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On the path to sustainable development: The nexus among owner gender diversity, energy management, and firms' innovation radicalness

Owner gender, energy management & innovation

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Abstract

This research focuses on the part of sustainable development related to energy management and thus aims to find the missing piece in research on the role of owner gender diversity (OGD) in processes of energy management (EM) introduction and the creation of radical and incremental innovation. Employing the World Bank's Enterprise Survey 2019 data covering 4,646 firms from 11 European countries, we confirm the hypothesis that OGD increases firms' chance to reach radical and incremental innovation. Contrary to the majority of prior studies, we reject the hypothesis that OGD increases firms' chance to introduce EM; rather, we empirically prove the positive effects of firms' value drivers and market pressure on EM. We also confirm the link between firms' introduction of EM and the creation of radical and incremental innovations. This study expands research into the gender diversity of the upper echelons, addressing recent calls to expand open innovation research into new research categories and identify the determinants of firms' introduction of EM.

Key words: owner gender diversity, energy management, radical innovation, incremental innovation, European countries, World Bank Enterprise Survey, sustainable development

1 Introduction

In the last 10 years, women have played an important role in firm governance (Liao et al., 2019) and have increasingly become the owners and managers of firms (Fu et al., 2020). Therefore, women's entrepreneurship has become growing field of entrepreneurship research (Rosca et al., 2020), and is at the forefront in contemporary issues and incentive policies (Özsungur, 2019). Such increased interest and changes could be, from the one perspective, because women may differ from men in several aspects and can therefore add new (different) perspectives, experiences, knowledge, values, working styles, and problem-solving ideas to firms, thereby influencing firms' performance (Torchia et al., 2011). From the other perspective, it could be due to the growing regulatory pressure for firms to address the underrepresentation of women in the boardroom (Chen et al., 2018). These initiatives also have their justifications in the form of legal mandates for board gender diversity (BGD), such as in Norway, Sweden, Finland, and Germany (Buertey, 2021).

Regarding the increasing role of women on boards, prior research has directed more attention to analysing how female directors influence firms and their outputs (Fu et al., 2020), primarily exploring the relationship between BGD and firm performance (Torchia et al., 2011; Post & Byron, 2015), or stakeholders value (Nadeem et al., 2020b). However, prior studies were not conclusive and did not provide strong empirical evidence. Indeed, we can find studies which have shown positive (Chen et al., 2018) as well as negative (Solakoglu & Demir, 2016) effects of BGD on the performance of firms. Moreover, Nadeem et al. (2020b) state that despite female directors significantly affect firms' environmental value creation (in family firms), economic and social value creation are not affected by them.

Limited attention has been paid also to the issues of women's ownership, firm innovation, and its radicalness. Therefore, we cannot satisfactorily conclude whether and how gender diversity relates to firm innovation performance. It is because current findings related to women's entrepreneurship and women in businesses have provided rather confusing implications (Dai et al., 2019); thus, there is a need for further research on innovation and growth in women-owned firms (Audretsch et al., 2020). The same is true also about the unanswered role of women within innovation processes designed to cope with and/or counter climate change. Le Loarne-Lemaire et al. (2021) state that involving more women in innovation processes contributes to an improved development and diffusion of these innovations; such involvement appears more relevant when it comes to the development of patents and applications that explicitly serve in the fight against climate change. However, to the best of our knowledge, research on the relationship between women's ownership (owner gender diversity – OGD), firm innovation and its radicalness, and firms' environmental orientation (EO) is very nascent.

Based on the above argument and limited number of studies focusing on this issue, this paper helps fill the gap in the literature pertaining to the link among OGD, energy management, and firms' innovation radicalness. The theoretical contribution is the creation of a multi-theoretical framework comprising insights from the upper echelons theory, open innovation theory, and theory on energy efficiency and management. In doing so, we contribute to the open innovation and energy efficiency and management literature by demonstrating how OGD aspects may change firms' propensity to create radical and incremental innovations and to introduce energy management. In addition, we confirm the positive effects of firms' energy management on both radical and incremental innovations and reveal the determinants of firms' introduction of energy

management. From the perspective of practical contributions, this study presents several suggestions for practical implications for public policy makers and companies. For example, to raise environmental awareness in Central and Eastern Europe and Southern Europe in various ways or to support firms' absorption capacity in creating both types of innovation, such as addressing "soft" R&D barriers. Moreover, compared to prior research that primarily analysed cross-sectional data and/or performed single-country studies, following Audretsch et al. (2020), we advance innovation research by using firm-level data and analysing 4,646 firms from 11 European countries using the World Bank's Enterprise Survey 2019.

The study is structured as follows. The next section covers the theoretical background and hypothesis development, followed by Section 3 presenting the methodology. In Section 4, the results are presented, while Section 5 discusses the results. The paper concludes with contributions and implications detailed in Section 6.

2 Theory and hypotheses development

2.1. Developing a multi-theoretical framework

This study contributes to the current state of knowledge by linking and combining the following theoretical frameworks: the upper echelons theory (UET), open innovation (OI) theory, and the theory of energy efficiency and management.

2.1.1 The upper echelons theory – adding OGD and EO perspectives

First, to link women's ownership, board representation, and firm performance, we build on the UET. Compared to other related theories that also deal with the role and composition of women on firm boards (e.g., agency theory, critical mass theory, social categorization theory), the UET provides a clear theoretical foundation for linking OGD and BGD with firm outcomes (Post & Byron, 2015; Wu et al., 2021). The advantage of the UET is that, despite the UET originally focusing on top management teams, previous research has gradually focused on various UET applications, such as comparing boards of directors with supra top management teams (Wu et al., 2021). Generally speaking, the UET points out the importance of considering top executives' demographic characteristics in understanding the strategic choices they make (Attah-Boakye et al., 2020), and emphasizes that homogeneous boards of directors are more likely to inhibit the critical evaluation of alternatives with negative effects on innovation (Torchia et al., 2011). In contrast, gender diversity could deliver several different perspectives that will lead to an increased search for information, enhanced quality of brainstorming activities, enhanced creativity, and new strategic alternatives triggering firms' innovation (Torchia et al., 2011).

Under the conditions of the UET, Nadeem et al. (2020a) state that prior research proved the effects of various board characteristics (e.g., BGD, CEO gender, CEO hubris) on firms' innovation and performance. However, in recent years, other extra tasks of framing firms' policies to satisfy the requirements of different stakeholders, including society and the environment, have emerged for top managers. According to Nadeem et al. (2020a), little attention has been paid to top management's characteristics and firms' environmental practices, which we generally refer to as firm EO. Following the preceding arguments, these authors confirm the relationship between BGD and environmental innovation on a sample of 10,334 U.S. listed firms between 2002 and 2018. However, the question of how OGD will be reflected in firms' EO, and innovation remains. Therefore, we bring a new perspective to this issue by

focusing on the role of OGD and put the UET under the umbrella together with the OI concept and with the theory focused on energy efficiency and management.

2.1.2 The open innovation theory – expanding into new research categories

Second, the OI concept is based on the creation of such models that enable firms to manage innovation by leveraging their R&D through the purposive inflows and outflows of new (innovative) knowledge and ideas, which are embodied in people and intellectual property (Hung & Chou, 2013). It could subsequently (i) accelerate internal innovation, and (ii) expand the markets for the external use of innovation (Cagno et al., 2015). Prior research has provided several determinants of firms' OI, including various forms of cooperation, such as the principles of triple-helix (Etzkowitz & Leydesdorff, 2000), quadruple-helix (Carayannis & Campbell, 2009), and quintuple-helix (Maruccia et al., 2020) cooperation as well as international cooperation (Chen et al., 2019), and co-opetition (Gnyawali & Park, 2011). Another string of studies pointed out the importance of R&D, both internal (Hung & Chou, 2013) and external (Hervas-Oliver et al., 2021), whereas the advantage of the OI model is that it allows the connection and integration of internal R&D with other innovation activities and innovation theories (Cagno et al., 2015). The role of the public sector and institutional environment were analysed and discussed by other authors, such as Tsinopoulos et al. (2018) and Leckel et al. (2020).

However, according to Bogers et al. (2017), there is still a call for expanding OI research into new research categories. Prokop et al. (2021) use the previously identified factors and extend OI research in terms of innovation radicalism in Europe. The authors show that European firms creating radical innovations (i) benefit from cooperation through various foreign channels, and (ii) use either internal or external R&D strategies, as the combinations of these strategies do not bring successful innovation outputs. However, the research is limited by relatively old data sources and the omission of other important factors, such as OGD (Audretsch et al., 2020). Therefore, we can state that the current state of knowledge is still limited by knowledge related to whether and how founders' characteristics (e.g., social, political, cultural) play a role in OI decision-making (Wyrwich et al., 2022). In this study, we contribute to the current research on OI by considering the demographic characteristics of top executives. To do so, we link the OI concept with the UET—concretely, with OGD. Moreover, we add the perspective of firms' EO (including energy management practices) and its determinants.

2.1.3 The theory of energy efficiency and management – finding the nexus among theories

Third, this study also contributes to the research on energy efficiency and management, which lacks a unified, comprehensive theoretical framework. To provide a clearer picture of these firms' environmentally friendly practices (EO), we will examine the determinants of firms' adoption of energy management measures and, consequently, we will reveal its role in the processes of innovation creation (with an emphasis on OGD).

From one perspective, prior research has already confirmed several determinants of firms' EO. For example, Gunawan et al. (2020) point out an important role of value drivers that could include personal, ecological, economic, social, and family values. Horbach et al. (2012) distinguish among four groups of drivers of firms' EO and eco-innovation: firm-specific factors, technology (push) factors, market (pull) factors, and regulations. Hojnik and Ruzzier

(2016) present a more comprehensive picture of the emerging literature on the theoretical frameworks and drivers of firms' EO and eco-innovation.

However, from another perspective, prior research has also confirmed that differences exist in drivers of firms' EO between female and male entrepreneurs (Gunawan et al., 2020), whereas the literature on the drivers of EO and eco-innovation has not yet considered the effects of the personal characteristics (including gender diversity) of firms' employees and decision-makers (Horbach & Jacob, 2018). This creates an important research gap and call for current research. Therefore, we link the previously described ever-evolving theory with the UET and analyse (i) the effects of OGD (please note, in this study, we perceive OGD when there is 50% or more women's ownership in the firm) on firms' adoption of measures of energy management, and (ii) the determinants of firms' adoption of energy management measures.

Moreover, to connect these theoretical frameworks, we refer to the study of Prokop et al. (2022). The authors confirm the reverse relationship between firms' EO and product innovation activities and point out the significant role of firms' monitoring of energy consumption, leading to firms' increased chance to create product innovation on the sample of 3,299 firms from countries in Central and Eastern Europe. We will develop this research in our study and examine the influence of radical and incremental innovations on firms' adoption of measures of energy management (with an emphasis on OGD) as well as the influence of firms' EO on the creation of radical and incremental innovations.

2.2 Hypotheses development: Effects of OGD and OI on energy management

2.2.1 OGD and energy management

Up-to-date findings show that top managers' experience and female ownership, together with exporting status and R&D, enhance energy efficiency (Macharia et al., 2022). More specifically, according to Macharia et al. (2022), female ownership positively influences electricity efficiency in the food sub-sector; fuel efficiency in the chemicals, pharmaceuticals, plastics, and food sub-sectors; and total energy in the chemicals, pharmaceuticals, and plastics sub-sectors. In addition, Atif et al. (2021) explore the influence of BGD on renewable energy consumption. The authors find that BGD and renewable energy consumption are positively associated. Umaerus et al. (2019) examine the differences between male and female owners regarding production values and ecological values as well as, to some extent, cultural values. They find significant differences—namely, women “think greener” than men. Likewise, McGuinness et al. (2017) find that, when a female officer is present at the CEO and/or vice-CEO levels, firms have stronger corporate social responsibility performance.

However, to the best of our knowledge, a link is missing between OGD and energy management. At this point, we refer to the study of Cordeiro et al. (2020), which state that prior research analysed the influence of BGD and ownership structure on firms' environmental performance separately and conclude that the diversity of a board is primarily affected by a firm's ownership configuration. The authors show interactions between BGD and different ownership types and their influence on corporate environmental performance in the case of 2,755 U.S. firms over the 2010–2015 period. In contrast, in our paper, we aim to identify the effects of OGD on energy management. More concretely, since it has been confirmed that women think greener and that BGD has positive effects on corporate EO, we expect this green

thinking also to be reflected in the ownership structure, and we therefore propose the following hypothesis:

H1: OGD (represented by at least 50% of owners being females) increases the chance of firms introducing energy management.

2.2.2 Innovation and energy management

In recent years, there has been a growing interest in the role of R&D and innovation in energy efficiency (Costa-Campi et al., 2015). However, the interaction between product innovation and companies' activities to improve production facilities' energy efficiency has received relatively little research attention; nevertheless, it is of great relevance to society and companies given the grand challenges like climate change, green innovation technologies, and environmental problems in general (Gerstlberger et al., 2014).

Giving some example of current research, Costa-Campi et al. (2015) explore the extent to which innovative Spanish companies pursue improvements in energy efficiency as an objective of innovation. Their results pinpoint that investment in tangible assets has a direct relationship with a commitment to energy efficiency whereas investments in R&D do not affect the firm's capacity to improve its energy efficiency. In addition, Costa-Campi et al. (2015) find that environmental and energy efficiency objectives complement each other and highlight the importance of organizational innovations as a key factor related to energy efficiency improvements. By contrast, Gerstlberger et al. (2014) find that market attention is important for the development of new products, while the green aspects of innovation and efficiency considerations are important for production companies aiming to improve their energy efficiency. Combining these models, the results highlight that energy efficiency moderates the effect of market attention on new product development.

In addition, Cagno et al. (2015) examine the relationship between innovation practices and energy efficiency and find a positive association between innovation and energy efficiency. The results further reveal that companies that complement internal R&D with inbound OI practices have a higher level of energy efficiency and a lower perception of barriers to efficiency improvements. Moreover, Subtil Lacerda and van den Bergh (2020) focus on the renewable energy sector and find that, for technology fields characterised by low technological turbulence and focused on incremental innovation, incentives to broaden knowledge sources (i.e., enhancing breadth) can be an effective means of improving innovative output whereas, for the high technological turbulence and more radical innovation, strengthening ties among a reduced number of diverse actors (depth) is likely to be more effective in fostering innovation.

Following above argumentation lines, we can see that there is a significant relationship between corporate innovative behaviour and especially energy efficiency. Therefore, to contribute to the current state of respective knowledge and to help to fill the gap in the research on energy management, we focus on the effects of firm's innovation on energy management. Here, we expect to find a positive relationship between firms' innovation outputs (radical and incremental) and energy management. Thus, we hypothesize that:

H2: Innovating significantly increases firms' introduction of energy management.

In addition, considering that both radical and incremental innovations are influenced by different factors (see, e.g., Prokop et al., 2021), we also examine whether a difference exists in

the influence of radical and incremental innovations on the firm's implementation of energy management, leading to the following research question:

RQ1: Does the introduction of radical and incremental innovations affect the implementation of energy management in different ways?

2.3 Hypotheses development: Effects of OGD and energy management on OI

2.2.3 OGD and innovation

Regarding the role of women within innovation processes, Le Loarne-Lemaire et al. (2021) conclude that more women within the technological innovation process promise greater productivity and better results. Under the conditions of the UET, prior research has confirmed that the presence of female executives could lead to an increase of knowledge heterogeneity, decreases of internal conflicts, and the inclusion of different ideas that could act as triggers of firms' innovation (Fu et al., 2020). For example, Chen et al. (2018) show that firms' female board representation leads to higher innovative success and point out that firms with female directors are more willing to invest more in innovation. Horbach and Jacob (2018) confirm that gender diversity in management boards is positively correlated with innovation outputs in the environmental sector in Germany. Liao et al. (2019) show that increasing the proportion of female directors on a board of directors leads to an increased level of the firm's environmental innovation. However, as Amoroso and Audretsch (2020) and Audretsch et al. (2020) suggest, the different roles of male and female ownership within innovation processes are a missing piece of evidence.

From the limited research on women's ownership and firm innovation, Fu et al. (2020) point out that female ownership could strengthen the relationship between (i) executives' experience and process innovations, and (ii) employees' average educational level and product and process innovations. Audretsch et al. (2020) show that women-led firms are less innovative than their counterparts, specifically in countries where fiscal freedom is weaker. However, both studies use only one variable to measure firms' product innovation. Furthermore, Fu et al. (2020) state that their study is limited because they use a 0–1 scale for women's ownership. To overcome the limitations of previous studies and contribute to the current state of knowledge, we bring new categories of innovation to this issue—namely, radical and incremental innovation; at the same time, we do not measure women's ownership on the 0–1 scale but use our own indicator of women's ownership accounting for 50% or more of a board.

The arguments mentioned above, which show that women are important players in the creation of innovations, lead us to assume that the same situation will be in the case of OGD. Therefore, we expect a positive relationship between OGD and firm innovations (both radical and incremental) and posit the following hypothesis:

H3: OGD (represented by at least 50% of firm owners being female) increases the chance of reaching firm innovation.

2.2.4 Energy management and innovation

In addition, we can find support for the relationship between firms' EO and innovation activities in the international literature (for example, Jakobsen & Clausen, 2016; Shu et al., 2016). Therefore, following the research conducted by Prokop et al. (2022) that confirm the reverse relationship between firms' EO and product innovation in Central and Eastern European

countries, we also test the reverse relationship between energy management and firms' innovation, both radical and incremental, and hypothesize that:

H4: Energy management increases firms' introduction of innovations.

We also aim to determine whether differences exist in the effects of energy management on firms' innovations due to their radicality. Therefore, we define the following research question:

RQ2: Does energy management affect the implementation of radical and incremental innovations in different ways?

3 Methodology

3.1 Models description

For the purpose of this study, we create three research models, which differ in the explained (dependent) variables. These models are as follows:

- **Model 1 (M1):** the firm's *adoption of measures of energy management* is the output variable.
- **Model 2R (M2R; R stands for radical innovation):** operates with firms' *creation of radical innovation* as the output variable.
- **Model 2I (M2I; I stands for incremental innovation):** analyses firms' *creation of incremental innovation* as the output variable.

As the explained (dependent) variables are dichotomous (binary; 1 indicates the answer is yes, 0 indicates the answer is no) for all estimated models, a binary logistic regression is used. The general form of the binary logistic model is:

$$\ln \frac{\pi_i}{1 - \pi_i} = \beta_0 + \sum_{j=1}^p \beta_j x_{ij}. \quad (1)$$

The expression on the left side of Eq. (1) is often called logit, and $\pi_i = \text{Prob}[Y_i = 1 | \mathbf{x}_i]$ denotes the probability that, for the i -th individual and given values of explanatory variables X_1, \dots, X_p , the explained variable Y is equal to 1. According to Eq. (1) the probability π_i has the expression:

$$\pi_i = \frac{\exp(\beta_0 + \sum_{j=1}^p \beta_j x_{ij})}{1 + \exp(\beta_0 + \sum_{j=1}^p \beta_j x_{ij})}. \quad (2)$$

An odds ratio OR is used to interpret the influence of the k -th explanatory variable X_k on a dependent variable Y and is given by:

$$OR = \frac{\left(\frac{\text{Prob}[Y = 1 | X_k = 1, X_1, \dots, X_{k-1}, X_{k+1}, \dots, X_p]}{\text{Prob}[Y = 0 | X_k = 1, X_1, \dots, X_{k-1}, X_{k+1}, \dots, X_p]} \right)}{\left(\frac{\text{Prob}[Y = 1 | X_k = 0, X_1, \dots, X_{k-1}, X_{k+1}, \dots, X_p]}{\text{Prob}[Y = 0 | X_k = 0, X_1, \dots, X_{k-1}, X_{k+1}, \dots, X_p]} \right)} = \exp(\beta_k). \quad (3)$$

In this case, we assume that the explanatory variable X_k is dichotomous while the other $p - 1$ explanatory variables may or may not be dichotomous. Therefore, the value of $\exp(\hat{\beta}_k)$ is the estimated odds ratio \widehat{OR} between Y and X_k when the values of the other $p - 1$ explanatory

variables are fixed. Details concerning the logistic regression model and its applications can be found in, for example, Hosmer & Lemeshow, (2000).

3.2 Data sources and research sample

As a data source, the World Bank's Enterprise Survey (WBES) 2019 is applied. WBES is an international firm-level survey with a representative sample of an economy's private sector, which includes various topics focused on the business environment and provides data on enterprises in the manufacturing and service sectors. WBES also contains the green economy module that provides information on environment-related aspects, management and the environment, environmental policy and regulation, and the environmental impact of the establishment.

WBES uses a global methodology, including standardized survey instruments and a uniform sampling methodology (stratified random sampling). The interviews are conducted in formal (registered) firms with five or more employees, and the respondents are business owners and top managers. Firms' accountants and human resource managers can also participate in the respective interviews to better answer selected questions in the sales and labour sections of the survey (for more detailed information about WBES, please visit www.enterprisesurveys.org/en/methodology).

Our research sample includes 4,646 firms from 11 European countries (Italy, Portugal, Slovenia, Czech Republic, Estonia, Latvia, Lithuania, Slovakia, Cyprus, Poland, and Bulgaria). Unlike previous studies (e.g., Torchia et al., 2011; Liao et al., 2019) that analyse selected single countries and are thus potentially limited by the lower ability to generalize the results, this study uses an aggregated data set of all 11 European countries to overcome such limitations. This designation allows us to subsequently propose practical implications that could be applicable across selected (and other) European countries. More specifically, we analyse countries from Central and Eastern Europe and from Southern Europe. Concerning innovation performance and environmental behaviour, several common features can be observed in these countries.

In terms of innovation performance, most of these countries fall below the average performance of EU Member States' innovation systems measured by the Innovation Performance Scoreboard developed by the European Commission. Therefore, although some of these countries (primarily countries in Central and Eastern Europe) have in the past struggled with inadequate infrastructure, insufficient funding, and a lower level of development of innovation systems, these countries are expected to have the greatest development innovation potential (Benetyte & Krusinskas, 2019).

According to Horbach (2016), Tokunaga (2016), and Prokop et al. (2022), several so-called Eastern bloc countries were perceived (i) to have lower environmental awareness in society and (ii) to be responsible for environmental degradation and pollution. Such perceptions have emphasized the need for a quality, effective, and targeted regulatory function of the state. In line with the Porter hypothesis (Porter & Van der Linde, 1995), these (properly designed) environmental regulations should subsequently spur firms' R&D and innovations. However, this assumption is not confirmed by, for example, (i) Hojnik et al.'s (2022) study of the Czech Republic and Slovenia or (ii) Prause and Olaniyi's (2017) study of the Estonian oil shale industry, which show that environmental regulations push some sectors into strategic traps

(because of the growing portfolio change requirements) and lead to increased restructuring costs.

Bringing these ideas together, we see the need for further research in a selected sample of countries leading to the design of implications that would help overcome the identified problems and barriers.

3.3 Description of variables

All variables that we use in this study are shown in Table 1. Variables pertaining to energy management, radical innovation, and incremental innovation are used as both input and output variables in the different models.

The most important explanatory independent variables, which should help address the research hypotheses and research questions, are gender diversity of the firm owners (marked as OGD) and the type of product innovations (labelled as Innovation). In line with prior studies (see Audretsch et al., 2020; Fu et al., 2020), OGD includes two categories: owned by men and owned by women. However, unlike the studies of Fu et al. (2020) and Audretsch et al. (2020), which use a 0–1 scale for men’s and women’s ownership, we work with percentages and divide this variable into two groups: 1 = owned by men (100% male ownership) and 0 = owned by women (at least 50% of owners are female). The Innovation variable contains three categories: Radical, Incremental, and Non-innovations.

Table 1 Description of input variables

Group	Variable	Description	Categories
Output (M1); Input (M2R; M2I)	Energy management	Adoption of measures of energy management.	1 = yes; 0 = no
Input (M1); Output (M2R)	Radical innovation	During the last three years, this establishment introduced new or improved products or services that were new for the establishment’s main market.	1 = yes; 0 = no
Input (M1); Output (M2I)	Incremental innovation	During the last three years, this establishment introduced new or improved products or services that were not new for the establishment’s main market.	1 = yes; 0 = no
Input – OGD	Owned gender diversity (OGD)	We distinguish between firms that are 100% owned by men and firms where females own 50% or more.	1 = male owned; 0 = at least 50% female owned
Inputs – Value drivers	Environmental objectives	In fiscal year, this firm has strategic objectives that mention environmental or climate change issues.	1 = yes; 0 = no
	Environmental manager	In fiscal year, this establishment has a manager responsible for environmental and climate change issues.	1 = yes; 0 = no
	Monitoring energy consumption	Over the last three years, this establishment has monitored its energy consumption.	1 = yes; 0 = no
	Targets for energy consumption	Over the last three years, this establishment has set targets for energy consumption.	1 = yes; 0 = no
Inputs – Market pressure (customers’ voice)	Customers’ environmental requirements	In a fiscal year, any of the establishment’s customers require environmental certifications or adherence to certain environmental standards as a condition to do business with this establishment.	1 = yes; 0 = no
Inputs – Policy and regulations	Free emission allowances	In a fiscal year, this establishment receives free emission allowances.	1 = yes; 0 = no

	Energy tax or levy	In a fiscal year, this establishment is subject to an energy tax or levy.	1 = yes; 0 = no
Inputs – OI instruments	Foreign technology	This establishment presently uses technology licensed from a foreign-owned company, excluding office software.	1 = yes; 0 = no
	External knowledge acquisition	Over the last three years, this establishment has spent money on the acquisition of external knowledge. This includes the purchase or licensing of patented and non-patented inventions, know-how, and other types of knowledge from other businesses or organizations.	1 = yes; 0 = no
	Internal R&D	Over the last three years, this establishment has spent money on research and development activities within the establishment.	1 = yes; 0 = no
Controls	Sector	We controlled firms according to the sector in which they operate.	manufacturing; other; retail
	Firm age	We controlled firms according to their age.	0–9; 10–19; 20–29; > 29
	Competition	We controlled firms according to the competition they face.	local; international; national
	Country group	We controlled firms according to the country group. Countries were divided into two groups according to their eco-innovation performance measured by the European Commission, where AVE = Average Eco-I performers (Italy, Portugal, Slovenia, Czech Republic, Estonia, Latvia) and Catch = countries catching up with Eco-I (Lithuania, Slovakia, Cyprus, Poland, Bulgaria)	AVE; Catch

In addition to these main variables, we identify four groups of variables based on the literature review (in line with the data provided by WBES), which represent the potential determinants of our output variables: value drivers (Gunawan et al., 2020) expressing the firm’s commitment to environmental behaviour (e.g., by setting environmental targets), market pressure (Horbach et al., 2012) expressed by customers’ voice for firms’ environmental behaviour, environmental policy and regulations (Rennings, 2000), and OI instruments allowing the flow of internal and external (foreign) knowledge (Cagno et al., 2015; Subtil Lacerda & van den Bergh, 2020; Prokop et al., 2021). These are binary variables (1 indicates the answer is yes, 0 indicates the answer is no).

Table 2 Relative frequencies of control variables

Firm age (in years)	Rel. freq. (in %)	Sector	Rel. freq. (in %)	Competition	Rel. freq. (in %)	Eco-innov. index	Rel. freq. (in %)
0-9	17.05%	Manuf.	56.13%	international	17.74%	Ave	54.43%
10-19	30.84%	Other	27.14%	local	35.75%	Catch	45.57%
20-29	34.59%	Retail	16.72%	national	46.51%		
> 29	17.52%						

We also include control variables representing the firm’s age (Sidorkin, 2015), industry sector (Banerjee et al., 2003), and competition (Blomström et al., 1994). Moreover, we create a country group control variable, which we use to divide countries into two groups according to their eco-innovation performance measured by the European Commission (for more details, please see https://ec.europa.eu/environment/ecoap/indicators/index_es), where AVE = Average

eco-innovation performers (Italy, Portugal, Slovenia, Czech Republic, Estonia, Latvia) and Catch = countries catching up with eco-innovation (Lithuania, Slovakia, Cyprus, Poland, Bulgaria). The relative frequencies of control variables are shown in Table 2.

Because all explanatory variables are categorical (factors), each parameter in Eq. (1) and Eq. (2) (see Section 3.1) is represented by q-1 estimated parameters, where q means the number of categories (levels) of corresponding explanatory variables. In this case, it is necessary to specify the reference category of each variable. The OGD variable is the reference category Owned by women; the Innovation variable is set to Radical. For binary variables (see Table 1), the reference category is set to 0, which means that the answer to the corresponding question was no. For control variables, the reference categories are manufacturing, less than 10 years, local and AVE.

4 Results

In the following sub-Sections 4.1 and 4.2, we present the results of our empirical analyses, which are then discussed and confronted with previous research in a separate Section 5.

4.1 Effects of OGD and OI on energy management

In Model 1 (see Table 3), we show the effects of OGD and different types of firms' innovations (radical and incremental) on firms' adoption of measures of energy management. In addition, we reveal the influence of different groups of determinants on the selected output. Estimated regression coefficients, odds ratios, and corresponding p-values of Model 1 are presented in Table 3.

The OGD results are significant (at the 0.05 level of significance) and show a slightly higher chance of achieving output (adoption of measures of energy management) in firms owned by men than in female-owned firms (at least 50% of owners are female).

Table 3 Results of Model 1 indicating the effects of OGD and OI on energy management

Model 1					
Dependent: Energy management					
Independent variable name	Code	Level	Coeff.	OR	P-value
Intercept			-2.54465	0.078501	< 2e-16***
<i>OGD (ref: female)</i>		Male	0.19248	1.212253	0.04654*
<i>Innovation (ref: radical)</i>	h2.n20	Incremental	-0.08502	0.918492	0.57051
	h2.n22	No innov.	-0.28711	0.750429	0.00753**
Env. objectives	BMGA.1	1	0.66240	1.939448	1.55e-09***
Env. manager	BMGA.2	1	0.26948	1.309289	0.04354*
Monitor its energy cons.	BMGC.1	1	1.12165	3.069901	< 2e-16***
Targets for energy cons.	BMGC.16	1	1.19415	3.300749	< 2e-16***
Customers' env. requirements	BMGA.4	1	0.49654	1.643030	2.08e-05***
Free emission allowances	BMGD.6	1	-0.27928	0.756325	0.00527**
Energy tax or levy	BMGD.7	1	0.87711	2.403944	3.59e-13***
Foreign technology	E.6	1	0.05031	1.051593	0.65406
External knowledge acquisition	BMh.1	1	0.20359	1.225792	0.10850
Internal R&D	BMh.2	1	0.20607	1.228841	0.07428†
Controls					
Sector (ref: manuf)	A0	Other	-0.41122	0.662844	5.72e-05***
		Retail	-0.36383	0.695009	0.00446**
Firm age (ref: 0-9)	B5	10-19	-0.25455	0.775265	0.04512*
		20-29	-0.21337	0.807855	0.08193†
		> 29	0.18628	1.204759	0.18266
Competition (ref: local)	E.1	Intern.	0.07642	1.079411	0.55244
		Nation	0.13175	1.140827	0.17888
Eco-innov. index (ref: AVE)	Country	Catch	-0.02512	0.975195	0.77083

Significant at: *** 0.001; ** 0.01; * 0.05; † 0.1

Regarding the effect of innovation, the results show that the radical innovations significantly increase the chance to adopt energy management measures compared to the case of no innovations. In contrast, introducing the incremental innovations does not bring a significant increase of that chance.

Concerning the effects of the described groups of determinants, we can state that monitoring energy consumption and targets for energy consumption (representing the group of value drivers) significantly increase the chance to adopt energy management measures. We also find significant effects of customers' environmental requirements (market pressure) and environmental policy regulations. On the other hand, most determinants representing OI instruments are not significant. These are foreign technologies and external knowledge acquisition. Only internal R&D is slightly significant. We also found significant effects of some control variables (i.e., sector and firm age).

4.2 Effects of OGD and energy management on OI

The results in Table 4 show that firms owned by men have significantly fewer chances to introduce innovation (similar for both types of innovation, radical and incremental). These results indicate that OGD significantly contributes to the creation of both radical and incremental innovation. Similar to OGD, energy management significantly influences the creation of both radical and incremental innovation.

Table 4 Results of Models 2R and 2I indicating the effects of OGD and energy management on OI

	Level	Model 2R: Radical Innovations			Model 2I: Incremental Innovations		
		Coeff.	OR	P-value	Coeff.	OR	P-value
Intercept		-2.40048	0.090674	< 2e-16***	-2.37775	0.092759	< 2e-16***
OGD (ref. Female)	Male	-0.24878	0.779753	0.01086*	-0.25339	0.776166	0.033904*
Energy management		0.24614	1.279077	0.01929*	0.23459	1.264395	0.075413†
Env. objectives	1	0.04016	1.040976	0.74439	-0.18602	0.830256	0.255731
Env. manager	1	-0.18272	0.832998	0.20494	0.03249	1.033027	0.863633
Monitor its energy cons.	1	0.47468	1.607501	4.81e-06***	0.69682	2.007355	4.37e-08***
Targets for energy cons.	1	0.18971	1.208896	0.07724†	0.15260	1.164862	0.256711
Customers' env. requirements	1	-0.06577	0.936346	0.60508	-0.31526	0.729601	0.068888†
Free emission allowances	1	0.18653	1.205063	0.06426†	0.41516	1.514616	0.000674***
Energy tax or levy	1	-0.05169	0.949621	0.69656	-0.08366	0.919748	0.624247
Foreign technology	1	0.31663	1.372492	0.00422**	-0.16245	0.850061	0.298347
External knowledge acquisition	1	0.76512	2.149246	3.73e-11***	0.86019	2.363604	1.73e-08***
Internal R&D	1	1.33013	3.781529	< 2e-16***	0.71876	2.051896	2.09e-06***
Controls							
Sector (ref: manuf)	Other	-0.06774	0.934501	0.52770	-0.11006	0.895777	0.398636
	Retail	0.05141	1.052756	0.69094	-0.16431	0.848480	0.308863
Firm age (ref: 0-9)	10-19	-0.09012	0.913818	0.50115	-0.25807	0.772541	0.098318†
	20-29	0.10590	1.111710	0.40818	-0.15582	0.855711	0.301554
	> 29	0.15101	1.163010	0.30433	-0.34900	0.705394	0.056134†
Competition (ref: local)	Intern.	-0.19387	0.823765	0.16277	-0.01742	0.982729	0.915684
	Nation	0.08745	1.091392	0.39376	-0.13629	0.872593	0.277762
Eco-innov. index (ref: AVE)	Catch	0.10944	1.115658	0.22576	0.26232	1.299949	0.018497*

Significant at: *** 0.001; ** 0.01; * 0.05; † 0.1

Concerning the effects of different groups of determinants on firms' innovation, most explanatory variables are insignificant (except monitoring of energy consumption and energy tax or levy). However, surprisingly, customers' requirements for environmental behaviour have a significant influence, but only on incremental innovation.

Regarding the effect of OI instruments on firms' radical and incremental innovations, the results show significant effects. The results point to the important role of foreign technologies in the creation of radical innovations.

5 Discussion of results and Hypothesis analysis

5.1 Effects of OGD and OI on energy management

5.1.1 Hypothesis 1

We reject H1—*OGD (represented by at least 50% of owners being females) increases the chance of firms introducing energy management*—based on the obtained results. Considering the gender diversity factor, our results show that a higher chance of introducing energy management occurs in firms owned 100% by men. Surprisingly, these findings go against the majority of prior studies reviewed that focused on the role of female ownership (Macharia et al., 2022) and the role of women on firms' boards (Torchia et al., 2011; Atif et al., 2021). We can agree with Umaerus et al.'s (2019) results, which state that significant differences exist between male and female owners in terms of, among others, ecological values. However, unlike Umaerus et al. (2019), we cannot confirm that, in the case of energy management, women “think greener” than men based on our sample of firms from Central and Eastern Europe and Southern Europe.

One possible explanation for these results is the fact that our sample consists of countries that currently face barriers from the past, such as lower innovation performance, lower levels of trust among cooperating actors, and lower environmental perceptions. Compared to countries in Western and Northern Europe (for example, Norway, Sweden, Finland, and Germany), where legal frameworks to promote gender diversity in firms already exist (Buerthey, 2021), our analysed countries (primarily countries from Central and Eastern Europe) may be lagging behind. Therefore, we could expect that changes in firms that lead to greater gender diversity may not lead to the positive effects that gender diversity brings to firms in more developed countries. Referring to Triana et al. (2014), in firms with low performance, gender diversity could cause conflict and impede decision-making and team productivity, thereby negatively influencing firms' ability to make strategic changes. In addition, Dwyer et al. (2003) state that it is more difficult and costly to coordinate and control diverse top management teams compared to homogenous teams. This can lead to increased costs that exceed the firm's performance. Moreover, gender differences in the field of ethics, including EO, could also diminish in some cases, for example, when women and men work under similar working conditions (Nadeem, 2021). Summing above arguments, we add that, if firms in these countries lag behind or face pressures on gender diversity, it may not lead to effects that would affect the introduction of energy management.

5.1.2 Hypothesis 2 and Research Question 1

Regarding the second hypothesis postulating that *innovating significantly increases firms' introduction of energy management*, we can only partially confirm it. Our results empirically confirm the importance of radical innovations for the implementation of energy management, in contrast to incremental innovations, which do not contribute to increasing the chances of implementing energy management in analysed firms. Because these are new results and, to the best of our knowledge, previous studies have not examined the separate effects of radical and incremental innovations on firm energy management, we can find empirical support for our

results only in studies that have examined the relationship between energy efficiency and management and product innovation in general. These are Gerstlberger et al. (2014), Costa-Campi et al. (2015), and Cagno et al. (2015). In addition, in line with Cagno et al. (2015), we also confirm an important role of internal R&D (but not the role of external sources).

These results lead to an answer for the first research question: *Does the introduction of radical and incremental innovations affect the implementation of energy management in different ways?* Based on the results summarized in Table 3, radical innovations affect the implementation of energy management in our study in a different way than incremental innovations. More specifically, we show that radical innovations significantly increase firms' introduction of energy management while incremental innovation does not.

5.1.3 Discussing other important results

Our results also reveal other important determinants of firms' introduction of energy management and confirm, similar to Gunawan et al.'s (2020) results, the key role of firms' value drivers in expressing their commitment to EO in countries in Central and Eastern Europe and Southern Europe. More concretely, we confirm the positive effects of strategic objectives that mention environmental or climate change issues, the presence of a manager responsible for environmental and climate change issues in the firm, the monitoring of energy consumption, and targets for energy consumption on a firm's introduction of energy management. In addition, the effects of market pressure that we expressed by customers' requirements for (i) environmental certifications or (ii) adherence to certain environmental standards as a condition to do business with the establishment are confirmed to be significant. The importance of external market pressures within our selected countries is in line with the statements of Prokop et al. (2022), who point out the historically rooted lower awareness of environmental problems in Central and Eastern Europe, which results in the need for external intervention in firms' behaviour in these countries.

From the perspective of the effects of environmental regulations on the introduction of energy management, the results are significant but mixed. On one side, free emission allowances have a negative effect on the introduction of energy management. These results are consistent with the claim of Fang et al. (2019), who conclude that the incumbent EU Emission Trading System style solutions for free emission allowance allocation are imperfect. It is because, for example, the grandfathering approach distributing the initial allowances based on the historical emissions primarily attracts emitters but repels new entrants or those already operating in an energy-efficient manner (Fang et al., 2019). In contrast, we show the positive effects of an energy tax or levy on firms' introduction of energy management, whereas Lee (2015) points out an important role of energy taxes (as part of the economic factors) in enhancing energy management practices in the case of Korea. Moreover, the author states that energy tax, cost savings, owner's demand, and top management commitments represent key triggers of energy efficiency within organizations.

If we consider other control variables, the results indicate that firms' age significantly influences the introduction of energy management. Newer firms (0–9 years) and the oldest firms (over 29 years) have the highest chance of introducing energy management compared to firms of other ages (i.e., 10–29 years). We also reveal that the highest chance of introducing energy management is in the manufacturing sector, which makes sense, as the energy consumption is higher in that sector.

5.2 Effects of OGD and energy management on OI

5.2.1 Hypothesis 3

The results summarized in Table 4 (Section 4.2) allow us to accept the third hypothesis that *OGD (represented by at least 50% of owners being females) increases the chance to reach firm innovation*. These results are consistent for both radical and incremental innovations and are in line with international literature focused primarily on BGD and its effects on firms' innovation (Horbach & Jacob, 2018; Le Loarne-Lemaire et al., 2021). We confirm that gender diversity leads to a greater chance to reach innovative outputs (Chen et al., 2018) in the sample of firms from Central and Eastern Europe and Southern Europe; at the same time, we help find a missing piece of evidence on the role of male and female ownership within innovation processes, which is required by prior research (see Amoroso & Audretsch, 2020; Audretsch et al., 2020).

Considering women's ownership and firm innovation, our empirical findings confirm the important role of OGD in the process of innovation creation, similar to Fu et al.'s (2020) findings that female ownership could be an important factor in strengthening the relationship between executives' experience and process innovations or between employees' average educational level and product and process innovations. Furthermore, the importance of female owners in the process of innovation creation is confirmed by Iman et al. (2022) in a sample of 11,617 private firms in post-Communist economies, including firms in Eastern Europe. The authors state that female owners are more likely than male owners to introduce new marketing strategies and that firm innovation increases among top female managers with the increase in democratization. Meanwhile, our results contradict those of Audretsch et al. (2020), who show that women-led firms are less innovative than their counterparts.

Summing up the role of OGD and its effects on our dependent variables, our results suggest that, in the firms we analysed, OGD is important for creating radical and incremental innovations, but not for implementing energy management (as discussed in Section 5.1).

5.2.2 Hypothesis 4 and Research Question 2

Regarding the fourth hypothesis that *energy management increases firms' introduction of innovations*, our results are consistent and, thus, we can confirm H4. This finding supports the results of Prokop et al. (2022), which empirically prove a reverse relationship between firms' EO and product innovation in Central and Eastern European countries. This reverse relationship is also confirmed in the case of Norwegian firms by Jakobsen and Clausen (2016), who demonstrate both direct and indirect effects of firms' EO on the innovation process. In addition, Shu et al. (2016) explore whether green management is more likely to lead to radical product innovation, compared to incremental product innovation, in firms operating in China. These findings lead us to answer our second research question: *Does energy management affect the implementation of radical and incremental innovations in different ways?* Our results show that the effects of energy management implementation on radical and incremental innovations are the same—namely, positive and significant. Our results also show the importance of firms' monitoring of energy consumption as a significant determinant of both radical and incremental innovations.

5.2.3 Discussing other important results

When looking at other determinants of firms' radical and incremental innovations, we note an important role of both internal and external sources forming OI instruments. Specifically, we confirm that internal R&D and external knowledge acquisition have significant effects on the creation of radical, as well as incremental, innovations. These results support the traditional definition of the OI concept as previously described (Cagno et al., 2015; Chesbrough, 2017). The importance of internal R&D for radical and incremental innovation outputs are also confirmed by Prokop et al. (2021), who consider a sample of European firms using domestic and/or foreign innovation cooperation. The authors also confirm the key role of knowledge flows across various partners. These results are in line with Cassiman and Veugelers's (2006) finding that internal R&D and external knowledge acquisition are complementary. However, the authors point out that the degree of complementarity is also dependent on the other factors of firms' strategic environment. The importance of knowledge acquisition for firms' radical innovation is also confirmed by Xie et al. (2018) among 376 high-tech Chinese firms. The authors indicate that external knowledge acquisition could help firms identify and acquire valuable external know-how, expand (renew) their knowledge base and knowledge pool, and subsequently offer new products (radical innovations). Shi et al. (2020) also confirm the importance of external knowledge acquisition for incremental innovations.

The results further suggest the importance of foreign technologies for radical innovations. These results lead us to assume that there could be a complementary relationship among firms' internal R&D, external knowledge acquisition, and foreign technology in the process of radical innovations creation. Support for these arguments could be found in the studies of Parisi et al. (2006) and Hu et al. (2017). However, the importance of foreign technologies for incremental innovations is not shown.

When considering the traditional Porter hypothesis (Porter & Van der Linde, 1995) and the effects of environmental regulations on firms' innovation, the results are mixed. From one perspective, we confirm positive effects of free emission allowances on firms' creation of radical and incremental innovations. These effects are stronger in the case of incremental innovations. From another perspective, in line with Prause and Olaniyi (2017) and Hojnik et al. (2022), who do not confirm the Porter hypothesis in Central and Eastern European countries, we do not confirm the Porter hypothesis for the effects of energy tax or levy on firms' innovation. More specifically, the results are negative and insignificant.

If we consider other control variables, we can conclude that older firms (20 years and older) have a greater chance to create radical innovations whereas the greatest chance to create incremental innovations occurs in the youngest firms (0–9 years). No differences occur due to sector.

6 Conclusions

6.1 Theoretical contributions

Drawing on the UET, OI, and the theory of energy efficiency and management, this article offers three theoretical contributions as we prove the nexus among OGD, energy management, and firms' innovation radicalness.

From the perspective of the UET, compared to the prior research examining primarily the effects of various board characteristics, such as BGD, CEO gender, and CEO hubris, on firms' innovation and performance (Miller & del Carmen Triana, 2009; Nadeem et al., 2020a), the

first theoretical contribution of this study is finding the missing piece of evidence in the research examining the different effects of OGD within innovation processes (Amoroso & Audretsch, 2020; Audretsch et al., 2020). This paper helps explain how OGD is reflected in firms' EO and innovation. We empirically prove that, in countries in Central and Eastern Europe and Southern Europe, OGD matters in the processes of innovation creation, including both radical and incremental. However, firms' EO, expressed by the introduction of energy management, is not affected by OGD. These results create further impetus for examining the issue of gender diversity in firms' top positions (see Section 6.2). Moreover, compared to the results of Fu et al. (2020) and Audretsch et al. (2020), we develop a new way to measure OGD (not on a scale of 0–1) by working with percentages and dividing OGD into two groups: owned by men (100% male ownership) and owned by women (at least 50% female ownership).

Second, we contribute to the research on OI by addressing recent calls to (i) expand OI research into new research categories (Bogers et al., 2017) and (ii) develop a better understanding of the micro-foundations of OI (Wyrwich et al., 2022). In line with Prokop et al. (2021), we focus on the issue of radical and incremental innovation. However, we mostly highlighted the “catching-up” countries, most of which perform below the average of EU Member States' innovation systems and are seen as having a lower environmental awareness in society. We also consider OGD and the introduction of energy management as determinants of firms' radical and incremental innovations, empirically confirming the importance of the first determinant mentioned.

In addition, we reveal the effects of firms' environmental regulations on their radical and incremental innovations. We verify the validity of the Porter hypothesis. Our results confirm the double-edged role of environmental regulations in the creation of radical and incremental innovations in selected European countries and contribute to the ongoing discussion of the Porter hypothesis. More concretely, we demonstrate that free emission allowances have positive effects on firms' innovation outputs whereas an energy tax or levy has negative effects on firms' innovations.

For the third main theoretical contribution of this research, we address the literature gap related to the theory of energy efficiency and management. Our empirical results indicate that the countries analysed, which include Central and Eastern European countries (unlike previous studies that analysed selected single countries—a limitation our study overcame by using an aggregated data set of all 11 European countries) that have historically faced problems of lower environmental awareness in society (Prokop et al., 2022), are probably not yet able to profit from the benefits that gender diversity brings. Therefore, we reject the hypothesis expecting positive effects from OGD on firms' introduction of energy management. In contrast, we reveal several important determinants of firms' introduction of energy management. First, we demonstrate a link between radical innovations and the introduction of energy management, but no link between incremental innovation and the introduction of energy management. We also confirm the important role of firms' value drivers of EO (Gunawan et al., 2020), which we expressed by strategic objectives that mention environmental or climate change issues, the presence of managers responsible for environmental and climate change issues in the firm, the monitoring of energy consumption, and targets for energy consumption on firms' introduction of energy management. Similarly, we prove that market pressure in the form of customers' requirements for environmental certifications or adherence to certain environmental standards

is significant. However, we show environmental regulations' mixed effects on firms' introduction of energy management.

6.2 Managerial and political implications, future research, and limitations

As the results show, OGD has less of an effect on energy management than 100% male ownership. This finding is quite unexpected and raises an interesting question of why as these results contradict the benefits of gender diversity. In future research, we could test whether these results occur only in the countries we analysed. However, we suppose that energy management is a more male-dominated sector and, thus, we believe we should compare this in a larger sample with more control variables. In the future, we recommend examining other characteristics of owners, such as education and experience, age, and personal attitudes toward environmental issues. We also believe that it is crucial for future research to focus on whether gender conflict occurs among heterogeneous owners. In terms of practical implications for firms, to reduce conflicts among owners (or, for example, top managers) and, conversely, to build social capital among these actors, we recommend that they build and perpetuate networks through informal social gatherings and activities, such as board dinners, annual retreats, and golf outings (Groysberg & Bell, 2013).

Based on our results, we propose implications for regulators and policy makers, which may lack useful data that will allow them to design new sustainable industrial policies that could be harmonized within Central and Eastern Europe territory (Viesi et al., 2017). Acknowledging the implications for public policy makers, we recommend performing activities that will lead to raising environmental awareness, especially in Central and Eastern European countries. As Hopwood et al. (2021) indicate, it is important to focus on personal environmental concerns that could trigger individual actions, as individual actions could be a powerful tool in the fight against environmental pollution. Policy makers' actions could therefore take the form of financial incentives for the training of employees and top managers, seminars for the public, and the promotion of dialogues between different stakeholders and representatives of institutes supporting the shift towards a circular economy. Empirical support for these arguments can also be seen in the confirmed positive effects of firms' value drivers expressing their commitment to environmental behaviour on energy management. Therefore, we also recommend that firms support their environmental activities, such as setting strategic objectives that mention environmental or climate change issues, creating management positions responsible for environmental and climate change issues in the firm, monitoring energy consumption, and setting targets for energy consumption.

Legislation calling for a minimum percentage of female board directors, similar to legislation in, for example, Belgium, France, Iceland, and the Netherlands (Groysberg & Bell, 2013), could also find support in the analysed countries. More generally, public policy makers should support the reduction of inequalities between men and women in society. Gender Equality Strategy 2020–2025 is committed to achieving the union of equality (European Commission, 2022b). For example, in the Czech Republic, public policy makers have made the effort to reduce these inequalities through the framework of the Strategy for Equality between Women and Men between 2021 and 2030.

We see initiatives that arise in Europe as an important source of inspiration for the countries we analyse. For example, the European Commission aims to encourage and help women entrepreneurs by supporting several tools, networks, and initiatives providing opportunities

geared toward women entrepreneurs. Such initiatives include (European Commission, 2022a): (i) WEgate (a Europe-wide online platform that unites all initiatives supporting women's entrepreneurship into one platform dedicated to women entrepreneurs and their needs related to starting, financing, and managing their businesses); (ii) the Enterprise Europe Network (EEN, which offers a women's entrepreneurship group on Facebook that gathers 21 partner organisations in 14 countries, connects women entrepreneurs to the network's business and innovation support activities, and provides concrete services, such as business partnering, access to foreign markets, cooperation with local networks, and access to EU funding); (iii) business angels (four pilot projects covering 14 EU countries that ran until mid-2019, raising awareness of business angels, training women who wanted to become business angels, and helping women entrepreneurs present their business ideas to potential investors); and (iv) other finance opportunities (a gender-smart finance initiative under the InvestEU programme to stimulate funding for female-led companies and funds).

Firms also need to realize that increasing firms' environmental awareness and behaviours cannot be stimulated by only, for example, legislative steps of regulators and policy makers resulting instead in general environmental awareness because firms' EO could also lead to the other benefits that might arise from cost reductions from their environmentally friendly practices (Gadenne et al., 2009).

Considering the implications that could lead to increased innovation within analysed countries, consistent with our results and those of previous studies, we strongly recommend that firms support gender diversity, which has proven to be important in the creation of both radical innovations and incremental innovations. The same is true of the use of internal and external knowledge resources and R&D. For their better absorption, which can be problematic in Eastern European countries given the lower trust levels among cooperating actors, we recommend creating informal links among cooperating actors to promote social capital and mutual trust. As Wyrwich et al. (2022) indicate, policy makers need to address "soft" barriers to R&D and cooperate with external partners to promote firm- and regional-level development. The authors also state that, considering for example the negative historical experiences of company founders, public policies should support awareness campaigns and trust-facilitating networking, which could subsequently help firms (founders, managers, and employees) become more aware of and address personal biases that negatively affect firm-level decision-making.

As the age of firms has proven to be a significant factor influencing both energy management and the creation of radical and incremental innovations, for the future research, we recommend focusing more on different categories of firms according to their age, such as the behaviours, environmental innovations, and performance of start-ups that "*have been argued on theoretical grounds to be ideally suited to solving traditional market failures, increasing social welfare, and bringing about positive social change*" (Yang et al., 2020: 3). Yang et al. (2020) add that gender diversity could also play an important role as start-ups are often founded by teams, where co-founders' gender diversity and its influence on the behaviour and results of these firms can be assumed.

We are also aware that this study may be subject to limitations, which could be seen as possible directions for future research. We consider the use of secondary questionnaire data to be the main limitation of this research. Furthermore, most variables are binary, which limits the possibility of applying other advanced methods. On the other hand, this type of data enables us

to get a closer picture of a larger group of countries and, thus, propose more widely applicable recommendations for both companies and public policy makers. In addition, a professional survey data ensures the representativeness of the data and justifies the use of the applied statistical methods (Prokop et al., 2022). At the same time, the results obtained can serve as a stimulus for additional analyses, which will use the primary data applied in individual countries. Another limitation may be that we focus only on OGD without working with gender diversity at other levels in the firm. Therefore, we also recommend analysing gender diversity for different categories of workers. In light of the limitation regarding the method used, we also recommend that future research adopt a mixed-method approach.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

Czech Sciences Foundation, Grant/Award Number: 20-030375

Authorship

All authors have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; all authors have further been involved in drafting the manuscript or revising it critically for important intellectual content; all authors give their final approval of the version to be published, and each author have participated sufficiently in the work to take public responsibility for appropriate portions of the content; and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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