Environment, Development and Sustainability
https://doi.org/10.1007/s10668-024-05593-3

# Circular economy in firms' strategies—What are the determinants of eco-innovation?

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Received: 25 March 2022 / Accepted: 19 October 2024


**Abstract**
Sustainability is a growing theme in society, and associated with it is the concept of circular economy (CE) that tries to reuse products for greater durability, thus contributing to reducing waste and pollution. A very important agent in this topic is eco-innovation (EI), which can be developed to promote the growth of this new economic concept. This study intends to determine the key drivers of EI for Portuguese companies, considering their evolution towards a circular economy. Using a Tobit model and data from the CIS, all the variables identified in the literature review were tested to understand their impact on firms' performance by measuring turnover growth (TG). Verifying all variables' effects was impossible from the estimations because not all were significant. Our findings allow concluding that not all drivers that appeared to have a positive impact on the TG had one. Therefore, the results show that not all theoretical drivers of eco-innovation are, in fact, drivers and may even represent negative impacts for the company, contrary to what one would predict. The negative effect that is still notorious regarding the costs that companies have associated with the implementation of these new measures should also be highlighted. It represents one of the biggest inhibitors for companies to integrate this action into their internal strategies.

**Keywords** Eco-innovations · Circular economy · Drivers · Portugal · Growth · Firm performance

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Published online: 07 November 2024

## 1 Introduction

Like Antoine-Laurent Lavoisier once said, “In Nature, nothing is lost, nothing is created, everything is transformed”. Everything that surrounds us, in our days and routines, is growing increasingly into a culture where it is necessary to transform our consumption patterns and the way we treat materials and processes in a more environmentally friendly manner. With a high demand for materials that will primarily generate a big amount of waste (Piscicelli & Ludden, 2016), we are taking natural resources (such as raw materials, water, or non-renewable sources of energy) to exhaustion, jeopardizing the life of the planet (Geissdoerfer et al., 2017) through our inconsequential attitudes, and sooner or later it will collapse.

Gaustad et al. (2018) argue that the bigger the competition between industries, the bigger the demand for products and, consequently, for the various types of materials these products will contain (criticality status). However, the supply of these same materials will be increasingly limited, which may give rise to geo-socio-political problems that altogether compromise the supply of materials (Gaustad et al., 2018). It should also be noted that all this demand for scarce resources will naturally increase their prices, which will not be positive for companies (Piscicelli & Ludden, 2016). The use of resources that cannot regenerate can have a major impact on the environment and society, leaving marks that might be irreversible (Ritzén & Sandström, 2017).

Furthermore, some authors claim that most of the material taken from nature does not go into the final product. Thus, radical dematerialization is the only solution for a sustainable economy (Lettenmeier et al., 2009). In representation of the "lost value" during the production of any product, Schmidt-Bleek, in the 1990s, created the concept of the "ecological backpack". This notion serves as a guide to represent all taken from nature and used in the final product, which usually means only about 10%. This concept will support eco-innovation when considering new products and adopting new measures (Lettenmeier et al., 2009).

For better performance of the Circular Economy (CE), it is essential to understand how eco-innovation (EI) can successfully contribute to this development. De Jesus et al. (2018) thus suggest the concept of "clean congruence" to try to make the most of the combination of these two concepts. It allows for correcting some mistakes of past economic models and overcoming the problems they generate in the environment through the combination of technological, social, and institutional advancement. Therefore, one of the greatest boosters of CE is the concept of Eco-Innovation (EI). This will allow companies to reinvent themselves and start innovatively developing their activities with greater ecological awareness, both within their internal environment and in their development and/or manufacture of new products. To overcome this problem and to search for eco-efficiency, specific key points are mentioned by the World Business Council for Sustainable Development. They are reducing the use of materials, products, and services, as well as the energy associated with them, for their extraction or production; reducing toxic disposal; greater acceptance of recycled products and increasing the use of recovered materials; trying to give products a longer life cycle and increasing the intensity of the Service related to these products (Ambec & Lanoie, 2008).

Portugal has a greater tendency to accumulate materials, extracting and importing more than exporting. Concerning productivity, it did not evolve as aggressively (23%) as some countries that were at the same level, remaining still below the EU average (30%) (APA, 2017). Regarding the efficient use of water, there is still a loss of about 35% of what is extracted and effectively used, and this percentage is even lower when we consider reusing

this loss (APA, 2017). There was an increase in renewable energies, but Portugal is still ruled mainly by imported fossil fuels. There was a significant decrease in GHG emissions and the waste produced by the different sectors. The former was based on developing technologies that helped prevent and control less polluting production and encourage process improvements. In contrast, the latter was based on reduced consumption and, consequently, in production, though the sector with the most significant impact is still the construction one (APA, 2017). Changes and incentives are necessary because not all sectors are in an equal situation; thus, these measures cannot be applied, nor can their strategies be adapted similarly. In this regard, it is important to define regional agendas to promote a collaboration network and to establish a perspective for Portugal in 2050, using action programs with the support of the Government (top-down actions), companies, and citizens (bottom-up actions). This national target for 2050 was defined using goals strongly related to the barriers described previously. It tries to overcome them with the development of a more resource-efficient economy, a strong focus on research and innovation to boost knowledge, the achievement of a carbon–neutral economy, economic development in all sectors showing inclusive economic prosperity, and also the stimulation for a more informed, collaborative and responsible society. This will be possible with the management of explicit tools to leverage results both at the macro (actions in structural terms), meso (actions in sectors), and micro (actions in regions and locals) levels.

To better understand this area, this study attempts to answer the research question of "What are the determinants (drivers) of eco-innovation for companies in a Circular Economy context?" using a statistical method applied at the micro-level in Portugal. This research tries to complement some gaps that emerged during a more in-depth literature review to better understand their connection and the influence of EI for CE on firms' actions. Moreover, it applies to a country where this topic has only been studied recently. Indeed, EI is not yet treated as a driver for the circular economy in Portugal, or at least, it does not appear in the existing studies (EIO, 2019). The lack of deepened research related to the CE at the national level might be associated with the fact that there is still a scarcity of statistical data and difficulty in evaluation. Based on companies' data, more studies are needed to get some real feedback and encourage other companies to follow the examples of those who have taken the initiative and risk in applying this new concept. This study tries to understand the behavior of Portuguese companies towards implementing environmentally positive measures, specifically the EI, to contribute to a CE. This understanding will allow us to delve into what the drivers will be for better companies' performance after adopting new measures and how they react to this evolution in terms of performance.

The remainder of this study is as follows: Sect. 2 presents a literature review of the circular economy and its position in the Portuguese economy. It also analyzes the concept of eco-innovation and its drivers, the relationship between the circular economy and eco-innovation concepts and their application to companies' routines. Section 3 presents data and the methodology, Sect. 4 presents the empirical results, and Sect. 5 concludes.

## 2 Literature review

The Circular Economy (CE) concept emerges to adopt a more sustainable economic development. This concept arises to counteract what is known as the linear model of the economy, "take-make-use-dispose" (Demirel & Danisman, 2019). In this model, materials are extracted, used in producing goods, distributed, consumed, and finally thrown away, ending

their life cycle without any future proposal (De Jesus et al., 2018; Piscicelli & Ludden, 2016). CE aims to redirect the end of the product life cycle in a closed way, unraveling a new application for it, thus reducing waste, energy use (De Jesus et al., 2018), and the speed with which resources are taken from nature. This approach will force industries to rethink their processes and strike a balance between what is environmentally acceptable in their production and the growth of their economy (Maldonado-Guzmán et al., 2020). This will also depend on the change in consumption habits of consumers (De Jesus & Mendonça, 2018), who will also have to adapt to this new thought of reusing with the help of marketing strategies (Lieder et al. (2017). CE has the advantage of creating new business models, products, and services and ensuring the perpetuity of resources, materials, or even products in the economic cycle for a longer time. Consequently, it reduces reliance on fossil fuels, thus protecting natural capital, minimizing waste, decreasing carbon emissions, and helping to combat climate change (Azevedo & Matias, 2017). The CE is related to several Sustainable Development Goals (SDGs), though it shows a stronger connection with goal 12—"Responsible Consumption and Production" (Demirel & Danisman, 2019). Although some economic models were created to turn the economy into a closed-loop economy mainly focused on changing consumer attitudes and consumption patterns, this area lacks information and studies. It is not yet clear to society whether this will have to be a joint process and whether the role of consumers will be central to a better adaptation of the CE (Piscicelli & Ludden, 2016).

Eco-innovation is crucial to help overcome all these difficulties (De Jesus & Mendonça, 2018). It focuses on the development of strategies that reveal how products, processes, and even economic models can be adapted to a circular concept through an innovation system (systemic innovation or technology-based innovation are the most commonly mentioned) that should be maintained after the transition (De Jesus & Mendonça, 2018). It will serve as a boost for change, but it will not be enough, as it is a method that requires a whole adaptation on the part of the market, production, consumer practices, and political measures supporting it (Prieto-Sandoval et al., 2018).

The study of EI is a crucial point for the success of the CE (Prieto-Sandoval et al., 2018) because it is an element that meets the essential components of sustainable development, the triple bottom line (He et al., 2018). Indeed, some studies help companies reorder their strategies towards these approaches, either through corporate social responsibility (CSR) policies or through environmental management systems (EMS), increasing the investment in eco-innovation (Cai & Zhou, 2014). Eco-Innovation is a concept that has not yet stabilized; therefore, several valid definitions can be found. Deconstructing the word, it is possible to understand that the root word "eco" derives from the Greek oĭko2 (oikos), which has meanings such as "home" or even "family" and "planet" more broadly speaking. In contrast, the word "innovation" follows from the Latin "in-novare", which, as previously explained, translates as adding value through the invention of something new or the recreation of something already existing (Colombo et al., 2019).

There is room for improvement because the Portuguese economy still faces barriers to success in this economic growth. Among those barriers are the lack of specific programs directed to the promotion and control of EI, the lack of private sector involvement and investment in EI, and the lack of balance between the registered patents and the high number of existing researchers. However, this might result from the increased perception of risk that these measures imply for those who invest in them, revealing insecurity in market demand (Curto, 2018). Furthermore, other obstacles can be added, such as the population's lack of perception of the existing environmental problems and the small size of companies that realize that resource-efficient measures can reduce production costs (EIO, 2019).

To encourage the development of best practices and address these barriers, Portugal has adopted several programs and action measures to promote the use of CE by taking advantage of one of its primary drivers, the EI. This has significantly helped increase exports and lower energy and materials costs.

EI and CE are very interconnected concepts aimed at improving environmental sustainability. While EI focuses on specific innovations to improve environmental performance, the CE emphasizes a holistic approach to redesigning entire systems to be sustainable and regenerative. Despite their differences, EI and CE require some complementarity with, for example, research development, especially at the EI scope, since it has higher deficits concerning past research, to understand how best to act together accordingly (Gente & Pattanaro, 2019). This relationship of concepts contributes not only to forget the connotation attributed by the EU as weak sustainability, which is associated with a more eco-centric economy, but also to a greater opportunity for the third sector, such as NGOs, to start contributing to these types of innovation-related initiatives and policies in the EU (Colombo et al., 2019). The importance of EI for the development of CE is especially identified. Still, it should also be noted that for these innovations to be successful, it is necessary to know how to apply them commercially. Hence, these concepts are complementary (Prieto-Sandoval et al., 2018).

There are also some types of EI, identified in the EIO (2016), with actions directed particularly to CE, which include product design, process, organizational, marketing, social, and system eco-innovation. Roughly speaking, in this dependency relation between EI and CE, we distinguish two domains of activities, one that focuses on a more technical part ("harder elements"), related to products and investment in new processes and cost reduction, and the other that focuses more on a structural part ("softer" elements), related to organizational redesign, business model, behavior trends or even marketing strategies (Maldonado-Guzmán et al., 2020; Vence & Pereira, 2018). Moreover, we might also establish a rationale for the connection between energy efficiency and CE. Energy plays a vital role in all areas of human life, essential for achieving a high standard of living and environmental stability. Our energy systems primarily rely on fossil fuels, leading to pollution, climate change, and health concerns that ultimately impact our quality of life (Barkhausen et al., 2022). Moreover, these resources are not evenly distributed globally, making some countries heavily reliant on external energy sources. Two main strategies are being pursued to address these challenges: adopting renewable energy sources and promoting energy efficiency (Fragkos, 2022). Enhancing energy efficiency is crucial to lower overall energy consumption. On a different note, the circular economy aims to reduce waste and pollution by promoting the reuse of materials and sustainable practices (like eco-friendly designs and industrial symbiosis) (Halkos & Petrou, 2019). The goal of prioritizing the circulation of products and materials at their highest value is to minimize the demand for new resources, alleviate the strain on natural ecosystems, and help maintain stable prices (Guven et al., 2024).

Focusing on the micro-level, there is a strong influence of EI in the economic growth of the company, showing a better performance when it presents activities related to EI rather than unrelated ones, which subsequently will be contributing to an increase in employment (Demirel & Danisman, 2019; Madaleno et al., 2020). Nevertheless, some authors argue the opposite, identifying a negative relationship between the previous variables (Demirel & Danisman, 2019). However, it should be noted that the effects of EI on a firm's economic growth depend a lot on the firm's characteristics, as well as on its structure or even the industry (Demirel & Danisman, 2019). Likewise, the policies implemented will only work correctly if they are targeted to the correct type of companies (Da Silva, 2014).

The policy measures are essential to avoid adverse market externalities (Mazzanti et al., 2016). They can more easily influence the use of EI-related practices when these represent financial rewards, as most companies cannot distinguish between economic and environmental returns (Da Silva, 2014). Radical EI may contribute to this distinction because it promotes substantial changes in these practices and is easier to perceive than incremental EI, which has a slower pace of implementation and is not so noticeable at first (Da Silva, 2014).

More studies are needed to better understand this topic and encourage other companies to adopt EI toward CE. This study aims to understand the behavior of Portuguese companies regarding the implementation of environmentally positive measures, specifically EI, to contribute to CE.

## 3 Hypothesis, data, and methodology

A structural model was developed with the focal points under study. This structural model combines the key points from the literature to help formulate hypotheses to answer the research question. Even though we have built a model from all available literature, we just took one specific approach, as in Cai and Zhou (2014). These hypotheses will be tested through econometric methods to assess their appropriateness. This is a model that aggregates internal factors—technological innovation capacity, organizational innovation capacity, structural management measures, structural characteristics (size, sector, or age)—and also external company factors—financial mechanisms, environmental regulation, greener demand, competitiveness—which, combined with the existence of an external network with qualified partners, are taken into account as the EI drivers that will have the most significant impact on the company's performance towards a more circular and environmentally friendly economy (Fig. 1).

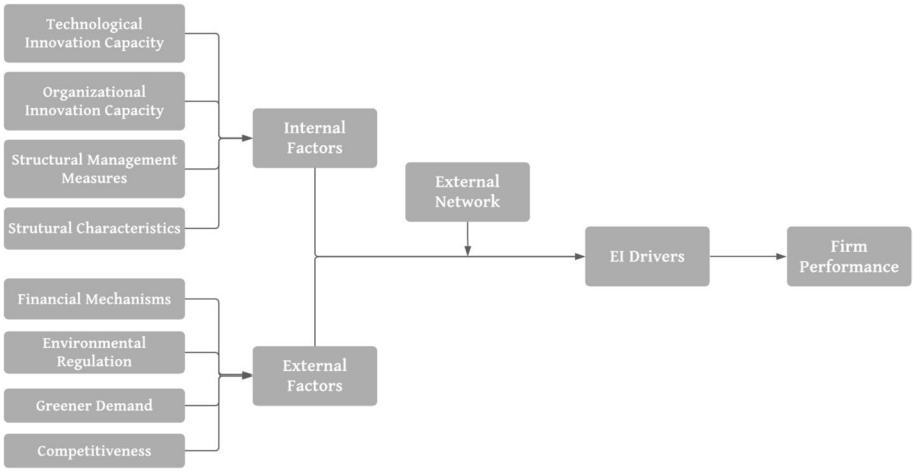


**Fig. 1** Structural model. Source: Own elaboration based on the study of Cai and Zhou (2014)

**Table 1** Hypothesis description

| Hypothesis | Description of hypothesis |
|---|---|
| H1 | Internal factors influence a firm's performance |
| H1.a | Technological innovation capacity influences a firm's performance |
| H1.b | Organizational innovation capacity influences a firm's performance |
| H1.c | Structural management measures influence a firm's performance |
| H1.d | Structural characteristics influence a firm's performance |
| H2 | External factors influence a firm's performance |
| H2.a | Financial mechanisms influence a firm's performance |
| H2.b | Environmental regulation influences a firm's performance |
| H2.c | Greener demand influences a firm's performance |
| H2.d | Competitiveness influences a firm's performance |
| H3 | External networks influence a firm's performance |

*Source*: Own elaboration

The data used in this study is from the Community Innovation Survey (CIS) between 2012 and 2014.[1] Since Portugal is the country under study, only the data specific to the Portuguese companies were selected. The CIS is carried out by the European Commission, following the methodology recommended by EUROSTAT and based on principles established in the Oslo Manual (Da Silva, 2014). It is directed to all EU members, allowing a comparative evaluation among them (Mazzanti et al., 2016). It generally highlights companies by sector of activity, according to the CAE (Classificação Portuguesa das Atividades Económicas—CAE-Rev. 31) (Da Silva, 2014), by the number of workers in the companies, and also by the region in which they operate. In general, this questionnaire intends to obtain information about the innovative development of companies in each country, highlighting, for example, the objectives that are imposed on them or the public funding that they can choose when they intend to develop activities related to innovation (Azevedo & Matias, 2017; Mazzanti et al., 2016).

The following hypotheses were formulated as a starting point for the empirical investigation. They derive from what was gathered during the literature review and try to constitute the foundation of the research through observations (data) that, after being worked on, will support a better understanding of the theme. These hypotheses (Table 1) connect what is obtained in theory and what may be obtained in practice after analyzing the results (Da Silva, 2014).

To measure H1, the included variables are more related to the firm's internal factors concerning the company's technological, organizational, and structural capabilities. To verify H2, the indicators used are external to the company but impact its performance. To validate H3, the chosen indicators relate the company to other qualified entities.

This is a biennial survey, so the information was treated considering a cross-section analysis since it does not focus on observations over time but rather on the study of the behavior of companies (individuals) when faced with innovation factors in a given period (Azevedo & Matias, 2017). The survey is not very recent due to the lack of available data. Up to this moment, only three surveys include questions regarding environmental issues, trying to understand the importance given by companies and their relations with innovations involving environmental benefits. These are the CIS 2008, the

[1] Firms answering the CIS 2014 had to answer questions from the previous last two years, meaning from the period 2012–2014. Accordingly, those answering the CIS 2008 had to answer questions related to the period 2006–2008.

CIS 2014, and the CIS 2020. Until now, data is only available for CIS 2008 and CIS 2014. The CIS 2020 data has not yet been released, which justifies using CIS 2014 (Madaleno et al., 2020). Still, this is the first survey to address the issue of EI in the EU. Firms answering the CIS survey had ten questions about eco-efficiency measures to respond. Therefore, it has been handy and relevant to deepen the subject further regarding its determinants, political support, and even economic impacts that EI can cause, besides focusing on the environmental consequences (Mazzanti et al., 2016). This sample is composed of 7083 Portuguese companies that validly answered the survey. Considering only the survey questions to which there were complete data, thus disregarding those with incomplete answers, it resulted in an adjusted sample of 1638 companies that introduced or adopted activities related to EI in their companies, influencing their performance. The CIS is a mandatory questionnaire, a National Statistical System rating tool (Da Silva, 2014), which collects these data through an electronic platform intended for this purpose. It should be noted that this sample is then refined according to the values of turnover growth (TG), the dependent variable, which is limited between 0 and 1 (0% to 100%) to reduce biases in the results.

Table 3, in the appendix, describes the variables used in this study. TG was selected as the dependent variable to assess the company's performance when faced with EI-related measures that contribute to progress towards a more circular economy. This variable was chosen as the dependent variable because turnover is one of the most important measures to be considered when evaluating the company's performance, as it allows the appreciation of the company's behavior in financial terms, reflecting the sales of products (goods and services) placed on the market, covering taxes, apart from VAT. The dependent variable (TG) is presented as a growth rate and is expressed in monetary values, so it was operated with a log to relate to the other variables. This is an advantageous transformation to convert a biased variable into more standardized elements. Still, when working with this variable type, where linear interactions are not verified, the possibility of negatively biased errors cannot be ruled out. Another variable that also resorted to the log for its normalization was the variable that refers to the company's size, in which the total number of employees in each company was used.

The independent variables were broadly decomposed into internal factors, external factors, and the external network. Each group of variables was subdivided into several components associated with the measure index derived from the CIS questions, which gave rise to the data obtained that will be analyzed.

Given the type of data used to analyze the main question developed throughout this research, it was stipulated that the Tobit model would be the most appropriate one for assessing the integrity of the proposed hypotheses. Tobit is a limited dependent variable model that fits this situation because of the type of cross-sectional data (Lee & Maddala, 1985) and due to its easiness in studying a database with a high number of zeros, which helps to test the model, as they are a representative part of the sample. This model allows testing the dependent variable within certain limits (upper and/or lower bounds), in this case between 0 and 1, without necessarily needing to be a binary variable. The turnover growth has a mean value of 0.2118. For it to be modeled, it is necessary to consider the portion of about 26% (0.2557998) that is not contemptible and has a zero value. The R program was used to test the regression adapted to this study. The model aims to determine the impact of the selected EI drivers on firms' performance through their TG. To test whether the variables are good drivers of EI (significant or not) and if they lead to good firm performance, we propose the model estimation based on Eq. (1).

$$
\begin{aligned}
TG^{*} = {} & \beta_1 ecomat + \beta_2 ecoeno + \beta_3 ecopol + \beta_4 ecosub + \beta_5 ecorep + \beta_6 ecorec \\
& + \beta_7 ecoenu + \beta_8 ecopos + \beta_9 ecorea + \beta_{10} ecoext + \beta_{11} ecoprd + \beta_{12} ecoprc \\
& + \beta_{13} ecorg + \beta_{14} ecomkt + \beta_{15} enagr + \beta_{16} enetx + \beta_{17} engra + \beta_{18} encost \\
& + \beta_{19} enrequ + \beta_{20} enereg + \beta_{21} enregf + \beta_{22} endem + \beta_{23} enrep + \beta_{24} gp \\
& + \beta_{25} co + \beta_{26} size + u, u|x \sim Normal\left(0, \sigma^2\right)
\end{aligned} \tag{1}
$$

where $TG$ – dependent variable; $TG^{*}$– latent dependent variable; $\beta_1, \ldots, \beta_{26}$- the regression parameters associated with each independent variable; $u$—error term, $u|x \sim \text{Normal}\left(0, \sigma^2\right)$. For more details, please see Table 3 in the appendix.

Considering the possibility of multicollinearity among independent variables, the model was tested with the appropriate tests, assuming different regression specifications and the usual 5% significance level in this econometric model to obtain the best possible outputs. No multicollinearity problem was detected from these tests, validating the results with what was predicted in the literature review section. Additionally, heteroscedasticity was checked using a significance level of 5%. However, the nature of the survey questions (categorical or dummy) did not allow for better proxies for the results, which turned out to be a limitation.

## 4 Empirical results

The model was tested in several ways, assuming different regression specifications to obtain the best possible outputs and validating them with what was predicted in the literature review section. Table 2 presents the results of the multiple types of tests done through the marginal effect of the model that measures the actual impact on the latent dependent variable (Martins, 2016), the Turnover Growth (TG). This type of testing evaluates the effect on the mean, i.e., the midpoint of the variable. From the very beginning, it can be ascertained that, according to their corresponding standard errors and the p-values, when all variables were tested simultaneously, only 5 (ecorea, ecoext, endem, gp, and size) of the 26 independent variables were significant. But, nothing could be determined regarding the behavior of the remaining 21 variables (ecomat, ecoeno, ecopol, ecosub, ecorep, ecorec, ecoenu, ecopos, ecoprd, ecoprc, ecorg, ecomkt, enagr, enetx, engra, encost, enrequ, enereg, enregf, enrep, co), as they did not show enough significance in explaining TG, in this first regression specification.

Among the statistically significant variables, the one that represents the facility for recycling a product after its use (ecorea) and the one that defines whether the firm belonged to a group of companies at the time of the survey (gp), both with a significance of 10%, presented a negative impact on the TG, contrary to what would be expected, especially concerning the ecorea variable. This result is opposite to what was collected through the literature. The adoption of new strategies to adjust the product design to be used until the end of its useful life or to help in the transformation of the processes (Vence & Pereira, 2018) towards cleaner production (Demirel & Danisman, 2019) is not found to be simultaneously beneficial for the company's growth and the adoption of a circular economy, but only for the latter. This would be easily explained by the fact that companies might have to spend more money making products that could be reused later than the profit they would make by implementing this type of strategy.

**Table 2** Results of the regression specifications

| TG | Coef | Coef | Coef | Coef | Coef | Coef | Coef |
|---|---|---|---|---|---|---|---|
| Ecomat | 0.000 | | 0.004 | | 0.011 | 0.004 | 0.011 |
| Ecoeno | −0.015 | | −0.009 | | 0.000 | −0.015 | 0.002 |
| Ecopol | −0.016 | | −0.025* | | −0.021’ | −0.02’ | −0.021’ |
| Ecosub | 0.015 | | 0.012 | | 0.02’ | 0.021’ | 0.018 |
| Ecorep | 0.000 | | 0.002 | | 0.005 | 0.000 | 0.008 |
| Ecorec | 0.008 | | −0.001 | | 0.004 | 0.003 | 0.002 |
| Ecoenu | 0.004 | | | −0.001 | | | −0.003 |
| Ecopos | −0.009 | | | −0.019 | | | −0.025* |
| Ecorea | −0.016 | | | −0.012 | | | 0.008 |
| Ecoext | 0.031 | | | 0.032** | | | 0.042*** |
| Ecoprd | | 0.008 | 0.017 | 0.010 | | | |
| Ecoprc | | 0.000 | 0.007 | −0.004 | | | |
| ecorg | | 0.012 | 0.011 | 0.01 | | | |
| Ecomkt | | 0.022 | 0.018 | 0.025 | | | |
| enagr | −0.012’ | −0.014* | | | −0.004 | | −0.003 |
| enetx | 0.002 | 0.003 | | | −0.006 | −0.006 | |
| engra | 0.005 | 0.005 | | | 0.009 | 0.008 | |
| Encost | 0.000 | −0.003 | | | 0.006 | 0.002 | |
| Enrequ | −0.004 | −0.003 | | | −0.005 | −0.003 | |
| Enereg | −0.002 | −0.003 | | | | | |
| Enregf | −0.016’ | −0.016’ | | | | | |
| endem | 0.014* | 0.015* | | | | | |
| enrep | 0.012’ | 0.011 | | | | | |
| gp | | | −0.047*** | | −0.024’ | | −0.025* |
| co | | | −0.008 | | 0.007 | | 0.008 |
| size | | | | | 0.043*** | | 0.042*** |
| Ecomat | 0.011 | 0.008 | 0.006 | | | | |
| Ecoeno | 0.003 | 0.000 | −0.009 | | | | |
| Ecopol | −0.021’ | −0.022’ | −0.024* | | | | |
| Ecosub | 0.019’ | 0.015 | 0.016 | | | | |
| Ecorep | 0.008 | 0.006 | 0.004 | | | | |
| Ecorec | 0.003 | 0.002 | 0.001 | | | | |
| Ecoenu | | | | 0.008 | 0.01 | 0.006 | 0.008 |
| Ecopos | | | | −0.015 | −0.015 | −0.017 | −0.018 |
| Ecorea | | | | −0.014 | −0.015 | −0.017 | −0.017 |
| Ecoext | | | | 0.031** | 0.032** | 0.029* | 0.03* |
| Ecoprd | | | | | | | |
| Ecoprc | | | | | | | |
| ecorg | | | | | | | |
| Ecomkt | | | | | | | |
| enagr | | | | | | | |
| enetx | | | | −0.005 | | | |
| engra | | | | 0.008 | | | |
| Encost | | | | 0.004 | | | |

**Table 2** (continued)

| TG | Coef | Coef | Coef | Coef | Coef | Coef | Coef |
|---|---|---|---|---|---|---|---|
| Enrequ | | | | −0.004 | | | |
| Enereg | 0.002 | | | | 0.003 | | |
| Enregf | −0.006 | | | | −0.006 | | |
| endem | | 0.011* | | | | 0.012* | |
| enrep | | | 0.008 | | | | 0.009 |
| gp | −0.025* | −0.025* | −0.048*** | −0.022’ | −0.023’ | −0.023’ | −0.023’ |
| co | 0.008 | 0.007 | −0.002 | 0.006 | 0.007 | 0.006 | 0.006 |
| size | 0.041*** | 0.042*** | | 0.043*** | 0.041*** | 0.042*** | 0.042*** |

(Signif. codes: ***0.001; **0.01; *0.05; ‘ 0.1). See Table 3 for the description of the variables. Coef. stands for coefficient value, the identified betas in Eq. (1). TG represents turnover growth, the dependent variable

It is crucial to remember that this sample includes a large number of small companies (more than medium and large companies combined). It is more convenient for these companies to manage with reactive measures (Pinget et al., 2015), as proven in the literature. Indeed, according to the EI index, in Portugal, SMEs show more positive results in adopting eco-innovative measures (EIO, 2019). Even so, their operation in the market must be affected because they do not have as much flexibility in financial terms to adapt to new conditions as larger companies have. Therefore, they could experience some difficulties in meeting the requirements and, at the same time, promoting good firm performance, including environmental conditions.

## 5 Conclusions

This study provides an in-depth investigation to answer the main determinants (drivers) of eco-innovation for companies in a Circular Economy context. Using a Tobit model to test the selected data from Portuguese firms obtained from CIS, it was possible to draw several conclusions. One of them is that not all the drivers determined in the literature review were likely to present a concrete answer for the hypotheses imposed. In other words, and according to the results obtained, not all the selected variables were explanatory of the model, and those found to be significant did not have the expected effect. For these same variables, there was no increase in TG for each additional value but rather a decrease in the latent dependent variable, meaning that the higher the variable, the lower the TG. Nevertheless, for other variables, it was possible to conclude what was predicted regarding their behavior towards TG, showing a positive relationship with the latent dependent variable, meaning that when there was an increase in those variables, there would also be an increase in TG.

This is a large representative sample of small companies that appear very receptive to market changes and need to quickly react and adapt their strategies. Even so, these companies generally show greater difficulty in financial terms, which does not allow them to advance much further in adopting the new measures. Adjusting them to the company's economy will mean a tremendous economic weight, not compensating for the growth and firm performance benefits this would bring. Although the controversial impact, in negative terms, that some variables demonstrated, as this sample is predominantly of

small companies, the results obtained are understandable due to the financial limitations that they may often present.

The central aspect to ascertain when comparing the literature review to the performed model is that not all EI drivers behaved as predicted. Considering the Internal Drivers, it was impossible to prove the Technological Innovation Capacity of all the defined variables to represent it. This is a driver that can only be proven under certain conditions. That is, when the variable is represented by the total or partial replacement of less polluting materials or hazardous substitutes (ecosub) or by extending product life through longer-lasting or stronger products (ecoext). If, in contrast, we consider the technological innovations related to the reduction of air, water, noise, or soil pollution, both the environmental benefits obtained within the company (ecopol) and for the final consumer during the use of the product (ecopos), and the easy recycling of the product after use (ecorea), have already proved to be contradictory as an EI driver, given their adverse effects on firm performance. For the Organizational Innovation Capacity driver, it was impossible to determine any integrity in what was described in the literature. With the data and methodology used, verifying their behavior towards TG was impossible, which would reflect the influence of variables on the company's performance. Hence, nothing can be concluded about this driver. Regarding the Structural Management Measures driver, it was possible to prove the opposite effect to what was described by other authors (in which this would be a good driver) because the variable that illustrates the voluntary actions or initiatives for good environmental practices within the company's sector (enagr) exerts a negative influence on TG. The driver related to Structural Characteristics was the most consistent with the literature. Represented by the company's size in terms of the number of employees, it revealed, as expected, that the larger the company, the higher the TG associated with adapting new EI strategies and the company's positive behavior towards them.

Regarding the External Drivers and considering the Organizational Innovation Capacity driver related to the Financial Mechanisms, it was also not possible to verify any representative relationship between the variables that defined it and the company's performance, neither proving nor denying what is assumed in the literature. The same cannot be said about the environmental regulation driver, represented by the variable that revealed the existence of environmental regulations or taxes planned for the future (enregf). Indeed, it presents controversial behavior based on what was portrayed in the literature, which is not a good driver for EI. As argued by some authors, this type of regulation could emerge as a barrier and not a driver when poorly specified and not adequately implemented, which was the case according to the results obtained through econometric testing. Still, under certain conditions, it was possible to prove that Greener Demand, through the current or expected market demand for environmental innovations (endem), and Competitiveness, represented by the variable that exposed the improvement of a company's reputation (enrep), are two good drivers of EI, according to the results obtained, as also predicted in the literature.

It should be noted, though, that the External Network variable has a negative effect, contrary to what was expected from the literature. Differently from what had been previously proposed, the connection with other qualified entities within the area, if not made in a coordinated and accessible way to the company, is shown to be unfavorable for the company's turnover growth for a large part of the inquired companies.

In this study, most of the predefined determinants of EI did not corroborate other authors due to a significant factor still defined by many as a barrier to EI. This factor relates to the costs associated with implementing these new EI measures in companies. Thus, it reveals that this element has still a strong influence when making decisions about introducing this

type of measure related to the environment, limiting certain types of drivers, no matter how consistent they may be.

Although most of the hypotheses defined in this study were not verified or presented results contrary to what was expected, it was possible to confirm some of the previously defined discoveries. Furthermore, it also helped us to understand that certain areas in this theme should be better studied in the future to confirm what is found in the literature, possibly through other, more specific studies and with a different type of data.

This is an analysis that, like many others, has limitations. One of them was the lack of temporal verification of the results obtained or the existence of the simultaneity problem due to the use of cross-sectional data. Supposing that another type of data had been obtained, with more observations over time, it might have been easier to better evaluate the behavior of the variables since some of them could demonstrate a positive effect on the company's performance if they were studied over a more extended period. Another limitation was that this is still a recent theme studied for the chosen country. Moreover, having access to the more recent CIS 2020 with eco-innovation measures would be beneficial, as access to other nature-based variables (as continuous). Nevertheless, no data has been made available to the more recent CIS, leading us to resort to the CIS 2014 data.

For future research, it is recommended to try to obtain more current data and to repeat the observations for a more extended period to demonstrate greater precision in the estimation of the coefficients of the independent variables, not limiting the study to only one type of isolated observation in a short period, as it is the present case. Another suggestion for future research would be to explore the topic regarding EI typologies, as this still appears quite confusing in the literature. It would also be interesting to conduct another study like this one but differentiating the companies by other types of structural characteristics, such as the sector in which they operate or even by the regions of the country to which they belong, comparing regional circular economy-oriented agendas by which they should be guided.

## Appendix

See Table 3.

**Table 3** Variables description

| Variable | Variable description | Measure index | Value range | Authors |
|---|---|---|---|---|
| **Dependent variable** | | | | |
| Firm performance | The logarithm of turnover growth | TG | [0,1] | (Madaleno et al., 2020) |
| **Independent variables** | | | | |
| *Internal drivers:* | | | | |
| Technological innovation capacity | Reduction of material or water used per unit produced | ECOMAT | 0 = No; 1 = yes | (Cai & Zhou, 2014), (Madaleno et al., 2020), (Pinget et al., 2015), (Di Stefano et al., 2012), (Da Silva, 2014) |
| | Reduction of energy used or $CO_2$ produced by the company (reduce total $CO_2$ production) | ECOENO | 0 = No; 1 = yes | |
| | Reduction of air, water, noise, or soil pollution (environmental benefits within the company) | ECOPOL | 0 = No; 1 = yes | |
| | Total or partial replacement by less polluting materials or hazardous substitutes | ECOSUB | 0 = No; 1 = yes | |
| | Replacing a share of fossil energy with a renewable energy source | ECOREP | 0 = No; 1 = yes | |
| | Recycling of waste, water, or materials | ECOREC | 0 = No; 1 = yes | |
| | Reduction of energy used or $CO_2$ produced | ECOENU | 0 = No; 1 = yes | |
| | Reduction of air, water, noise, or soil pollution (environmental benefits for the final consumer during the use of the product) | ECOPOS | 0 = No; 1 = yes | |
| | Easy recycling of the product after use | ECOREA | 0 = No; 1 = yes | |
| | Extended product life through longer-lasting or stronger products | ECOEXT | 0 = No; 1 = yes | |

**Table 3** (continued)

| Variable | Variable description | Measure index | Value range | Authors |
|---|---|---|---|---|
| Organizational innovation capacity | Product (goods or services) innovations | ECOPRD | 0 = No; 1 = yes | (Cai & Zhou, 2014), (Madaleno et al., 2020) |
| | Process innovations | ECOPRC | 0 = No; 1 = yes | |
| | Organizational innovation | ECORG | 0 = No; 1 = yes | |
| | Marketing innovations | ECOMKT | 0 = No; 1 = yes | |
| Structural management measures | Voluntary actions or initiatives for good environmental practices within your sector | ENAGR | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | (Cai & Zhou, 2014) |
| Structural characteristics | A factor with 3 levels, depending on the number of employees | SIZE | 1 = < 50; 2 = 50—249; 3 = > 250 | (Madaleno et al., 2020), (Pinget et al., 2015) |
| *External drivers:* | | | | |
| Financial mechanisms | Existence of environmental taxes, charges or fees | ENETX | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | (Madaleno et al., 2020), (Da Silva, 2014) |
| | Public Administration support, subsidies, or other financial incentives for environmental innovations | ENGRA | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | |
| | High costs of energy, water or materials | ENCOST | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | |
| | Need to meet the requirements for public procurement contracts | ENREQU | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | |
| Environmental regulation | Existence of environmental regulations | ENEREG | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | (Cai & Zhou, 2014), (Da Silva, 2014) |
| | Environmental regulations or taxes planned in the future | ENREGF | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | |
| Greener demand | Current or expected market demand for environmental innovations | ENDEM | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | (Cai & Zhou, 2014), (Da Silva, 2014) |

**Table 3** (continued)

| Variable | Variable description | Measure index | Value range | Authors |
|---|---|---|---|---|
| Competitiveness | Improve the company's reputation | ENREP | 0 = Irrelevant; 1 = low; 2 = medium; 3 = high | (Cai & Zhou, 2014) |
| External network | In 2014, the company was part of a group of companies | GP | 0 = No; 1 = yes | (Cai & Zhou, 2014), (Pinget et al., 2015) |
| | During the period from 2012 to 2014, the company cooperated within the scope of innovation activities with other companies or organizations | CO | 0 = No; 1 = yes | |

*Source*: Own elaboration based on CIS survey

**Acknowledgements** The authors acknowledge the support provided by the Research Unit on Governance, Competitiveness and Public Policy (UIDB/04058/2020), funded by national funds through FCT-Fundação para a Ciência e a Tecnologia.

**Author contributions** All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Maria Massapina and Mara Madaleno. The first draft of the manuscript was written by Maria Massapina, Mónica Meireles, and Mara Madaleno, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Funding** Open access funding provided by FCT|FCCN (b-on). This work was supported by the research unit on Governance, Competitiveness and Public Policy (UIDB/04058/2020)+(UIDP/04058/2020), funded by national funds through FCT - Fundaçãopara a Ciência e a Tecnologia.

**Data availability** The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interests** The authors have no competing interests to declare that are relevant to the content of this article.

**Compliance with ethical standards** The authors have nothing to declare in this regard, relevant to the content of the article.



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