-efficiencies in Latin American firms.

Other innovation expenditures have also been considered as possible drivers in high-income economies (Horbach et al., 2012; Triguero et al., 2018). Innovation expenditures could act as substitute inputs in countries where the expenditures in R&D are low (Álvarez et al., 2010; Benavente, 2006; Crespi et al., 2016; Dutrénit et al., 2019). The main innovation expenditures considered in this category are the acquisition of machinery, equipment, and advanced hardware or software, the innovation expenditures in engineering and design, and the training in R&D.

Regarding the acquisition of machinery, equipment, and advanced hardware or software (*Non-R&D Embodied),* evidence in middle-income economies postulates it as a driver (Fernández et al., 2021; Sanni, 2018). Specifically, Sanni (2018) has found a positive relationship between non-R&D embodied and the development of eco-innovations in Nigerian firms. In this sense, imitative pressure generates the development of new materials, technologies, and equipment to improve innovation abilities (Cai and Li, 2018). In Latin America, the acquisition of machinery and equipment remains the main innovation activity in countries such as Chile, and in other countries, such as Uruguay, this expenditure is also very important (Chudnovsky et al., 2006; Dutrénit et al., 2019). In these countries, the empirical evidence has shown a link between eco-efficiencies and other innovation expenditures (Fernández et al., 2021). These authors found that acquiring machinery and equipment positively affects the development of energy and material efficiency in product, process, and incremental innovations.

Other innovation expenditures such as engineering, and design (*Non-R&D Disembodied)* have been also considered as a driver. Non-R&D disembodied activities could complement the low level of R&D expenditures in these countries, being essential for innovation in low-tech sectors (Navarro et al., 2010). In Latin America, while Crespi and Zuniga (2012) show that product design affects positively the development of general innovations, Fernández et al. (2021) have not found evidence for energy and other green efficiencies in Chile.

Finally, *Training in R&D* has been also considered essential for the development of eco-efficiencies (Arranz et al., 2019; Bossle et al., 2016). The formation of employees allows the development of skills that enable the introduction of eco-innovations in a different sample of countries (Fernando and Wah, 2017). For middle-income economies, De Jesús Pacheco et al. (2018) and Sanni (2018) have found that R&D training could act as a driver, although Sanni (2018) considers that R&D training is a key factor only for process eco-innovation. However, Fernández et al. (2021) have not found support for this hypothesis in the sample of Chilean firms. With this previous background, we propose the following hypotheses:

H3. Non-R&D embodied affects positively all eco-efficiencies in Latin American firms.

H4. Non-R&D disembodied affects positively all eco-efficiencies in Latin American firms.

H5. Training expenditures affects positively all eco-efficiencies in Latin American firms.

Technological push factors also include the sources of knowledge and cooperation agreements as drivers, according to the definition by Horbach (2008). In addition, lack of information has been identified as one of the main barriers to eco-innovation (Arranz et al., 2019; Musaad et al., 2020).

Different sources of knowledge, *Breadth,* such as customers, suppliers, competitors, or universities, also help to complement the internal knowledge base being successful in the development of eco-efficiencies in high-income economies (Frigon et al., 2020; Mothe et al., 2018; Triguero et al., 2013).

Breadth is considered a key driver of eco-efficiencies also in other countries (Cai and Zhou, 2014). This relationship has been supported by Fernando and Wah (2017) in Malaysia and by Cai and Zhou (2014) particularly for suppliers in Chinese firms. Furthermore, Yu et al. (2019), for a sample of Korean manufacturing firms, find that the breadth of sources of knowledge positively affects energy and material efficiency in process innovations and environmental efficiency in product innovations. Regarding the African continent, Sanni (2018), for a sample of Nigerian firms, has shown that formal sources of knowledge are more important than informal sources for eco-innovate. In the Latin American region, Sanchez-Henriquez and Pavez (2021) show that market knowledge sources affect positively the eco-innovation of Chilean firms. For the same country, Fernández et al. (2021) have confirmed this relationship for all eco-innovations except for environmental efficiency in process innovation and energy and material efficiency in radical innovations.

On the other hand, since eco-efficiencies require the use of new and complex technologies, *cooperation* will facilitate access to the external knowledge necessary to develop it in middle-income economies. In this sense, cooperation can be seen as a source of compensation for the absence of technological capabilities to develop green innovations (Diez-Martínez et al., 2022). Considering Latin American countries, Da Silva Rabêlo and De Azevedo Melo (2018) find for Brazil that cooperation increases the likelihood of being an eco-innovator. However, Fernández et al. (2021) have found only partial support for the relationship in Chilean firms. Specifically, these authors have shown a positive effect for all efficiencies in process innovations and energy and material efficiencies in product and radical innovations. Given the above, we propose the following set of hypotheses:

H6. The influence of the external knowledge, breadth, affects positively all eco-efficiencies in Latin American firms.

H7. Technological cooperation affects positively all eco-efficiencies in Latin American firms.

The second group of drivers is the *Market pull.* Market share or the entrance into new markets as innovation effects are considered also drivers in high-income economies (Horbach, 2008; Kesidou and Demirel, 2012; Triguero et al., 2013). The positive relationship between them has been confirmed in different regions.

In Asia, Galbreath et al. (2021), with a sample of Taiwanese firms, showed that the international demand for green products influences positively the development of eco-innovations, acting as a moderator of exports. Moreover, Keshminder and Del Río (2019) indicate that consumer pressure is relevant to eco-innovate for Malaysian companies in the chemical industry but note that its impact is indirect. In addition, Shao et al. (2022), for China, and Han and Chen (2021), for Myanmar, showed that customer demand and rivalry pressures are key factors for the development of eco-innovations.

For African countries, researchers also show a positive link. Specifically, Sanni (2018) for Nigeria finds a positive relationship between satisfying consumer demand and competitors and eco-innovations. In the same line, Rama et al. (2022), for a sample of Ghana firms, consider that the market characteristics and the demand are determinant factors for the introduction of eco-innovations. Instead, Mady et al. (2022) show an indirect effect of green demand on eco-innovative performance through an impact on green absorptive capacity for Egyptian SMEs.

However, the evidence found until now for Latin American countries is not so clear. While Fernández et al. (2021) have partially confirmed the relationship between market driver and energy and other green efficiencies in Chilean firms (except for product and radical innovations), De Jesús Pacheco et al. (2018) have noted that the implementation of eco-innovations is related to the increase on the market share in a sample of Brazilian firms. On the contrary, Aloise and Macke (2017) have found that market factors are not a determinant of eco-innovation also in Brazil.

Considering the evidence obtained above both in Latin America and other countries, it is understood that market share and entry into new markets adequately represent the market drivers and a positive relationship with the development of energy and other green efficiency is expected.

H8. Market drivers affect positively all eco-efficiencies in Latin American firms.

Finally, Porter's Hypothesis postulates that environmental regulation could force firms to carry out production through technological innovation to reduce costs, improve production efficiency, gain competitive advantages, and cover the negative cost impact of environmental regulations (Fethi and Rahuma, 2020; Porter and Van der Linde, 1995). In this sense, empirical studies have shown that regulatory push-pull is an important driver in Europe (Del Río et al., 2017; Doran and Ryan, 2016; Horbach et al., 2012; Kesidou and Demirel, 2012). However, Carfora et al. (2022) in a study of Italian SMEs, and Musaad et al. (2020) for the case of Saudi Arabia SMEs have shown that the regulatory aspect can be a barrier to eco-innovation for this type of companies.

Evidence from countries outside of Europe considers that environmental regulations affect positively the development of eco-innovations. Studies in Asia generally show such a positive link. Liao and Zhu (2022), using patents as eco-innovation variables for China, consider that institutions play an indispensable role in the eco-innovation development process. In the same line, Han and Chen (2021), in the case of Myanmar, Keshminder and Del Río (2019), for Malaysian chemical firms, and Cai and Zhou (2014), in China, found that environmental regulations affect positively the development of eco-innovations. However, using a sample of Chinese firms, Shao et al. (2022) postulate that the environmental regulation effects on eco-innovation follow a U-shaped curve, reducing, in the first stages, the eco-efficiencies and showing positive effects after a certain level.

Regarding African countries, Sanni (2018) finds a positive effect of regulation on eco-innovations in Nigeria, while Rama et al. (2022) point out the same influence using a sample of small firms and analysing the informal sector in Ghana. In contrast, Mady et al. (2022) for a sample of Egyptian SMEs do not find a direct effect of regulation on eco-innovations, but rather an indirect effect through the improvement of green absorptive capacity.

However, in the case of Latin American countries, Fernández et al. (2021) have shown no evidence of the relationship between energy and other green efficiency innovations and regulatory factors measured by subsidies in Chile. These results are different from those findings found in the rest of the middle-income economies. Due to the controversial results, the importance given by firms to comply with regulations and standards has been chosen to approximate the driver of regulation following the paper by Horbach (2008). According to the above, we hypothesize that:

H9. Regulatory drivers affect positively all eco-efficiencies in Latin American firms.

The hypotheses development presented in this section is included in Fig. 1. This research strategy details also introduced the types of innovation -process, product, incremental and radical innovation[6]-, and the types of efficiency.

3. Data and methodology

The dataset used for testing our hypotheses is the Harmonized Latin American Innovation Surveys Database (LAIS), published by Inter-American Development Bank in March 2022 (Crespi et al., 2022). Therefore, it is a very recent source of data used by Canêdo-Pinheiro et al. (2022), Chavez (2022) and Vargas (2022).

This dataset includes innovation data at the firm level for some Latin American countries following the recommendations of the Community Innovation Survey –CIS– and the Oslo Manual (OECD, 2018b). It is

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[6] Regarding Incremental and Radical Eco-innovations, we were no able to identify the eco-design dimension of the eco-innovations: Component addition, Sub-System Change, and System Change due to the composition of our variables.

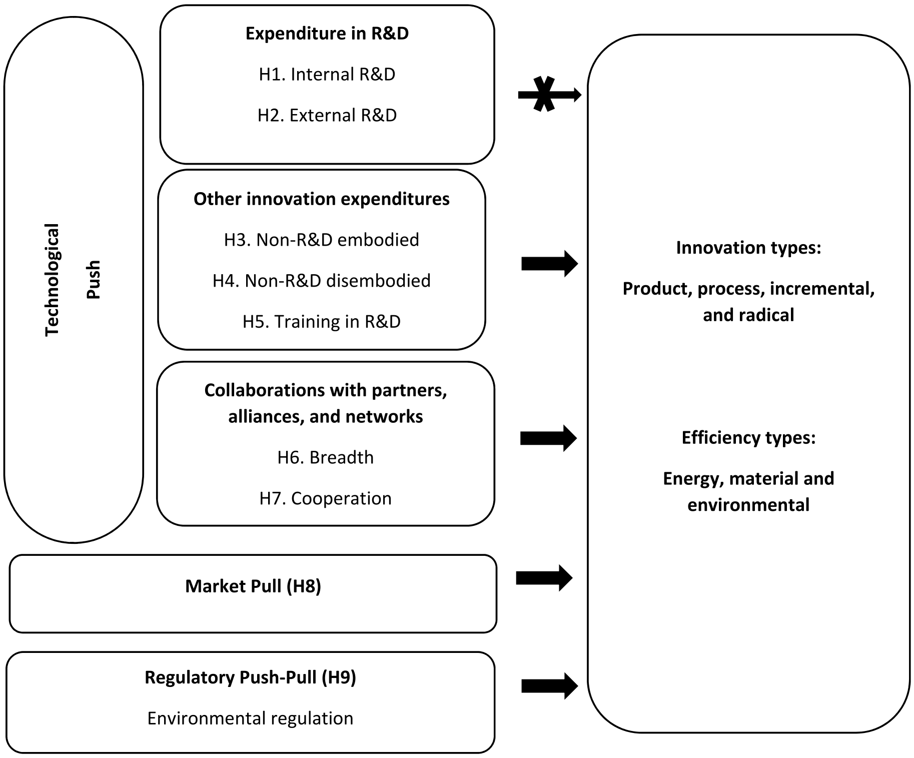

Fig. 1. A research strategy for our sample of Latin America countries.
Source: own elaboration

important to remark that this dataset harmonizes all variables and data from different innovation survey methods, allowing researchers to compare different countries in terms of innovation activities. However, the harmonization of the innovation surveys has many challenges and there are still some differences in the questionnaires and the variables available for each country (Vargas, 2022).

In this study, we analyse Uruguay, Peru and Panama, through the tri-annual data that the survey contains. The year used in the analysis corresponds to the last year's available for each country.[7] Panel data has not been allowed because of the limitations of the years and the difficulties in the identification of the firms.

Our sample consists of 11,964 observations for the three countries chosen. The eco-efficiencies representativeness of the countries in our sample in decreasing order is Peru, Uruguay, and Panama. Data shows that product and process innovation has a higher percentage of eco-innovators, than incremental and radical for our three efficiencies and countries. Table 1 contains the details of the sample by country and eco-efficiencies.

Regarding the variables used in this study, we follow the work of Fernández et al. (2021), Torrecillas and Fernández (2022) and Triguero et al. (2018), among others.

Our analysis defines 12 different dependent variables related to eco-efficiencies. The type of innovation (product and process) and the degree of novelty of the innovations (incremental and radical)[8] are used to define the innovation side of the dependent variables. The efficiency side is defined by three variables. Specifically, *energy* captures the reduction of energy consumption; *material* refers to the reduction of material consumption; and finally, *environmental* collects the reduction of environmental impacts and health and security improvements. These variables are built using the answer of high and medium importance to each of the green effects. Both the innovation and efficiency variables are measured through dummies (see Table A1 of the Appendix for more details). Therefore, each dependent variable used in our analysis is the interaction of the innovation and the efficiency variables, with a value of 1 if the firm implements a specific type of innovation and considers it highly important to obtain a specific efficiency, and 0 otherwise. Notice here that this interaction procedure for the building of these variables allows us to incorporate the innovations with environmental motivations, but also the environmental benefits of normal innovations (Carrillo-Hermosilla et al., 2010).

On the other hand, the explanatory variables (9 in total) are merged into three main groups. The first group is technology push drivers, which includes R&D expenditures (Internal and External R&D), other innovation expenditures (Non-R&D Embodied, Non-R&D Disembodied and Training in R&D), and sources of knowledge, alliances, and networks (Breadth and Cooperation). Detailed mention requires the variable Breadth, which is a categorical variable that takes values between 0 and 10, where 0 represents the firm that does not have any knowledge source of innovation and 10 represents the firm that has all the possible knowledge sources for innovation. The second and third groups of factors are Market pull and Regulatory push/pull. Additionally, two control variables are included: Age and Size. Age is used in its squared form due to the non-linear trends similar to Fernández et al. (2021) who found that this form is relevant in explaining eco-innovation. The detail of all variables appears in Table A1 of the Appendix.

The multivariate probit models are used to test the proposed hypotheses. The selection of this methodology is based on the need to test simultaneously multiple binary dependent variables. In this sense, we can test the drivers simultaneously in the three efficiency variables. This is the key advantage of the methodology in comparison to other simpler models such as the univariate or bivariate probit models (Aitchison and Silvey, 1957; Ashford and Sowden, 1970; Chib and Greenberg, 1998). In addition, authors analysing eco-efficiencies have highlighted the

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[7] The latest year available for Uruguay, Panama, and Peru is 2015, 2014, and 2013 respectively.

[8] For incremental and radical innovation, we use the definition of the Oslo Manual (OCDE, 2018), which has been also applied by Triguero et al. (2018); Fernández et al. (2021) and Torrecillas and Fernández (2022).

Table 1
Eco-Efficiencies by country.

Eco-Efficiencies [a]	URUGUAY			PERU			PANAMA		
	Total obs.	% Total Eco-Efficiencyinnovators	% Total obs.	Total obs.	% Total Eco-Efficiency innovators	% Total obs.	Total obs.	% Total Eco-Efficiencyinnovators	% Total obs.
ENERGY Efficiency	**536**	**23.29%**	**6.69%**	**484**	**31.07%**	**18.79%**	**95**	**30.35%**	**6.91%**
Product	343	63.99%		378	78.10%		51	53.68%	
Process	467	87.13%		400	82.64%		89	93.68%	
Incremental	244	45.52%		136	28.10%		34	35.79%	
Radical	140	26.12%		278	57.44%		22	23.16%	
MATERIAL Efficiency	**623**	**27.08%**	**7.77%**	**477**	**30.62%**	**18.52%**	**93**	**29.71%**	**6.77%**
Product	398	63.88%		384	80.50%		60	64.52%	
Process	539	86.52%		390	81.76%		81	87.10%	
Incremental	267	42.86%		143	29.98%		37	39.78%	
Radical	153	24.56%		275	57.65%		24	25.81%	
ENVIRONMENT Efficiency	**1142**	**49.63%**	**14.25%**	**597**	**38.32%**	**23.18%**	**125**	**39.94%**	**9.10%**
Product	721	63.13%		467	78.22%		85	68.00%	
Process	977	85.55%		493	82.58%		109	87.20%	
Incremental	482	42.21%		158	26.47%		50	40.00%	
Radical	285	24.96%		342	57.29%		38	30.40%	
Total Eco-Efficiency	**2301**	**100.00%**	**28.71%**	**1558**	**100.00%**	**60.48%**	**313**	**100.00%**	**22.78%**
Total observations	**8014**	**-**	**100.00%**	**2576**	**-**	**100.00%**	**1374**	**-**	**100.00%**

Source: own elaboration

[a] Note: The percentages show the proportion of eco-efficiencies in total and for each type of innovation. For example, in the case of Uruguay, the percentage of energy efficiency in product innovation is 63.99%. This means that of the 536 observations for Uruguay that have some type of energy efficiency, 343 are included in product innovation.

complementarity between different types of eco-efficiencies and the need to analyse them jointly (Costa-Campi et al., 2015b).

The implementation of the multivariate probit model is divided into four independent models (product, process, incremental and radical), each one with three response-dependent variables according to the three efficiency variables.

We follow the works of Capellari and Jenkins (2003, 2006), which use the simulated maximum likelihood (SML) estimator for multivariate probit analysis.

For each observation, $i = 1, \ldots, N$, where N represents the total observations for each country, the model is described by M pairs of equations, one for each latent dependent variable, $y^*_{l,m,i}$, and the other, for the corresponding binary estimated outcome, $\widehat{y}^*_{l,m,i}$. In our case, the efficiency variables are Energy, Material, and Environmental, and hence $M = 3$ ($m = \{1, 2, 3\}$). Additionally, for our modelization, l represents the number of estimated independent models obtained, corresponding to the four types of innovation (product, process, incremental and radical). In this sense, each dependent variable $y^*_{l,m,i}$ -corresponding to models (1) to (4)-, is the result of the interaction between the innovation (l) and efficiency variables (m).

Considering all the previous premises, the modelization would be as follows:

$$\begin{cases} y^*_{Prod,m,i} = X'_{Prod,m,i}\ \beta_{Prod,m,i} + \epsilon_{Prod,m,i} & (1) \\ y^*_{Proc,m,i} = X'_{Proc,m,i}\ \beta_{Proc,m,i} + \epsilon_{Proc,m,i} & (2) \\ y^*_{Incre,m,i} = X'_{Incre,m,i}\ \beta_{Incre,m,i} + \epsilon_{Incre,m,i} & (3) \\ y^*_{Radi,m,i} = X'_{Radi,m,i}\ \beta_{Radi,m,i} + \epsilon_{Radi,m,i} & (4) \end{cases}$$

$$\widehat{y}^*_{l,m,i} = 1 \ \text{ if } \ y^*_{l,m,i} > 0 \ (0 \text{ otherwise})$$

$$y^*_{l,m,i} = l_i \times (\, Energy_i \quad Material_i \quad Environmental_i \,)$$

$$l = \{Prod, Proc, Incre, Radi\} \quad m = \{1, 2, 3\} \quad i = 1, \ldots, N$$

$\epsilon_{l,m,i}$ represents the error term, distributed as a multivariate normal with a mean equal to zero and a matrix of variances-covariances equal to V_l. The matrix V_l takes the value 1 on the leading diagonal, and correlations $\rho_{j,k} = \rho_{k,j}$, with $j, k = 1, \ldots, M$ and $j \neq k$, are the off-diagonal elements. Since $M = 3$, the off-diagonal correlations of each matrix V_l are $\rho_{1,2}$, $\rho_{1,3}$ and $\rho_{2,3}$.

Finally, it is important to analyse the robustness and good fit of the methodology used and its appropriateness for the results obtained. On the one hand, the Wald and the Likelihood Ratio (LR) tests show that the models proposed can adequately predict the observed data (see Tables 2–4). Specific details of the tests used can be found in Appendix B. On the other hand, the correlation tables manifest that there is no correlation between the variables (see Table A2 of Appendix A). Furthermore, the multicollinearity tests confirm that there are no problematic collinearity problems. For more statistical information and multicollinearity detection values see Table A3 in Appendix A.

4. Results

Tables 2–4 show the results of the multivariate probit analysis for Uruguay, Peru, and Panama, respectively.

Regarding our three research questions, several differences are found in drivers by country, type of innovation and efficiency.

Concerning R&D expenditures, results show that *Internal R&D* could act as a driver in some countries. While in Uruguay internal R&D is a driver of all products, incremental and radical innovations, in Peru it is only a significant factor for all product and radical innovations. The results are consistent with previous literature on eco-innovation drivers in high-income countries (Horbach, 2016; Horbach et al., 2012; Jové-Llopis and Segarra-Blasco, 2018), which show a positive relationship between this driver and eco-efficiencies. However, the results for Panama differ, suggesting that internal R&D does not favour the development of eco-efficiencies, with the only exception of material and environmental efficiency in product innovations. This finding is in line with Fernández et al. (2021), who found that R&D intensity was not a driver in Chile, as these types of investments involve high costs and many companies could have problems obtaining the necessary resources for such investments (Arranz et al., 2019; Cassiolato and Lastres, 2000; Crespi and Zuniga, 2012; Navarro et al., 2010). Therefore, our results partially confirm H1, showing that internal R&D can play a relevant role

Table 2
Eco-efficiencies drivers in Uruguay.

	PRODUCT			PROCESS			INCREMENTAL			RADICAL		
	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR
Internal R&D	0.036***	0.041***	0.048***	0.004	0.001	−0.004	0.0457***	0.035***	0.044***	0.037***	0.041***	0.046***
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.009)	(0.009)	(0.007)	(0.011)	(0.010)	(0.008)
External R&D	0.004	0.009	0.002	0.011	0.029**	0.017	−0.005	0.010	−0.003	0.023	0.021	0.019
	(0.012)	(0.012)	(0.011)	(0.012)	(0.012)	(0.011)	(0.014)	(0.013)	(0.012)	(0.015)	(0.015)	(0.012)
Non-R&D Embod.	0.035***	0.041***	0.039***	0.053***	0.049***	0.055***	0.037***	0.042***	0.042***	0.023**	0.035***	0.032***
	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.008)	(0.008)	(0.007)	(0.010)	(0.010)	(0.008)
Non-R&D Dissem.	0.022**	0.033***	0.040***	0.038***	0.040***	0.046***	0.015	0.030***	0.027***	0.023*	0.046***	0.048***
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)	(0.011)	(0.010)	(0.009)	(0.013)	(0.012)	(0.010)
Training in R&D	−0.013	−0.010	0.013	−0.011	−0.017**	0.008	−0.005	−0.001	0.015*	0.004	0.003	0.006
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.007)	(0.010)	(0.010)	(0.008)	(0.012)	(0.012)	(0.009)
Breadth	0.049**	0.009	0.017	0.029*	0.013	0.043***	0.027	−0.012	0.019	0.028	0.009	−0.033
	(0.019)	(0.019)	(0.017)	(0.018)	(0.017)	(0.016)	(-0.021)	(0.021)	(0.018)	(0.026)	(0.026)	(0.021)
Coop	0.065	0.134	0.061	0.331***	0.437***	0.317***	0.074	0.151	0.061	−0.133	−0.020	0.083
	(0.088)	(0.087)	(0.074)	(0.077)	(0.076)	(0.067)	(0.097)	(0.097)	(0.081)	(0.124)	(0.122)	(0.097)
Market index	0.741***	0.815***	0.856***	0.491***	0.649***	0.599***	0.629***	0.760***	0.820***	0.735***	0.679***	0.747***
	(0.078)	(0.077)	(0.063)	(0.064)	(0.064)	(0.055)	(0.084)	(0.088)	(0.071)	(0.124)	(0.118)	(0.087)
Regulatory	0.632***	0.568***	0.797***	0.520***	0.477***	0.860***	0.483***	0.454***	0.617***	0.718***	0.571***	0.615***
	(0.066)	(0.064)	(0.055)	(0.059)	(0.058)	(0.051)	(0.072)	(0.071)	(0.059)	(0.096)	(0.090)	(0.071)
Age2	1.60E-05	7.37E-06	4.27E-05***	1.77E-05	−6.83E-06	3.62E-05***	3.25E-05**	2.32E-05*	5.07E-05***	2.39E-05	2.61E-05	4.55E-05***
	(1.33E-05)	(1.33E-05)	(1.00E-05)	(1.15E-05)	(1.27E-05)	(9.53E-06)	(1.33E-05)	(1.38E-05)	(1.03E-05)	(1.69E-05)	(1.61E-05)	(1.15E-05)
Size	0.004	0.011	0.033**	0.024*	0.027**	0.058***	−0.012	−0.008	0.001	−0.002	−0.011	0.009
	(0.015)	(0.015)	(0.013)	(0.013)	(0.013)	(0.012)	(0.016)	(0.017)	(0.014)	(0.020)	(0.019)	(0.015)
_cons	−2.818***	−2.931***	−3.127***	−2.955***	−2.989***	−3.323***	−2.593***	−2.737***	−2.739***	−3.101***	−2.947***	−3.049***
	(0.264)	(0.266)	(0.230)	(0.238)	(0.237)	(0.216)	(0.277)	(0.293)	(0.245)	(0.356)	(0.336)	(0.271)
Obs.		7969			7972			7975			7975	
Wald test X^2		1776.27			2289.85			1155.9			743.31	
(p-value)		(0.000)			(0.000)			(0.000)			(0.000)	
Likelihood ratio test X^2		858.092			911.427			873.612			667.834	
(p-value)		(0.000)			(0.000)			(0.000)			(0.000)	
Rho 21		0.666***			0.646***			0.699***			0.733***	
		(0.024)			(0.022)			(0.024)			(0.028)	
Rho 31		0.541***			0.491***			0.590***			0.683***	
		(0.026)			(0.024)			(0.027)			(0.027)	
Rho 32		0.617***			0.548***			0.660***			0.685***	
		(0.024)			(0.024)			(0.045)			(0.028)	

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard error is in parentheses.
Source: own elaboratio

Table 3
Eco-efficiencies drivers in Peru.

	PRODUCT			PROCESS			INCREMENTAL			RADICAL		
	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR
Internal R&D	0.069***	0.034**	0.078***	0.020	0.006	0.015	0.003	−0.017	0.01	0.061***	0.037**	0.064***
	(0.017)	(0.017)	(0.019)	(0.017)	(0.017)	(0.017)	(0.018)	(0.019)	(0.017)	(0.017)	(0.017)	(0.017)
External R&D	−0.034	−0.003	0.005	0.0174	0.047	0.073**	−0.041	0.003	−0.034	0.005	0.015	0.024
	(0.028)	(0.029)	(0.032)	(0.028)	(0.03)	(0.034)	(0.033)	(0.033)	(0.031)	(0.028)	(0.028)	(0.028)
Non-R&D Embod.	0.003	0.008	0.023*	0.013	0.008	0.016	0.016	0.018	0.055***	0.003	0.005	−0.001
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.016)	(0.016)	(0.016)	(0.014)	(0.015)	(0.013)
Non-R&D Dissem.	0.014	0.036**	0.027	−0.010	0.016	0.008	0.013	0.022	0.013	−0.001	0.029*	0.013
	(0.017)	(0.017)	(0.017)	(0.015)	(0.016)	(0.015)	(0.019)	(0.019)	(0.018)	(0.017)	(0.017)	(0.016)
Training in R&D	0.001	−0.010	0.024	−0.003	−0.002	0.014	−0.004	−0.009	0.025	0.021	0.003	0.029
	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.020)	(0.022)	(0.023)	(0.020)	(0.020)	(0.021)	(0.019)
Breadth	0.075***	0.092***	0.048*	0.038	0.036	0.003	0.027	0.031	−0.020	0.067**	0.093***	0.053**
	(0.027)	(0.027)	(0.027)	(0.026)	(0.027)	(0.027)	(0.021)	(0.023)	(0.022)	(0.028)	(0.028)	(0.027)
Coop	0.321*	0.110	0.035	0.380**	0.205	0.350**	0.082	−0.074	−0.231	0.213	0.194	0.066
	(0.165)	(0.165)	(0.159)	(0.16)	(0.161)	(0.157)	(0.185)	(0.181)	(0.172)	(0.174)	(0.175)	(0.152)
Market index	0.584***	0.390**	0.645***	0.275	0.275	0.330**	0.487**	0.378*	0.499**	0.616***	0.364*	0.503***
	(0.186)	(0.184)	(0.178)	(0.174)	(0.176)	(0.168)	(0.223)	(0.226)	(0.212)	(0.197)	(0.195)	(0.176)
Regulatory	0.624***	0.535***	0.610***	0.612***	0.519***	0.659***	0.335**	0.221	0.395***	0.317**	0.322**	0.298**
	(0.128)	(0.127)	(0.123)	(0.126)	(0.126)	(0.123)	(0.146)	(0.147)	(0.142)	(0.128)	(0.130)	(0.120)
Age2	−5.59E-05	−3.02E-05	−2.23E-05	−2.11E-05	−1.14E-05	3.90E-05	−4.74E-05	−1.10E-05	−3.83E-06	−1.16E-05	2.46E-05	5.58E-05
	(3.70E-05)	(3.74E-05)	(3.98E-05)	(3.80E-05)	(3.77E-05)	(4.27E-05)	(4.28E-05)	(4.50E-05)	(3.69E-05)	(3.93E-05)	(3.79E-05)	(3.67E-05)
Size	0.013	0.019	0.018	0.008	0.036	0.029	−0.028	−0.043*	−0.039*	0.028	0.036	0.029
	(0.023)	(0.023)	(0.024)	(0.023)	(0.023)	(0.024)	(0.025)	(0.026)	(0.024)	(0.024)	(0.024)	(0.023)
_cons	−1.974***	−1.683***	−1.658***	−1.381***	−1.645***	−1.399***	−1.405***	−0.863*	−1.059**	−2.284***	−2.302***	−1.815***
	(0.429)	(0.423)	(0.429)	(0.413)	(0.415)	(0.416)	(0.458)	(0.467)	(0.438)	(0.447)	(0.447)	(0.405)
Obs.		735			735			735			735	
Wald test X^2		150.87			101.67			65.11			111.22	
(p-value)		(0.000)			(0.000)			(0.000)			(0.000)	
Likelihood ratio test X^2		581.424			566.246			861.49			786.573	
(p-value)		(0.000)			(0.000)			(0.000)			(0.000)	
Rho 21		0.809***			0.790***			0.938***			0.863***	
		(0.026)			(0.028)			(0.013)			(0.020)	
Rho 31		0.748***			0.731***			0.922***			0.842***	
		(0.035)			(0.038)			(0.014)			(0.022)	
Rho 32		0.827***			0.820***			0.951***			0.900***	
		(0.026)			(0.026)			(0.011)			(0.016)	

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard error is in parentheses.
Source: own elaboration

Table 4
Eco-efficiencies drivers in Panama.

	PRODUCT			PROCESS			INCREMENTAL			RADICAL		
	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR	ENERGY	MATER	ENVIR
Internal R&D	−0.003	0.079**	0.058*	−0.042	−0.030	−0.021	−0.026	0.053	−0.006	−0.017	0.011	0.023
	(0.040)	(0.038)	(0.033)	(0.037)	(0.040)	(0.037)	(0.045)	(0.050)	(0.041)	(0.045)	(0.040)	(0.033)
External R&D	−0.006	−0.053	−0.018	−0.004	0.011	0.008	−0.094	−0.037	−0.044	0.0413	−0.013	−0.079
	(0.051)	(0.051)	(0.042)	(0.047)	(0.053)	(0.048)	(0.084)	(0.068)	(0.067)	(0.055)	(0.056)	(0.051)
Non-R&D Embod.	−0.006	−0.052	0.015	−0.028	−0.039	0.029	−0.061	−0.035	−0.008	−0.033	−0.046	0.042*
	(0.032)	(0.031)	(0.027)	(0.029)	(0.030)	(0.028)	(0.036)	(0.038)	(0.032)	(0.037)	(0.033)	(0.025)
Non-R&D Dissem.	1.18E-05	−0.073	−0.035	0.061	−0.066	−0.048	0.053	−0.055	−0.023	0.071	0.006	0.005
	(0.044)	(0.046)	(0.039)	(0.048)	(0.047)	(0.043)	(0.047)	(0.057)	(0.048)	(0.045)	(0.045)	(0.037)
Training in R&D	0.021	0.016	0.041	0.076*	−0.021	0.035	0.044	0.058	0.071	0.025	0.086*	0.070*
	(0.047)	(0.045)	(0.038)	(0.044)	(0.051)	(0.043)	(0.059)	(0.061)	(0.049)	(0.054)	(0.047)	(0.039)
Breadth	−0.124	−0.116	−0.084	−0.146	−0.092	−0.165	−0.067	−0.165	−0.072	−0.018	0.044	0.033
	(0.104)	(0.100)	(0.089)	(0.105)	(0.106)	(0.101)	(0.121)	(0.133)	(0.109)	(0.105)	(0.105)	(0.093)
Coop	0.531	0.061	0.181	0.158	−0.441	0.556	−0.213	−0.127	−0.172	−0.459	−0.227	−0.366
	(0.386)	(0.331)	(0.304)	(0.354)	(0.351)	(0.372)	(0.406)	(0.449)	(0.377)	(0.336)	(0.312)	(0.275)
Market index	0.138	0.380	0.683**	−0.179	0.345	0.801***	0.398	0.576	0.632*	0.429	0.280	0.505*
	(0.284)	(0.283)	(0.266)	(0.261)	(0.287)	(0.306)	(0.340)	(0.392)	(0.326)	(0.361)	(0.311)	(0.265)
Regulatory	0.493**	0.260	0.910***	0.280	0.450*	0.975***	0.306	0.444	0.962***	0.493*	0.320	0.698***
	(0.230)	(0.223)	(0.197)	(0.229)	(0.239)	(0.224)	(0.291)	(0.300)	(0.249)	(0.268)	(0.250)	(0.212)
Age2	8.98E-05	−2.10E-05	1.04E-04*	−1.74E-05	−1.31E-05	−6.73E-05	7.96E-05	−1.86E-05	1.33E-04**	−2.75E-05	−4.41E-05	7.47E-05
	(6.78E-05)	(7.19E-05)	(5.75E-05)	(7.26E-05)	(6.84E-05)	(7.63E-05)	(8.23E-05)	(1.07E-04)	(6.46E-05)	(9.86E-05)	(9.51E-05)	(6.13E-05)
Size	0.004	0.089*	−0.032	0.032	0.072	0.023	−0.059	0.004	−0.061	0.062	0.087*	−0.009
	(0.049)	(0.050)	(0.040)	(0.052)	(0.056)	(0.052)	(0.055)	(0.062)	(0.050)	(0.052)	(0.052)	(0.041)
_cons	−1.970**	−2.595***	−1.598**	−1.166	1.436	−2.164**	−0.524	−1.850*	−1.085	−2.659***	−2.994***	−1.915***
	(0.802)	(0.798)	(0.676)	(0.896)	(0.950)	(0.942)	(0.962)	(-1.091)	(0.919)	(0.906)	(0.887)	(0.697)
Obs.		230			185			226			306	
Wald test X^2		58.87			66.51			52.89			46.29	
(p-value)		(0.003)			(0.000)			(0.015)			(0.062)	
Likelihood ratio test X^2		54.221			64.727			61.245			134.741	
(p-value)		(0.000)			(0.000)			(0.000)			(0.000)	
Rho 21		0.585***			0.758***			0.779***			0.878***	
		(0.119)			(0.086)			(0.088)			(0.050)	
Rho 31		0.640***			0.536***			0.602***			0.844***	
		(0.096)			(0.109)			(0.111)			(0.048)	
Rho 32		0.630***			0.594***			0.842***			0.907***	
		(0.100)			(0.096)			(0.065)			(0.050)	

Note: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard error is in parentheses.
Source: own elaboration

in the development of some types of innovations -process and incremental-. However, the relevance of this factor will depend on the resources of the firms involved, as well as on certain characteristics of the countries in which they are located, such as the development of their national innovation systems (Arranz et al., 2019; Viotti, 2002).

In contrast, *External R&D* is only significant for process innovation of material efficiency in Uruguay and of environmental efficiency in Peru. These results are close to those obtained in other studies for high-income economies (De Marchi, 2012; Li-Ying et al., 2018; Triguero et al., 2018) and Latin American countries (De Jesús Pacheco et al., 2018; Fernández et al., 2021). Therefore, H2 is confirmed, indicating that although external R&D could improve the absorptive capacity of firms, in these countries, resources seem to be oriented towards other types of innovation expenditures that involve less risk and effort for the firm (Crespi and Zuniga, 2012). These doubts about the internal and external R&D as a driver of eco-efficiencies have been confirmed also for energy efficiency by Costa-Campi et al. (2015b), Li and Lin (2016), and Luiten and Blok (2003).

Regarding other innovation expenditures, results show that *Non-R&D Embodied* is a key driver for Uruguay, being positive and significant for all eco-efficiencies. However, it plays a relevant role in environmental efficiency in Peru for product and incremental innovations and, in Panama for radical innovations. Therefore, H3 is partially confirmed, showing that embodied technology is an important driver of some types of innovation and efficiency. This evidence is like that found in other studies in middle-income countries (Fernández et al., 2021; Sanni, 2018). Specifically, for Chile, Fernández et al. (2021) show that this factor is a driver in energy and material efficiencies for all product, process, and incremental innovations. Based on the above, we can affirm that the acquisition of machinery, equipment or software is relevant for the development of both types of efficiencies in these countries. Concretely, this type of expenditure could complement the R&D investments made by firms for eco-innovation or, in those firms that do not have sufficient resources to carry out R&D, non-R&D embodied technologies could act as substitutes (Álvarez et al., 2010; Benavente, 2006; Crespi et al., 2016; Dutrénit et al., 2019). This substitution relationship has been also confirmed for energy efficiency by Costa-Campi et al. (2015b).

Considering *Non-R&D Disembodied,* results are positive and significant in practically all eco-innovations in Uruguay, and material efficiency product and radical innovations in Peruvian firms. However, it does not seem to be a key factor in the development of eco-efficiencies in Panama. Therefore, H4 can only be partially confirmed. It should be noted that the results for European studies indicated that non-R&D disembodied was more related to product and radical eco-innovations (Triguero et al., 2018), similar to what was obtained in this study; while to our knowledge, on the only study that considers this factor in a Latin American country, it resulted to be non-significant, as is the case for Panama (Fernández et al., 2021). Furthermore, these results show that the influence of this driver depends not only on the type of innovation and efficiency but also on the country. In this sense, these activities could complement low levels of R&D (Navarro et al., 2010) in countries with learning innovation systems (Dutrénit et al., 2019; Viotti, 2002).

Finally, *Training in R&D* has been noted as a possible driver of eco-innovations, but the results are not conclusive. While for Panama this driver favours the development of energy efficiency in process innovations, and material and environmental efficiency in radical innovations (as found by Sanni, 2018 – for Nigeria), in Peru, they have no effect (as found by Fernández et al., 2021 – for Chile). The most complex case is shown in Uruguay, where training favours environmental efficiency in incremental innovations, but disfavours material efficiency in process innovations. Similar behaviour was found in Spain by Triguero et al. (2018), where training also exerted a negative effect on some types of eco-innovations. Based on the above, H5 is only weakly confirmed. It should be noted that if firms do not have sufficient resources for R&D activities, they may prefer to acquire the technology directly also saving part of the costs of employee training (Navarro et al., 2010; Sanni, 2018).

Regarding networks and cooperation, the results point out *Breadth* as a driver of energy efficiency in product and process innovations and of environmental efficiency in process innovations in Uruguay, as well as for all product and radical innovations in Peru. Thus, H6 is partially confirmed, showing that the characteristics of the countries where firms are located matter in determining the drivers of each type of eco-innovation (Arranz et al., 2019). However, despite these partial results, it should be noted that the use of different sources of information increases the likelihood of eco-efficiencies and that the absence of these could become a barrier to eco-innovation (Arranz et al., 2019). This evidence has also been found for Chile by Fernández et al. (2021) and Sanchez-Henriquez and Pavez (2021), as well as in other studies conducted in other regions with lower levels of income (Cai and Zhou, 2014 – for China; Sanni, 2018 – for Nigeria).

In addition, we hypothesized (H7) that *Cooperation* positively affects all eco-innovations. Nevertheless, this effect is found only for all process innovations in Uruguay, for energy efficiency in product innovation, and energy and environmental efficiency in process innovation in Peru. Therefore, H7 can only be weakly confirmed. These results are like those previously obtained for Chile by Fernández et al. (2021), where cooperation was more closely linked to process innovations. This direct association between process eco-innovations and cooperation has also been found in other countries such as Spain (Marzucchi and Montresor, 2017). Then, although cooperation agreements are considered key to compensate for the absence of technological capabilities (Diez-Martínez et al., 2022) and cooperation positively influences innovative results (Crespi and Zuniga, 2012), in this research the link is not observed.

Therefore, these results have only confirmed partially the role of networks and cooperation, as drivers of eco-efficiencies as was postulated among others by Cagno et al. (2015), Costa-Campi et al. (2015a), Kounetas (2015), and Rexhäuser and Löschel (2015).

Considering *Market pull* (H8)*,* it has a positive and significant influence on all eco-innovations of Uruguayan firms. Moreover, while for Peru the results are similar except for energy and material efficiency in process innovations, in Panama this variable favours environmental efficiency for all types of innovations. This evidence is consistent with results obtained in different regions: Europe (Horbach, 2016; Triguero et al., 2018), Asia (Galbreath et al., 2021; Han and Chen, 2021; Shao et al., 2022), Africa (Rama et al., 2022; Sanni, 2018) and Latin America (De Jesús Pacheco et al., 2018; Fernández et al., 2021). Thus, H8 is supported.

Finally, *Regulatory push/pull* favours the development of eco-innovations in Latin American firms. This premise is true for both Uruguay and Peru (except for incremental innovations in material efficiency in the latter). In Panama, this variable has a positive and significant sign for all types of innovation of environmental efficiency, product and radical innovations of energy efficiency, and process innovations of material efficiency. Similar results have been found in other middle-income countries such as those obtained by Han and Chen (2021) for Myanmar, Sanni (2018) for Nigeria, and Rama et al. (2022) for Ghana. In addition, as Marzzuchi and Montresor (2017) found for Spain or Fernández et al. (2021) for Chile, a closer link between the regulatory push-pull factor and environmental efficiency innovations is observed. Therefore, these results confirm H9 and suggest the importance of establishing regulations that favour not only environmental efficiency but also energy and material efficiency. The connection between the regulatory factors and the eco-efficiency gains has been argued among others by Cainelli et al. (2020), Luiten and Blok (2003), and Rubashkina et al. (2015).

Results for control variables differ by country. The age-squared variable is positive and significant in all incremental innovations and for environmental efficiency in Uruguay. This effect is only found in Panama for environmental efficiency in product and incremental innovations, similar to that observed by Fernández et al. (2021) for Chile. This indicates that the experience of the firms is a relevant factor when analysing eco-efficiencies. In terms of size, the variable is generally not significant (except for all process and environmental efficiency product innovations in Uruguay, material and environmental efficiency incremental innovations in Peru, and product and radical innovations of material efficiency in Panama) as other studies have found (Fernández et al., 2021; Sanni, 2018), but contrary to the results obtained by Carfora et al. (2022) for Italy.

Table 5 summarizes the main results obtained by country and their relationship with the hypotheses formalized in Section 2.

To conclude this section, it is important to comment that all $\rho_{j,k}$ are positive and significant. Therefore, the multivariate model is more appropriate than the three probit models estimated individually. In addition, we observe possible complementary effects among the three efficiency alternatives. Authors postulate the complementarities between different types of efficiencies as climate change targets -energy, material, and environmental efficiencies- (Costa-Campi et al., 2015b; Del Río et al., 2013; Horbach et al., 2012).

5. Conclusions and policy implications

Innovation and efficiency improvements have become key factors for the sustainable development of the countries as it has been highlighted in the Sustainable Development Goals (SDGs). In this sense, this paper links four of the SDGs: the combat of climate change (SDG13), introducing innovations (SDG9) to increase eco-efficiencies -energy efficiencies (SDG7) and material and environmental efficiencies (SDG 12)-. Specifically, an analysis of the drivers of eco-innovation which stimulate energy, material, and environmental efficiencies in three Latin American countries (Uruguay, Peru, and Panama) is carried out.

Answering the first research question, results show that the main drivers of eco-innovation in the region are market pull and regulatory push-pull factors. Therefore, changes in green consumer demands and green norms are key drivers for the explanation of eco-innovations in these countries. Literature analysing drivers out of Europe confirms this evidence (Fernández et al., 2021; Galbreath et al., 2021; Han and Chen, 2021; Liao and Zhu, 2022; Rama et al., 2022; Sanni, 2018; Shao et al., 2022).

Regarding technology push factors, their effect on eco-efficiencies

Table 5
Summary of hypotheses results.

Hypotheses	Result	Observations
H1: Internal R&D is not a driver of eco-efficiencies in Latin American firms.	Partially Supported	Supported for: - Uruguay: all process eco-efficiencies. - Peru: all process and incremental eco-efficiencies. - Panama: all process, incremental and radical eco-efficiencies and energy efficiency in product innovations.
H2: External R&D is not a driver of eco-efficiencies in Latin American firms.	Supported	With the exception only of Process innovation in *Material Efficiency* in Uruguay, and Process innovation in *Environmental efficiency* in Peru.
H3: Non-R&D embodied affects positively all eco-efficiencies in Latin American firms	Partially Supported	Supported for: - Uruguay: all eco-efficiencies - Peru: environmental efficiency in product and incremental innovations. - Panama: environmental efficiency radical innovations.
H4: Non-R&D disembodied affects positively all eco-efficiencies in Latin American firms.	Partially Supported	Supported for: - Uruguay: all types of innovation, except for energy efficiency in incremental innovations. - Peru: material efficiency in product and radical innovation.
H5: Training expenditures affects positively all eco-efficiencies in Latin American firms.	Weakly Supported	Confirmed only for: - Uruguay: environmental efficiency in incremental innovations. - Panama: energy efficiency in process innovations and material and environmental efficiency in radical innovations.
H6: The influence of the external knowledge, breadth, affects positively all eco-efficiencies in Latin American firms.	Partially Supported	Supported for: - Uruguay: energy efficiency in product and process innovations and environmental efficiency in process innovation. - Peru: all eco-efficiencies in products and radical innovations.
H7: Technological cooperation affects positively all eco-efficiencies in Latin American firms.	Weakly Supported	Confirmed only for: - Uruguay: all process eco-efficiencies. - Peru: energy efficiency in product and process innovations, and environmental efficiency in process innovations.
H8: Market drivers affect positively all eco-efficiencies in Latin American firms.	Supported	With the exception only of: - Peru: energy and material efficiency in process innovations. - Panama: energy and material efficiency in all types of innovation.
H9: Regulatory drivers affect positively all eco-efficiencies in Latin American firms.	Supported	With the exception only of: - Peru: material efficiency in incremental innovations. - Panama: energy efficiency in process and incremental innovations and material efficiency in product and incremental innovations.

Note: Considering the number of cases where the driver in question was individually significant for the total number of models, the hypotheses were considered "supported" if the percentage of cases was above 70%, "partially supported" if the percentage of cases was above 25%, and "weakly supported" if the percentage of cases was below 25%.
Source: own elaboration

depends on the country. In this sense, R&D expenditure is not necessarily the main driver, although it is still an important factor. In contrast, machinery acquisition and engineering and design innovation expenditures seem to exert an important effect on the development of eco-innovations, so these other innovation expenditures could complement internal and external R&D. The effects of training on eco-innovations are reduced, affecting only two types of eco-innovation in three of the countries analysed. Finally, breadth has more effect as an eco-efficiency driver than cooperation.

The next research question was whether these drivers varied considering different types of innovations (product, process, incremental and radical). In this sense, we have found evidence for regulatory and market drivers for our four types of innovations. On the other hand, internal R&D and other innovation expenditures appear to be more relevant in product innovation rather than in process innovation, while the opposite occurs with technological cooperation. Moreover, radical eco-efficiencies seem to be more affected by internal R&D expenditure, non-R&D disembodied, and breadth, than incremental eco-efficiencies. Therefore, this research shows that there are drivers that affect some types of innovation to a greater extent.

Finally, regarding the third research question -differences in efficiencies-, various results are found different results depending on the country. Firstly, for all types of efficiencies market pull and regulatory push-pull factors may be considered drivers since they increase energy and other green efficiencies in the three countries. Considering *energy efficiency*, we have found that internal R&D, non-R&D embodied and disembodied and breadth are significant drivers in almost all the estimations in Uruguay. Results for Peru show that internal R&D, breadth, and cooperation affect positively energy efficiency. In Panama, training is found as a driver of energy efficiency in process innovation. Related to *material efficiency*, results are very similar to energy efficiency findings, except for external R&D in process innovation in Uruguay. Finally, some differences have been found in *environmental efficiency*. In Uruguay, internal R&D, non-R&D embodied and disembodied, training, breadth, and cooperation affect positively these efficiencies. In Peru, external R&D appears as a driver, while neither training nor non-R&D disembodied show effect; and in Panama internal R&D, training in R&D and non-R&D embodied are relevant for this efficiency. Therefore, it can be observed that the drivers that stimulate energy and material efficiency are very similar, with the country making the difference between them. In the case of environmental efficiency, the results underline the importance of internal R&D and non-R&D embodied in all three countries.

The main contribution of our paper is shown in Fig. 2, where we highlight the drivers of eco-efficiencies in Latin American countries proposing a different classification of drivers. Specifically, the figure shows how the drivers can be divided into three groups: *common, frequent,* and *occasional* drivers.

Common drivers include those aspects related to the market pull and regulatory push-pull factors, which affect all countries in our sample and practically all types of efficiencies and innovations considered. Indeed, the literature has found the demand for eco-products as a driver in other regions (in Europe: Horbach, 2008, Kesidou and Demirel, 2012; Triguero et al., 2013; in Asia: Galbreath et al., 2021, Han and Chen, 2021; Shao et al., 2022; and in Africa: Rama et al., 2022; Sanni, 2018). The same is true for the regulatory factor (in Europe: Del Río et al., 2017, Horbach et al., 2012; Kesidou and Demirel, 2012; in Asia: Cai and Zhou, 2014, Han and Chen, 2021, Keshminder and Del Río, 2019; Liao and

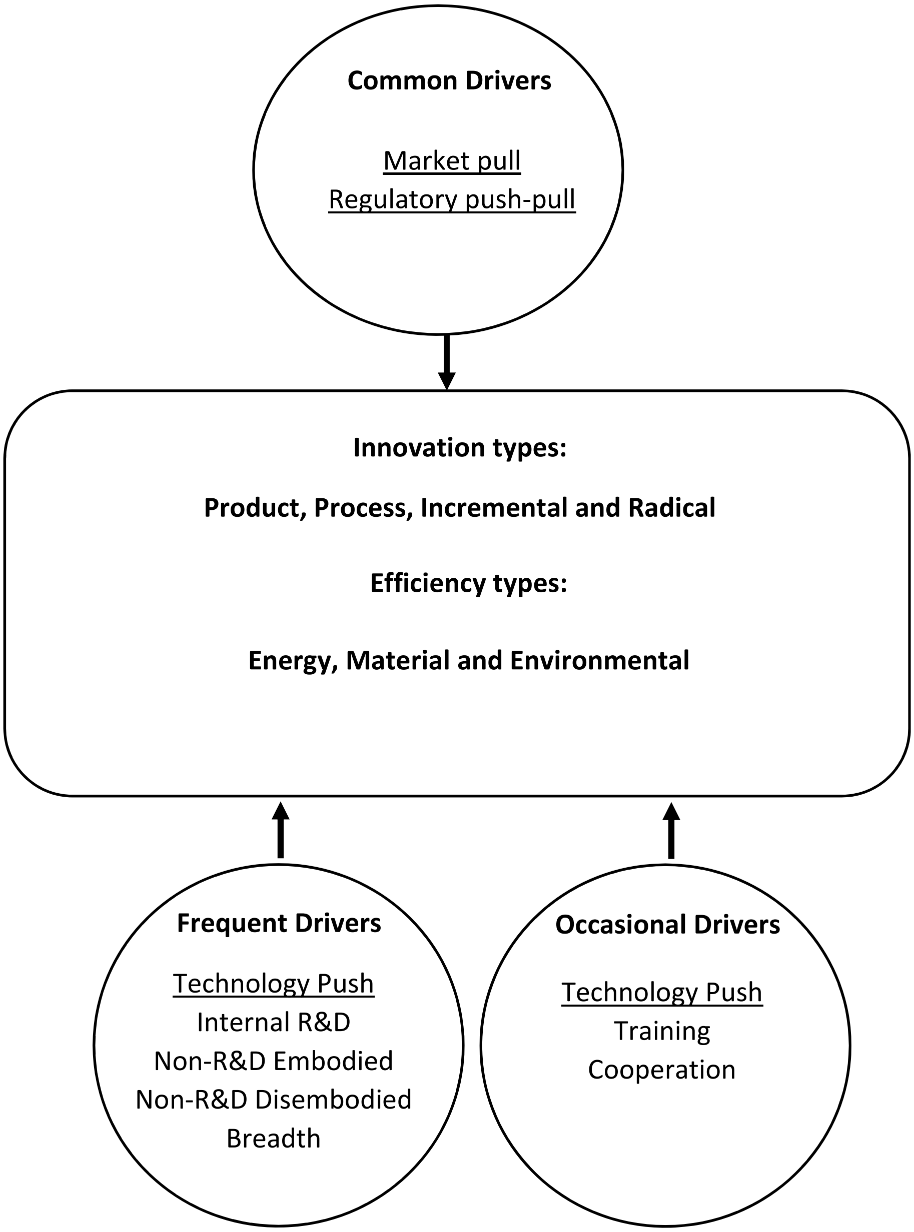

Fig. 2. Eco- efficiency drivers in Latin American countries. Note: External R&D would be not a driver in the Latin American region.
Source: own elaboration

Zhu, 2022; and in Africa: Rama et al., 2022; Sanni, 2018). Therefore, it seems that these types of drivers improve eco-efficiency through innovation regardless of the geographical area in which they are located.

Frequent drivers consider internal R&D, non-R&D embodied, non-R&D disembodied and breadth. These drivers have a very important influence on eco-efficiencies but only in some countries, showing that these factors are strongly influenced by the specific characteristics of the countries. Although these have been considered as drivers in other regions showing a positive relationship (Horbach et al., 2012, or Triguero et al., 2018, in Europe; Sanni, 2018, in Africa; Cai and Li, 2018, in Asia), only one paper in Latin America had considered them (Fernández et al., 2021). For Chile, these authors found some effects, but not all of them. Thus, the influence of these *frequent* factors on eco-efficiency improvements is affected by the country and regional context.

Finally, the *occasional drivers*, which are training and cooperation, have a sporadic influence on eco-efficiencies in Latin American countries. The effect of these factors on eco-innovation performance in this region has only been studied in Chile and Brazil. In the case of training, the study by Fernández et al. (2021) indicated that there were no effects between training and any eco-efficiency. For cooperation, the results in Brazil showed a positive relationship (Da Silva Rabêlo and De Azevedo Melo, 2019), but only partial results were found for Chile by Fernández et al. (2021). This corroborates that these factors have a limited influence on the development of eco-innovations in Latin America. For other regions, the results were also unclear. Regarding training, Triguero et al. (2018) for Europe found no clear evidence, while Sanni (2018) for Nigeria obtained influence only for process eco-innovations. Concerning cooperation, while Del Río et al. (2017) and Mothe et al. (2018) considered it a driver of all types of eco-innovation, Marzucchi and Montresor (2017) only found it for some types, and Jové-Llopis and Segarra-Blasco (2018) for none in high-income countries. Therefore, these Latin American occasional drivers could also belong to this category in other regions.

The first main policy is related to our drivers. Policymakers should be aware of drivers that boost eco-efficiencies and, thus, they should develop policies for encouraging expenditure in R&D, other innovation expenditures, alliances, networks and market and regulatory factors.

In this sense, the results obtained show that common drivers -market and regulatory-are key in the Latin American region for the achievement of energy, material and environmental efficiencies. On the one hand, considering market factors, policies should facilitate the *development of green products or services* according to green demand requirements. On the other hand, policies should incorporate *specific regulations* for improving eco-efficiencies and particularly, energy efficiency, as has been noted by Costa-Campi et al. (2015b). Furthermore, it is important to check at the political level how the environmental regulations are implemented and how some mechanism for monitoring companies is incorporated to increase eco-efficiencies (Ouyang et al., 2020).

However, results also show that there are other frequent drivers (internal R&D, non-R&D embodied, non-R&D disembodied and breadth), and occasional (cooperation and training) which should be improved by policies to obtain higher efficiency results. In this regard, policymakers should consider the promotion of these groups of technological push-pull drivers because they could contribute to the development of eco-efficiencies in these countries and, at the same time, they help middle-income economies to catch eco-innovation leaders (Kounetas, 2015).

Specifically, to promote internal R&D, non-R&D embodied and non-R&D disembodied, financial policies should be incorporated, given the high costs involved in developing eco-efficiencies and the scarcity of own resources in the firms of these countries (De Marchi, 2012). Evidence of policies boosting these drivers has been pointed out by Jaffe et al. (2005) and Kounetas (2015). Therefore, policies should provide *financial facilities* to companies so that the development of innovations materializes in the generation of eco-efficiencies. Particular mention requires the promotion of energy use efficiency, in which authors have indicated that internal R&D and non-R&D embodied and disembodied play a key role as drivers over external R&D (Costa-Campi et al., 2015b). Thus, we call for the *development of policies boosting these drivers for energy use efficiency*. Furthermore, regarding breadth, cooperation, and training, policies that *foster networking* among the different agents (firms, universities, governments or consumers) are necessary. These networks will enhance these specific drivers and help to complement the firm's internal knowledge.

Secondly, given that our study relates the complementarities between different eco-efficiencies and innovation types, policymakers should be aware of it. Accordingly, innovation policies should be connected to green policies, given that innovation is the engine for obtaining eco-efficiencies. In this context, regulations to promote one type of eco-efficiency cannot be developed in isolation from other green eco-efficiencies. Moreover, eco-efficiencies policies cannot be implemented without considering innovation policies. Indeed, Duch-Brown and Costa-Campi (2015) had already noted that energy, environmental and innovation policies are strategically interconnected, and their design must consider the others to raise their efficiency.

Finally, we propose policies promoting eco-efficiencies at different levels since results suggest that drivers have different effects depending on the country. In this sense, some drivers are more common than others and results highlight that the specific profile of countries matters for the development of policies (Dutrénit et al., 2019). Specifically, policymakers should not ignore the characteristics of the country and region in which they are located (Cagno et al., 2015). Common drivers emerge as the most usual in Latin America as well as other regions, showing the relevance of green demand of products and regulation drivers in these countries. Therefore, a regulatory framework that enhances eco-efficiencies could be implemented at a supranational level, affecting these common drivers in different regions. Conversely, since frequent drivers are found in some countries, but their effects are not the same in all of them, this group requires regulation at the national level. Finally, occasional drivers need more specific legislation, at the national or even local level. Despite the supranational, national and local levels of policies in eco-efficiencies, all of them should be in consonance.

To conclude, it is important to remark that our results are subject to several limitations. Firstly, a cross-section analysis has been performed due to the availability of data. Secondly, we were not able to classify eco-innovation according to its dimensions, particularly according to the eco-design level of incremental and radical innovation based on Carrillo-Hermosilla et al. (2009, 2010). Thirdly, we were not able to classify the sample by industry and we could not show evidence of all Latin American countries because of the data limitation. However, despite these limitations, the effort of the LAIS dataset must be recognised for the joint of the innovation surveys in different countries. Finally, as Beltrán-Esteve and Picazo-Tadeo (2017) noted, environmental policies need to be based on robust indicators of environmental performance, so there is still work to be done to clarify the drivers in Latin American countries. Future lines of research will deal with the previous limitations by analysing these drivers considering different sectors, including other countries, and applying other techniques as a case of study for the identification of the dimensions of eco-innovations: design, users, product service dimension, and governance dimension.

Author statement

Celia Torrecillas: Conceptualization; Investigation; Methodology; Roles/Writing – original draft; Writing – review & editing; Supervision.

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Claudia García-García: Conceptualization; Investigation; Methodology; Roles/Writing – original draft; Writing – review & editing; Supervision.

Declaration of competing interest

No conflict of interest.

Data availability

The data that has been used is confidential.

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Appendix A. Data and main statistics of the variables.

Table A1
List of variables.

Dummies used for the creation of Eco-efficiencies variables*			Meaning
Innovation variables	Product innovation	Product	=1 if the firm has introduced at least one product innovation during the reference period; =0 otherwise.
	Process innovation	Process	= 1 if the firm has introduced at least one new process during the reference period; =0 otherwise.
	Incremental innovation	Incre	=1 if the firm reports sales corresponding to product innovations that are new to the firm during the reference period; =0 otherwise.
	Radical innovation	Radi	=1 if the firm reports sales corresponding to product innovations that are new to the market (domestic or international) during the reference period; =0 otherwise.
Efficiency variables	*Energy*	Energy	=1 if the firm indicates high or medium importance of the reduction of energy consumption as an innovation effect; =0 otherwise.
	Material	Mate	=1 if the firm indicates high or medium importance of the reduction in consumption of materials as an innovation effect; =0 otherwise.
	Environmental	Enviro	=1 if the firm indicates high or medium importance of the reduction in environmental impacts and/or the improvement of health and safety as an innovation effect; =0 otherwise.
Independent variables			**Meaning**
Technology Push	R&D expenditures	Internal R&D	Internal R&D expenditure in local currency over the number of employees (in logarithms).
		External R&D	External R&D expenditure in local currency over the number of employees (in logarithms).
	Other innovation expenditures	Non-R&D-Embodied	Acquisition of machinery, equipment, and advanced hardware or software for innovation in local currency over the number of employees (in logarithms).
		Non R&D Disembodied	Innovation expenditures in engineering and design in local currency over the number of employees (in logarithms).
		Training in R&D	Innovation expenditures in training in local currency over the number of employees (in logarithms).
Technology push (cont.)	Sources of knowledge, Alliances and Networks	Breadth	Knowledge sources composed of 10 sources of innovation: 1) internal sources, 2) suppliers, 3) customers, 4) competitors, 5) consultants, laboratories and research centres, 6) universities, 7) public research organisms, 8) conferences and expositions, 9) research journals, and 10) professional or industrial associations. For Uruguay and Peru: all these variables report values between 1 and 4. These values have been transformed in a dummy variable (0–1), considering high and medium importance, and 0 otherwise. The resulting variable (Breadth) has a range between 0 and 10 as a sum of the 10 knowledge sources. For Panama, these variables are dummies that report if each source is considered an important source of external information. The resulting variable (Breadth) has a range between 0 and 10 as a sum of the 10 knowledge sources.
		Coop	=1 if the firm has cooperated; =0 otherwise.
Market Pull	Market index		=1 if the firm indicates high or medium importance of the increase in the market share or the entrance into new markets as an innovation effect; =0 otherwise.
Regulatory Pull/Push	Regulatory		=1 if the firm indicates high or medium importance of compliance with regulation and standards; =0 otherwise.
Control variables			
Age			The variable that indicates the constitution year of the firms. We have calculated the Age by subtracting the final year from the year of the constitution of the company. We have developed Age2 to identify non-linear trends associated with this variable.
Size			Sales in local currency (in logarithms).
Variables used for transformation of variables			
Employment			The number of employees.

* The interaction of the "Innovation variables" and "Efficiency variables" has developed 12 dependent Eco-Efficiencies variables: 3 Variables referring to product innovation = Prod-Energy Efficiency, Prod-Material Efficiency, Prod-Environmental Efficiency. 3 Variables referring to process innovation = Proc-Energy Efficiency, Proc-Material Efficiency, Proc-Environmental Efficiency. 3 Variables referring to incremental innovation = Incre-Energy Efficiency, Incre-Material Efficiency, Incre-Environmental efficiency. 3 variables referring to radical innovation = Radi-Energy Efficiency, Radi-Material Efficiency, Radi-Environmental Efficiency.
Source: own elaboration

Tables A2
Correlation matrix by country.

URUGUAY

	R&D intensity	External R&D	Non R&D Emb	Non R&D Dissem	Training in R&D	Breadth	Coop	Market index	Regulatory	Age	Size
R&D intensity	1.0000										
External R&D	0.4145	1.0000									
Non R&D Emb	0.2687	0.1592	1.0000								
Non R&D Dissem	0.2331	0.1468	0.1539	1.0000							
Training in R&D	0.3727	0.2334	0.3406	0.2213	1.0000						
Breadth	0.2841	0.1396	0.3676	0.2284	0.4508	1.0000					
Coop	0.3924	0.2500	0.5121	0.2574	0.5489	0.6836	1.0000				
Market index	0.3728	0.1816	0.4153	0.2257	0.4473	0.5341	0.6371	1.0000			
Regulatory	0.3027	0.1734	0.3162	0.2220	0.3823	0.3919	0.4870	0.5343	1.0000		
Age	0.0727	0.0663	0.0996	0.0888	0.0761	0.0661	0.1020	0.0540	0.0850	1.0000	

(*continued on next page*)

Tables A2 (*continued*)

URUGUAY

	R&D intensity	External R&D	Non R&D Emb	Non R&D Dissem	Training in R&D	Breadth	Coop	Market index	Regulatory	Age	Size
Size	0.0558	0.0461	0.0842	0.0471	0.0704	0.0649	0.1086	0.0782	0.0874	0.1087	1.0000

PERU

	R&D intensity	External R&D	Non R&D Emb	Non R&D Dissem	Training in R&D	Breadth	Coop	Market index	Regulatory	Age	Size
R&D intensity	1.0000										
External R&D	0.4282	1.0000									
Non R&D Emb	0.2944	0.1204	1.0000								
Non R&D Dissem	0.3763	0.1724	0.2745	1.0000							
Training in R&D	0.3855	0.2158	0.3099	0.3974	1.0000						
Breadth	0.2886	0.1743	0.3535	0.2152	0.2933	1.0000					
Coop	0.1842	0.1073	0.2139	0.1184	0.1711	0.3508	1.0000				
Market index	0.0607	0.0585	0.0010	0.0762	0.0412	0.1574	0.0829	1.0000			
Regulatory	0.2186	0.1667	0.3282	0.2524	0.3070	0.3100	0.1590	0.2804	1.0000		
Age	0.1178	0.0280	0.0446	0.0321	0.0494	0.0922	0.0402	0.0242	0.0248	1.0000	
Size	0.0469	0.0611	0.0294	0.0147	0.0275	0.0780	0.0286	−0.0444	0.0062	0.1115	1.0000

PANAMA

	R&D intensity	External R&D	Non R&D Emb	Non R&D Dissem	Training in R&D	Breadth	Coop	Market index	Regulatory	Age	Size
R&D intensity	1.0000										
External R&D	0.544	1.0000									
Non R&D Emb	0.3936	0.2418	1.0000								
Non R&D Dissem	0.4057	0.2147	0.3449	1.0000							
Training in R&D	0.2545	0.1601	0.3425	0.2283	1.0000						
Breadth	0.5144	0.2794	0.5355	0.4077	0.2402	1.0000					
Coop	0.4756	0.2693	0.4401	0.3648	0.2991	0.5971	1.0000				
Market index	0.4213	0.1945	0.3834	0.3028	0.4002	0.4809	0.5493	1.0000			
Regulatory	0.3749	0.1703	0.2787	0.2018	0.3598	0.2551	0.3869	0.5547	1.0000		
Age	0.0140	0.0232	0.0519	0.0248	−0.0063	0.0820	0.0550	0.0258	0.0394	1.0000	
Size	−0.027	0.0066	−0.0145	0.0006	−0.0326	−0.0634	−0.0754	−0.0519	−0.0265	−0.0419	1.0000

Note: Due to the missing data, a formal redundancy analysis using pairwise associations is performed in each case to not greatly reduce the sample size (Harrell, 2015).
Source: own elaboration

Table A3
Statistical Information and Multicollinearity by Country.

Uruguay.

Explanatory variables	Mean	Std. Dev.	Min.	Max.	NA's	Coef. Var.	VIF
R&D intensity	8.0900E+13	2.3980E+14	0.0000	9.9920E+14	0	2.9641	1.3994
External R&D	2.2730E+13	1.3101E+14	−5.746E+14	9.9900E+14	0	5.7631	1.2222
Non-R&D Emb.	1.4250E+14	3.0093E+14	−6.802E+14	9.9960E+14	0	2.1116	1.2341
Non-R&D Dissem.	2.9720E+13	1.4945E+14	0.0000	9.9720E+14	0	5.0291	1.1026
Training in R&D	1.1720E+14	2.6736E+14	−6.802E+14	9.9980E+14	0	2.2812	1.4253
Breadth	0.7133	1.3996	0	5	0	2.2947	1.3765
Coop	0.3183	0.4659	0	1	0		
Market index	0.2640	0.4408	0	1	0		
Regulatory	0.1596	0.3663	0	1	0		
Age	1054.0000	1944.0980	1.0000	48400	39	1.8452	
Size	1.5760E+14	5.3068E+13	0.0000	6.9080E+14	0	0.3367	
Correlation matrix determinant (w/o control variables)	0.0573			**Condition number (w/o intercept)**	4.8741		
Correlation matrix determinant (w/ control variables)	0.0551			**Condition number (w/ intercept)**	5.1175		

Explained variables	Mean	Std. Dev.	Min.	Max.	NA's
Energy Product	0.0428	0.2025	0	1	6
Material Product	0.0497	0.2173	0	1	6
Environ. Product	0.0900	0.2862	0	1	6
Energy Process	0.0583	0.2343	0	1	3
Material Process	0.0673	0.2505	0	1	3
Environ. Process	0.1220	0.3273	0	1	3
Energy Increm.	0.0305	0.1718	0	1	0
Material Increm.	0.0333	0.1795	0	1	0

(*continued on next page*)

Table A3 (*continued*)

Explained variables	Mean	Std. Dev.	Min.	Max.	NA's
Environ. Increm.	0.0601	0.2378	0	1	0
Energy Radical	0.0175	0.1310	0	1	0
Material Radical	0.0191	0.1369	0	1	0
Environ Radical	0.0356	0.1852	0	1	0

Peru.

Explanatory variables	Mean	Std. Dev.	Min.	Max.	NA's	Coef. Var.	VIF
R&D intensity	1.3820E+14	2.6391E+14	0	9.9500E+14	0	1.9095	1.5210
External R&D	2.8490E+13	1.2977E+14	0	9.6550E+14	0	4.5549	1.2332
Non-R&D Emb.	2.9380E+14	3.7190E+14	0	9.9960E+14	0	1.2656	1.2534
Non-R&D Dissem.	9.5690E+13	2.2360E+14	0	9.9030E+14	0	2.3362	1.2987
Training in R&D	1.0990E+14	2.1309E+14	0	9.5490E+14	0	1.9393	1.3589
Breadth	2.6950E+00	2.3197E+00	0	7	0	1.8267	1.2264
Coop	7.9140E-01	4.0637E-01	0	1	11		
Market index	9.1030E-01	2.8591E-01	0	1	1840		
Regulatory	2.3060E-01	4.2129E-01	0	1	0		
Age	7.0770E+02	1.3043E+03	4	22801	0	1.8428	
Size	1.4700E+14	5.0260E+13	0	2.3330E+14	2	0.3418	
Correlation matrix determinant (w/o control variables)	0.5063			**Condition number (w/o intercept)**	8.5234		
Correlation matrix determinant (w/control variables)	0.4854			**Condition number (w/ intercept)**	14.1076		

Explained variables	Mean	Std. Dev.	Min.	Max.	NA's
Energy Product	0.1467	0.3539	0.1253	0	1
Material Product	0.1491	0.3562	0.1269	0	1
Environ. Product	0.1813	0.3853	0.1485	0	1
Energy Process	0.5435	0.4984	0.2484	0	1
Material Process	0.5299	0.4994	0.2494	0	1
Environ. Process	0.6698	0.4706	0.2215	0	1
Energy Increm.	0.0528	0.2237	0.0500	0	1
Material Increm.	0.0555	0.2290	0.0525	0	1
Environ. Increm.	0.0613	0.2400	0.0576	0	1
Energy Radical	0.1079	0.3103	0.0963	0	1
Material Radical	0.1068	0.3089	0.0954	0	1
Environ Radical	0.1328	0.3394	0.1152	0	1

Panama.

Explanatory variables	Mean	Std. Dev.	Min.	Max.	NA's	Coef. Var.	VIF
R&D intensity	7.0010E+13	2.0283E+14	0	9.9440E+14	0	2.8962	1.9029
External R&D	2.0570E+13	1.1196E+14	0	9.7980E+14	0	5.4400	1.4234
Non-R&D Emb.	8.1980E+13	2.2896E+14	0	9.9030E+14	0	2.7920	1.5488
Non-R&D Dissem.	3.4800E+13	1.3994E+14	0	9.8370E+14	0	4.0197	1.3109
Training in R&D	3.3900E+13	1.2738E+14	0	9.7700E+14	0	3.7557	1.1643
Breadth	3.6900E-01	8.7363E-01	0	4	0	3.2475	1.7123
Coop	4.1810E-01	4.9354E-01	0	1	525		
Market index	1.8410E-01	3.8773E-01	0	1	0		
Regulatory	8.6610E-02	2.8136E-01	0	1	0		
Age	9.5740E+02	1.4667E+03	1	12996	462	1.5312	
Size	1.6290E+14	1.4514E+14	0	9.9530E+14	464	0.8906	
Correlation matrix determinant (w/o control variables)	0.0671			**Condition number (w/o intercept)**	4.3929		
Correlation matrix determinant (w/control variables)	0.1062			**Condition number (w/ intercept)**	4.7687		

Explained variables	Mean	Std. Dev.	Min.	Max.	NA's
Energy Product	0.1589	0.3661	0.1341	0	1
Material Product	0.1863	0.3900	0.1521	0	1
Environ. Product	0.2623	0.4406	0.1941	0	1
Energy Process	0.0648	0.2462	0.0606	0	1
Material Process	0.0590	0.2356	0.0555	0	1
Environ. Process	0.0793	0.2704	0.0731	0	1
Energy Increm.	0.0248	0.1554	0.0242	0	1
Material Increm.	0.0269	0.1619	0.0262	0	1
Environ. Increm.	0.0364	0.1873	0.0351	0	1
Energy Radical	0.0160	0.1256	0.0158	0	1
Material Radical	0.0175	0.1311	0.0172	0	1
Environ Radical	0.0277	0.1640	0.0269	0	1

Source: own elaboration

Appendix B. Tests used to check the robustness of the model and goodness of fit.

Two tests have been used. The first one is the Wald test and the second one is the Likelihood Ratio (LR) test. Both values for each country are presented in Tables 2–4 of the paper. Results show satisfactorily as the model proposed can adequately predict the observed data.

The Wald test evaluates the restrictions of the statistical parameters as a function of the weighted distance between the unrestricted estimate and the restricted estimate (Fahrmeir et al., 2013; Ward and Ahlquist, 2018). The larger this weighted distance, the less likely it is that the restriction is true, so by rejecting the null hypothesis we can say that there is a lot of distance and that the model is adequate.

With the LR test, we estimate the restricted and unrestricted models. This test compares the goodness-of-fit of these two models, based on the ratio of their likelihoods (King, 1989). If the restricted model (the null hypothesis) is supported by the observed data, the ratio will be small, and the model will not be adequate.

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