



An analysis of the influence of female directors on environmental innovation: When are women greener?

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ABSTRACT

This paper develops a unique analysis of the impact of board gender diversity on environmental innovation, considering diverse factors that determine the influence of female directors. To that end, different methodological approaches are employed, including panel data analysis and quantile regression. A number of robustness tests are also considered. Using a sample composed of the firms listed on the FTSE-250, our results highlight that the one-size-fits-all approach proves to be inappropriate to understand the role of female directors. Particularly, our findings confirm that board gender diversity positively impacts environmental innovation, but only when there are at least three women in the boardroom, and only for firms with greater levels of environmental innovation. Moreover, the effect of board gender diversity is strengthened in the presence of CSR committees, but weakened in boards with larger size and longer tenure. Given the ever-increasing importance of environmental innovation and the ongoing debates surrounding gender diversity, our evidence has direct implications for firms when selecting board members, for regulators and professionals when refining their legislation and recommendations, and for academics when defining theoretical frameworks and methodological approaches.

1. Introduction

In light of the growing awareness of climate change and environmental degradation, environmental innovation has become crucial vis-à-vis minimizing firms' environmental problems and addressing consumer and government concerns, as well as increasing economic outcomes through the efficient use of resources (Horbach and Jacob, 2018). Environmental innovation is a key issue for international bodies and public representatives, including the OECD and the European Commission,¹ among others, and it is one of the targets of the United Nations' (UN) 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDG).² Accordingly, governments around the world have increasingly introduced new regulations and public incentives to promote environmental innovations (Aldieri et al., 2019). In this regard, the need for environmental innovation, as well as its economic and environmental benefits, has been widely acknowledged (García-Granero et al., 2018).

Therefore, the identification of the influencing factors of

environmental innovation remains a research question of great significance with direct professional and policy implications. Corporate governance mechanisms have received growing attention in the literature as an internal organizational factor affecting environmental innovation (Zhou et al., 2021). In particular, boards of directors are subject to ever-increasing pressure as drivers of environmental business strategies and, more specifically, board gender diversity has been considered a key element in corporate social responsibility (CSR) decisions, which may result in a greater orientation of boards toward environmental innovation (Nadeem et al., 2020).

The study of how environmental innovation may be conditioned by female directors is timely and relevant since board gender diversity remains at the core of political and professional agenda, being the focus of a number of international regulatory reforms³ and contributing toward specific targets of the SDG.⁴ At the same time, there is a strong academic discussion worldwide concerning the influence of female directors in the boardroom (Amorelli and García-Sánchez, 2020), and the literature emphasizes the need for further studies to elucidate the specific

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¹ OECD Report (2009); European Commission (2011).

² SDG 9 explicitly considers the need to foster innovation for sustainable development.

³ GRI (2016), Financial Reporting Council (2018), European Commission (2020).

⁴ Board gender diversity will help firms achieve gender equality, which is the objective of SDG 5.

advantages of female directors (Yarram and Adapa, 2021).

Particularly, research on female directors and environmental innovation is emerging and provides limited evidence. Some papers have explored the association between board gender diversity and green patents (He and Jiang, 2019) and the impact of female board members on environmental benefits of innovation (Galía et al., 2015). Recent research has also examined whether the level of environmental innovation, measured by surveys or scores provided by analysts, can be determined by the proportion of women in top management teams and boards of directors (Horbach and Jacob, 2018; Nadeem et al., 2020; García-Sánchez et al., 2021). However, the predominant standpoint in the literature generally assumes that women directors have a homogeneous effect, which constitutes a significant research gap, since this myopic approach is likely to be a handicap to understand the true influence of female directors on environmental innovation, thus leading to inaccurate results for firms, professionals, and public bodies to guide their actions. In this regard, researchers are increasingly wondering whether the mere presence of women directors would be sufficient to impact on corporate decisions and when women are actually decisive in the boardroom (Usman et al., 2021; Weck et al., 2021). In particular, to gain a real understanding of the role of female directors, recent research has underlined the importance of exploring new methodological approaches and of taking into account the organizational context when seeking to ascertain what actual effect female directors have (Kirsch, 2018; Bolourian et al., 2021).

Our paper is unique compared with other studies as it considers not only whether female directors contribute toward environmental innovation, but the conditions that may shape their influence on this kind of innovation. Our objective is to unravel the role of women directors by examining diverse factors that might determine their influence on environmental innovation decisions. Specifically, our paper differs from the previous studies and questions the one-size-fits-all approach, examining how (1) the existence of a critical mass, (2) the level of environmental innovation of firms, and (3) the interactions of gender diversity with other board attributes explain the actual role of female directors. To that end, we first analyze whether the association between gender diversity and environmental innovation is dependent on the existence of a certain number of women in the boardroom. This is vital if we are to understand the dynamics of women directors, since they may need to achieve a specific mass to become influential and prevail on boards and so encourage environmental decisions (Manita et al., 2018; Yarram and Adapa, 2021). Second, we emphasize that assuming that board gender diversity has a uniform effect on corporate outcomes can be short-sighted, as the influence of female directors may be actually dependent on the level of these outcomes. In this sense, a quantile regression analysis is performed to explore whether the effects of gender diversity on environmental innovation are conditional on the level of this kind of innovation of firms. While linear regression analysis only estimates the conditional mean effects of a response variable, quantile regression has emerged as a key tool to determine whether the influence of directors is different across levels of organizational outcomes (Chi et al., 2020). Third, we examine how certain board characteristics moderate the influence of female directors. Recent research calls for a contextual approach to expand current understanding of how directors affect corporate outcomes (Bolourian et al., 2021). Particularly, considering how gender diversity might interact with other board attributes and vis-à-vis their connections with CSR is fundamental to ascertain the role of female directors (Endrikat et al., 2020).

Using a sample composed of the firms listed on the FTSE-250, our findings provide novel insights in the literature since, contrary to previous research, female directors are shown to influence environmental innovation only under certain specific circumstances. In this regard, we confirm that board gender diversity positively impacts environmental innovation when there are at least three women in the boardroom, and only for firms with greater levels of environmental innovation. Moreover, our analysis reveals that the effect of board gender diversity on

environmental innovation is strengthened in the presence of CSR committees, but weakened in boards with a larger size and longer tenure.

Our study thus offers several key contributions. First, it provides valuable evidence for the sustainable development literature by shedding some light on the drivers of corporate environmental innovation from the organizational perspective. In this regard, our research highlights the circumstances under which boards and, concretely, female directors, enhance environmental innovation. Second, our findings underline that the one-size-fits-all perspective may prove unsuitable when exploring the effects of board gender diversity. In particular, our study broadens the perspective adopted by previous research and provides a unique picture of the conditions in which female directors influence environmental innovation, thus helping to explain whether and when women in the boardroom add value in terms of environmental strategies. In this regard, our paper is pioneering in highlighting that gender diversity might have positive, neutral or negative effects on environmental innovation, depending on certain conditions. Third, our paper also makes a significant methodological contribution towards a deeper understanding of the effects of board gender diversity. Our evidence demonstrates that traditional regression analyzes might conceal important quantitative effects of board gender diversity on environmental decisions. On the one hand, quantile regression is proven to be decisive with regard to capturing the true effect of female directors. This method has merits in complementing research on gender diversity since it provides a more thorough investigation of the relationship between board gender diversity and environmental innovation, conditional on the distribution of the latter variable. On the other hand, contextual analysis remains crucial in terms of gaining a clearer insight into what influence female directors have on environmental innovation.

2. Theoretical framework and hypothesis development

Environmental innovation is generally defined as “the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use compared to relevant alternatives” (Kemp and Pearson, 2007 p.7). There is a consensus regarding the environmental inclination of female directors, who may boost efforts made by boards in terms of investment in resources and incentives to support environmental innovation. Despite the multitheoretical nature of the relation between board gender diversity and environmental outcomes, stakeholder theory and upper echelons theory provide strong basis to understand the expected influence of female directors on environmental innovation (He and Jiang, 2019; Nadeem et al., 2020).

On the one hand, firms need to pay attention to multiple stakeholders' concerns and, particularly, environmental innovation has increased the pressure from a variety of stakeholders. A more diverse board is more likely to understand the environment of the firm (Helfaya and Moussa, 2017), grasp concerns from a broader pool of stakeholders and recognize their interests (Harjoto et al., 2014). In particular, female directors increase empathy within the board toward others and may improve key relations with stakeholders, and put greater emphasis on the service role of the board and the engagement with stakeholders' environmentalism (Arayssi et al., 2016). Women in the boardroom are also inclined to increasing participation and deliberation, thus leading to richer debates regarding stakeholders' concerns about environmental initiatives (Galbreath, 2018). In short, board gender diversity is expected to allow a better reaction to the market in terms of environmental innovation.

On the other hand, the upper echelons perspective relies on the idea that strategic decisions are significantly conditioned by behavioral factors and emphasizes the importance of personality characteristics (Hambrick and Mason, 1984). As regards female directors, there are important differences in core values compared to their male

counterparts, since women tend to care more about others, be more democratic and less power oriented (Adams and Funk, 2012). At the same time, women possess stronger communal traits, as they are likely to be more affectionate, sympathetic and interpersonally sensitive (He and Jiang, 2019). Due to these features, women tend to have a better perception of environmental initiatives and their return (Aryssi et al., 2016). In addition, the higher ethical standards of women also lead them to a proactive environmental behavior (Pan et al., 2020).

2.1. Critical mass

According to the critical mass theory, when women represent a minority group, they are likely to encounter barriers to expressing their opinions and when seeking to influence board decisions (Torchia et al., 2011). A solo female director will be subject to a greater degree of scrutiny and pressure and will tend to assimilate and imitate the behavior of the majority directors, with the woman's views coming down to token representation only (Yarram and Adapa, 2021). Therefore, the dominant group may exhibit non-conciliatory behavior towards women, who may then find it difficult to share their experiences and views when they are a minority. This theory has extended to the environmental domain. The literature has highlighted that the achievement of a critical mass of female directors improves the environmental behavior of firms, which enhances their environmental disclosures and actions (Post et al., 2011), and results in these firms being less subject to environmental controversies (Yarram and Adapa, 2021). More specifically, this critical mass has been proven to be decisive in the implementation of sustainability initiatives endorsed by stakeholders, such as the participation in the Carbon Disclosure Project (Ben-Amar et al., 2017), and sustainable investment (Atif et al., 2020). Women are seen as unequal board members when they are underrepresented, which limits their effective participation in decision-making and might neutralize their impact on strategic environmental discussions (Cook and Glass, 2018). Therefore, only above a certain threshold of representation are female directors expected to be valued for their individual contributions and involvement in the board when undertaking tasks oriented towards aspects that are considered to be "soft" by men, such as those related to social and environmental issues (Amorelli and García-Sánchez, 2020). In addition, the presence of merely one or two female directors could be insufficient to make a difference to pushing toward innovative decisions (Ben-Amar et al., 2013). In this regard, the literature has also suggested that attaining a critical mass favors female influence on corporate innovation (Torchia et al., 2011; Rossi et al., 2017). Consequently, the following hypothesis is formulated:

H1. Board gender diversity positively influences environmental innovation when female directors reach a critical mass.

2.2. Non-uniform effects of female directors across different levels of environmental innovation

The traditional linear regressions employed in the previous research rely on the assumption that the effect of female directors is uniform and impede ascertaining whether the response of female directors to environmental innovation differs across the different levels of innovation, which may be achieved through a quantile regression approach (Magazzino et al., 2021). Theoretically, given the increasing external pressures, low levels of environmental innovation may constitute a threat or a stress situation for firms in terms of competitiveness. In line with threat-rigidity theory (Staw et al., 1981), groups react in rigid ways when they are under pressure, and thus firms with low levels of environmental practices will have more trouble responding to environmental challenges. In these firms, control is likely to be constricted by concentrating influence and decision-making at the highest levels of the organizational hierarchy (Triana et al., 2013). In this regard, boards are more likely to restrict information and centralize authority (Conyon and

He, 2017), and board diversity might reduce cohesion and make reaching a consensus more difficult (Miller et al., 1998). This is particularly a problem for the development of environmental innovation, which requires an adequate flow of information as well as a structured organization working on innovation (Bhuiyan et al., 2021). In contrast, firms with higher levels of environmental innovation have less pressure, the required resources, and decision-making processes within their boards being likely to be less rigid. Thus, in these firms, it is more probable for female directors to have more capacity to utilize their specific characteristics and influence concerning strategic changes regarding environmental initiatives. In line with the above arguments, we posit that the effect of board gender diversity on environmental innovation is likely to be more significant in firms with higher levels of this kind of innovation. We therefore formulate the following hypothesis:

H2. The relationship between board gender diversity and environmental innovation is stronger for high environmentally innovative firms compared to low environmentally innovative firms.

2.3. Contextual approach

As female directors do not work in isolation, their influence in the boardroom is likely to be moderated by their interaction with other board attributes. Different economic-related theories have been employed to explain the effects of board attributes on firm innovation. Agency theory plays a fundamental role in explaining the relation between boards and innovative decisions, which are inherently risky, costly, and uncertain, and therefore they are usually accompanied by agency problems, and so require adequate board monitoring abilities (Bravo and Reguera-Alvarado, 2017; He and Jiang, 2019). In this regard, the impact of gender diversity on environmental innovation may depend to a great extent on certain board characteristics that have proven to be decisive in shaping board monitoring, such as the existence of a sustainability committee, board size, board independence, board tenure, and board meetings.

CSR committee. Under agency theory, this committee plays a vital role in the mitigation of agency costs associated with sustainability policies, since it focuses on planning and reviewing environmental strategy, which strengthens the monitoring of environmental issues at board level (Bhuiyan et al., 2021). In particular, sustainability committee members will display greater interest, dedication, and commitment towards environmental decisions, and will improve the board's capacity to supervise these decisions (García-Sánchez et al., 2019). As a result, boards that have a specific CSR committee may be better placed to implement environmental initiatives such as environmental innovation (Arena et al., 2018). Therefore, the following hypothesis is formulated:

H3a. The presence of a CSR committee positively moderates the association between board gender diversity and environmental innovation.

Board size. Arguments from agency theory can be contradictory, as larger boards have a greater variety of ideas, skills, and links with the environment, which may improve their monitoring capacity (Raimo et al., 2021), which may enable addressing environmental challenges (Barakat et al., 2015), achieving more active discussions towards environmental actions (Haji, 2013), and facilitating the identification and implementation of environmental concerns (Miller and Triana, 2009). However, agency theory also tends to emphasize that a high number of directors often induces less optimal monitoring, since boards may present divided positions and increase agency costs, thus harming decision-making (Sierra-Morán et al., 2021). Larger boards can form factions and coalitions, and face coordination and communication problems, which might hamper any consensus from being reached, especially regarding complex and risky decisions (Zona et al., 2013).

Given the non-mandatory nature of environmental innovation, the negative effect of board size in group dynamics may be predominant (Hussain et al., 2018). At the same time, smaller boards tend to exhibit more cohesion, greater engagement and accountability towards stakeholders, including social and environmental issues (Arayssi et al., 2016). Taking into consideration the existence of contradictory arguments, the following hypothesis is formulated:

H3b. Board size moderates the association between board gender diversity and environmental innovation.

Board independence. Agency theory suggests that independent directors are less constrained by concerns about economic performance, and they exert greater monitoring to preserve long-term sustainability (He and Jiang, 2019). These directors display important links to the firm's environment and tend to enhance board monitoring acting like outsiders, considering stakeholders' expectations, and integrating environmental issues in board discussions (Galia et al., 2015). Therefore, they may serve as accountability mechanisms in terms of reducing agency costs from environmental actions, being responsible for catering to the interests of stakeholders, society, and the environment (Nadeem et al., 2020). However, in some cases, independent directors may be reluctant to oversee environmental decisions due to their lack of in-depth knowledge of the specific environmental measures taken by a firm (Guerrero-Villegas et al., 2018). In addition, the existence of an excessive control by the independent directors might also be counterproductive and deteriorate relations within the board (Guldiken and Darendeli, 2016) and lower group efficacy (Zona et al., 2013), this hindering the approval of complex and risky projects. As a result, the following hypothesis is formulated:

H3c. Board independence moderates the association between board gender diversity and environmental innovation.

Board tenure. Agency theory provides conflicting arguments since, on the one hand, directors with tenure provide the board with specific knowledge and experience of the firm's capabilities and processes, which proves necessary in terms of developing and controlling innovative projects (Bravo and Reguera-Alvarado, 2017). In particular, tenure provides directors with a better understanding of a firm's internal and external structures, thereby improving their ability to monitor decisions regarding innovation (Chen, 2013). Nevertheless, excessive tenure makes boards less effective in identifying and overseeing new innovation opportunities (Hambrick, 1995). Boards with long-tenured members are more rigid, have an increased commitment to established practices and procedures, and tend to be reluctant to carry out strategic changes and new ideas (Golden and Zajac, 2001). As a result, they become stagnant, more disconnected from external environments, and less willing to commit to innovative investments that do not deliver short-term returns and which may increase agency costs (Khan et al., 2021). Hence, the following hypothesis is formulated:

H3d. Board tenure moderates the association between board gender diversity and environmental innovation.

Board meetings. From an agency perspective, board meetings allow directors to devote more time to analyze and monitor corporate environmental strategy (Hussain et al., 2018). Directors share their experiences and knowledge and provide critical information and resources at board meetings, and thus environmental policies can be better identified, as well as effectively defined and discussed in greater depth when the number of meetings increases (Naseem et al., 2017). However, the ability of boards to monitor environmental decisions when they meet frequently may also be questioned, as an excessive number of meetings may reduce board attendance and prove to be time-consuming for directors, thus affecting the efficiency of their supervisory functions (Lin et al., 2014). In addition, frequency of meetings might not actually add value to stakeholders and improve monitoring skills due to the amount of routines involved in board meetings (Vafeas, 1999). Therefore, the

following hypothesis is formulated:

H3e. Board meetings moderate the association between board gender diversity and environmental innovation.

Fig. 1 sums up the conceptual framework of the study.

3. Research method

3.1. Sample and data

Our sample is made up of the firms listed on the FTSE 250 for the period 2013–2018. This offers a particularly interesting setting because this period is subsequent to the European Proposal for a Directive of the European Parliament and of the Council on improving the gender balance among directors of companies listed on stock exchanges (European Commission, 2012), and related measures, and these UK firms are subject to high environmental pressures (Wendling et al., 2020).

In order to ensure the comparability and reliability of the results, the design of the variables included in our empirical analysis focuses on three recognized databases, which provides auditing data. Specifically, the data needed to calculate our dependent variable, environmental innovation, as well as the variables regarding corporate governance, are obtained from Thomson Reuters ASSET4 and Sustainabilitycs databases. Moreover, financial data has been extracted from Datastream database. However, some data fields are missing and, as a result, the final sample is composed of an unbalanced group of 932 firm-observations. Table 1 shows the sample selection. This sample is representative, since these firms represent most of the capitalization of the UK stock exchange.

3.2. Variables

3.2.1. Dependent variable: Environmental innovation

The measurement of environmental innovation is a complex task and a number of variables have been considered by the previous literature. Although some papers have employed the number of patents as a proxy for this kind of innovation, not all company research efforts and investments are patented (García-Granero et al., 2018). In this line, recent research has focused on measures elaborated from surveys and analysts to capture all the inputs or environmental innovation activities. Therefore, similar to recent studies (Arena et al., 2018; Nadeem et al., 2020), we rely on the environmental innovation (Env_inno) score provided by Thomson Reuters ASSET4 database, which offers auditable information and minimizes the inherent subjectivity associated to other measures, thereby enabling further replication and generalization of the results. This reflects a company's capacity to reduce environmental costs and burdens for its customers, thus creating new market opportunities through new environmental technologies and processes or eco-designed products. The environmental innovation score takes values from 0 to 100; the closer to 100, the greater the firm's environmental innovation.

3.2.2. Independent variables and control variables

Our main explanatory variable, board gender diversity (BGender) is calculated as the proportion of female board members. In order to capture female critical mass, several dummy variables have been designed (Manita et al., 2018). Specifically, FEMALE1 equals 1 when a board has one female director, and 0 otherwise, FEMALE2 equals 1 when a board has two female directors, and 0 otherwise, and FEMALE3 equals 1 when a board has at least three or more female directors, and 0 otherwise.

In addition, a set of control variables considering both board-related and firm-level variables is also included (Arena et al., 2018; Nadeem et al., 2020). As regards board-related variables, which are also the moderating variables in our empirical analysis, the variable concerning CSR Committee (CSR_Committee) is a dummy that equals 1 if the company has this committee, and 0 otherwise; board size (BSize) refers to the number of directors in the boardroom; board independence

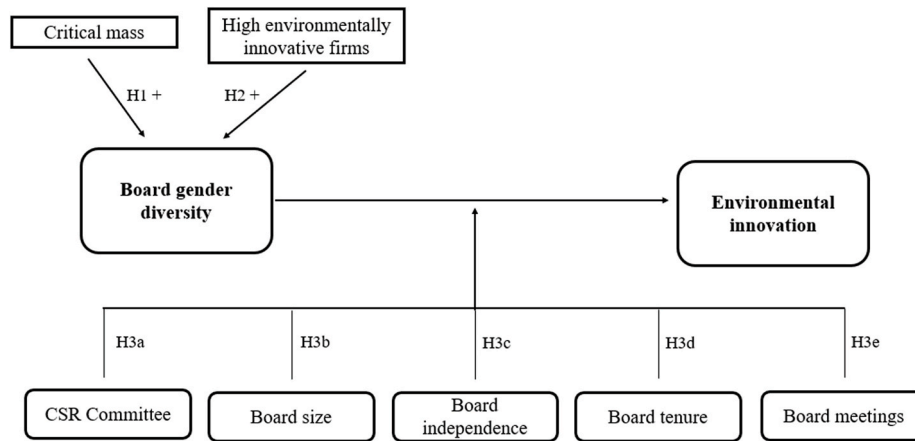


Fig. 1. Research framework.

Table 1
Sample selection.

A	Total firms	250
B	Period (2013–2018)	6
C = A x B	Original firm-year sample	1500
D	Incomplete information firm-year	568
E = C – D	Final firm-year sample	932

(BIndep) considers the proportion of independent directors within a board; board tenure (BTenure) indicates the average number of years directors have been on the board; board meetings (BMeetings) measures how often the board meets each year. In relation to firm-level characteristics, firm size (Asset) is computed as the logarithm of total assets; firm leverage (Leverage) is calculated as the ratio of total debt to total assets; firm financial performance is proxied by the ratio return on assets (ROA). Industry (Sector_CSR) is a dichotomous variable that takes the value 1 if the company belongs to a sector that is intensive in CSR activities⁵ following the SIC CODES classification, and 0 otherwise (Birkey et al., 2016; Miras-Rodríguez et al., 2020). Finally, we use a set of year dummies to control for time.

3.3. Model specification

Our database combines time-series and cross-sectional data to form panel data, where environmental innovation is regressed on independent and control variables. The Hausman test is applied to determine whether a fixed effects (FE) or a random effects (RE) estimation model is the most suitable.

The general model used is presented as follows:

$$Env_inno_{it} = \beta_0 + \beta_1 BGender_{it} + \beta_2 CSRCommittee_{it} + \beta_3 BSize_{it} + \beta_4 BIndep_{it} + \beta_5 BTenure_{it} + \beta_6 BMeetings_{it} + \beta_7 Asset_{it} + \beta_8 Leverage_{it} + \beta_9 ROA_{it} + \beta_{10} Sector_CSR_{it} + \beta_{11} Dum_Year_{it}$$

Specifically, quantile regression modelling is adopted for hypothesis H2. This method is more robust to non-normal errors and outliers than traditional regression approaches and permits the results of a regressor to vary from the distinct phases of the distribution (Chi et al., 2020; Magazzino et al., 2021). It therefore allows us to analyze our main relationship depending on the degree of environmental innovation that

⁵ Industries intensive in CSR activities are: Pharmaceuticals and Biotechnology, Chemicals, Engineering & Machinery, Electronic & Electrical Equipment, Electricity, Media & Entertainment, Real Estate, Construction and Buildings Materials, Food & Drug Retailers, Household Products, Steel & Other Metals, Food Producers & Processors, Clothing & Personal Products, Automobiles & Parts, Leisure Goods, Consumer Services and Transport.

companies engage in. We distinguish between high environmentally innovative firms (those from quantile 50 onwards) and low environmentally innovative firms (up to the median).

4. Empirical results

4.1. Descriptive statistics and correlations

Table 2 provides the main descriptive statistics. The mean value for environmental innovation is 55.71, with a standard deviation of 26.34. Female directors average almost 22% of total board members, which shows an underrepresentation of women on boards in comparison with men. Although most boards include at least one woman, only 35% of boards have three or more female directors. As regards the control variables, most of the firms in our sample (78%) have a CSR Committee. The average board of directors is composed of almost ten directors, with around 61% of them being independent. As for tenure, directors average five and a half years on a board, and boards meet over eight times a year.

Table 3 reports the correlations and variance inflation factor (VIF) coefficients. Although the correlations only show univariate relations and offer no conclusive findings, the correlation coefficients are, in general, below or equal to 0.7, and the VIF values are all found to be below 5. Therefore, multicollinearity can be discarded in our sample.

4.2. Main analysis

As regards our hypothesis H1, the results of the influence of a critical mass of women in boards are reported in Table 4. The findings including our measure for board gender diversity (BGender) confirm that female board representation is positively associated to environmental

Table 2
Descriptive statistics.

Variable	Mean	Std. Dev.	Q1	Median	Q3
Env_inno	55.71	26.34	32.85	54.90	78.76
BGender	21.78	10.09	14.29	21.43	28.57
Female 1	0.26	0.44	0	0	1
Female 2	0.35	0.48	0	0	1
Female 3	0.35	0.48	0	0	1
CSR_Committee	0.78	0.42	1	1	1
BSize	9.77	2.53	8	9	11
BIndep	61.29	11.83	53.33	61.54	70
BTenure	5.68	1.93	4.38	5.39	6.52
BMeetings	8.57	2.74	7	8	10
Asset	15.59	2.15	14.09	15.07	16.32
Leverage	0.17	0.15	0.05	0.17	0.26
ROA	0.41	0.25	0.21	0.42	0.61
Sector_CSR	0.36	0.48	0	0	1

Table 3
Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Env_inno	1.00													
(2) BGender	0.06*	1.00												
(3) Female1	-0.07**	-0.54***	1.00											
(4) Female2	-0.01	-0.43***	-0.43***	1.00										
(5) Female3	0.13***	0.66***	-0.07**	-0.54***	1.00									
(6) CSR_Committee	0.17***	0.10***	-0.07**	-0.01	0.15***	1.00								
(7) BSize	0.26***	0.04	-0.34***	-0.07**	0.45***	0.09***	1.00							
(8) BIndep	0.12***	0.19***	-0.12**	-0.11***	0.27***	0.18***	-0.14***	1.00						
(9) BTenure	-0.06*	-0.18***	0.09***	-0.03	-0.06*	0.06*	0.14***	-0.16***	1.00					
(10) BMeetings	-0.01	-0.05	-0.05	0.04	0.00	0.02	0.39***	0.24***	0.09***	1.00				
(11) Asset	0.30***	0.11***	-0.27***	-0.13***	0.45***	0.35***	0.70***	0.24***	0.24***	1.00				
(12) Leverage	-0.01	0.00	-0.01	0.02	0.00	0.15***	-0.00	0.02	-0.02	-0.04	1.00			
(13) ROA	-0.15***	-0.04	-0.19**	-0.01	-0.20***	-0.27***	-0.39***	0.22***	0.22***	-0.33***	-0.54***	1.00		
(14) Sector_CSR	0.04	-0.09***	0.15***	0.01	-0.16***	0.11***	-0.15***	0.14***	0.14***	-0.12***	-0.23***	0.01	1.00	
VIF			1.21	1.82	1.69	1.26	2.35	1.15	1.31	1.20	3.30	1.32	2.13	1.20

* p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Table 4
Analysis of a critical mass.

Variables	(1)	(2)	(3)	(4)
BGender	0.27*** (0.07)			
Female1		-3.48*** (1.26)		
Female2			0.62 (0.99)	
Female3				3.02** (1.34)
CSR_Committee	6.94*** (1.96)	8.53*** (1.93)	8.42*** (1.94)	8.30*** (1.93)
BSize	-0.53 (0.37)	-0.75** (0.37)	-0.56 (0.37)	-0.74* (0.38)
BIndep	0.12* (0.06)	0.14** (0.06)	0.14** (0.06)	0.14** (0.06)
BTenure	1.53*** (0.52)	1.20** (0.51)	1.15** (0.51)	1.33** (0.52)
BMeetings	0.17 (0.24)	0.15 (0.24)	0.16 (0.24)	0.19 (0.24)
Asset	13.01*** (2.07)	12.64*** (2.09)	13.09*** (2.09)	12.85*** (2.09)
Leverage	-41.44*** (15.15)	-41.18*** (15.23)	-41.44*** (15.39)	-44.93*** (15.29)
ROA	-22.87** (10.57)	-19.93* (10.65)	-21.49** (10.73)	-23.64** (10.66)
Sector_CSR	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	923	923	923	923
R-squared	0.20	0.19	0.19	0.19
F-test	12.13***	11.51***	10.87***	11.28***
Fixed/Random effect (FE/RE)	FE	FE	FE	FE

Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

innovation (column 1). However, only when they reach a critical mass of at least three women do female directors display a positive and significant association with environmental innovation. The presence of only one or two women on the board, which is the case in most firms, has been shown to be insufficient in terms of enhancing environmental innovation. In particular, when there is only a woman in the boardroom the association between gender diversity and environmental innovation is negative. Therefore, our hypothesis H1 is accepted.

With regard to our hypothesis H2, the results from the quantile regression analysis are presented in Table 5 and Fig. 2. We estimate the coefficients at the 1st, 10th, 15th, 25th, 50th, 75th, 85th, 90th, and 99th quantiles in order to have more specific information about how the level of environmental innovation determines the influence of women directors. We find that the sign of board gender diversity is positive and significant from the 50th quantile up, which means that increased board gender diversity boosts environmental innovation in high environmentally innovative firms. Nevertheless, we fail to find a significant association between women directors and environmental innovation in low environmentally innovative firms. Therefore, the results confirm our hypothesis H2.

Finally, as regards hypotheses H3a to H3e, the results from the moderation analysis are reported in Table 6. Columns 1, 2, 3, 4, and 5 present the interaction between board gender diversity and CSR committee, board size, board independence, board tenure, and board meetings, respectively. Our findings highlight that the influence of female directors is contingent on certain board characteristics. Specifically, the positive effect of board gender diversity on environmental innovation is enhanced when there is a CSR committee. However, board size and board tenure negatively moderate the relation between board gender diversity and environmental innovation. In addition, board independence and board meeting frequency do not appear to moderate the previous relationship. In sum, hypotheses H3a, H3b, and H3d are supported.

Table 5
Quantile regression analysis.

Quantile	q0.01	q0.10	q0.15	q0.25	q0.50	q0.75	q0.85	q0.90	q0.99
BGender	-0.29 (0.52)	0.09 (0.13)	0.12 (0.12)	0.15 (0.12)	0.24** (0.12)	0.32** (0.13)	0.34** (0.14)	0.37*** (0.14)	1.23** (0.58)
CSR_Committee	11.07 (9.17)	7.33*** (2.71)	7.08*** (2.54)	6.75** (2.69)	5.89** (2.98)	5.14 (3.26)	4.90 (3.59)	4.67 (3.65)	-3.74 (10.46)
BSize	1.99 (2.42)	0.09 (0.48)	-0.04 (0.46)	-0.21 (0.43)	-0.65* (0.37)	-1.04** (0.41)	-1.16*** (0.39)	-1.28*** (0.41)	-5.57* (2.99)
BIndep	0.53 (0.38)	0.25*** (0.08)	0.23*** (0.08)	0.21*** (0.08)	0.15* (0.08)	0.09 (0.08)	0.07 (0.07)	0.06 (0.08)	-0.57 (0.42)
BTenure	1.49 (3.16)	1.17 (0.75)	1.15 (0.78)	1.12 (0.79)	1.05 (0.77)	0.98 (0.84)	0.96 (0.91)	0.94 (0.95)	0.21 (2.51)
BMeetings	0.04 (1.77)	0.13 (0.39)	0.13 (0.42)	0.14 (0.36)	0.16 (0.31)	0.18 (0.32)	0.18 (0.34)	0.19 (0.33)	0.37 (1.78)
Asset	19.06* (11.49)	13.69*** (2.60)	13.33*** (2.74)	12.86*** (2.61)	11.63*** (2.73)	10.55*** (3.49)	10.21*** (3.34)	9.88*** (3.66)	-2.18 (12.82)
Leverage	-162.65 (108.32)	-69.64*** (21.53)	-63.25*** (20.54)	-55.02*** (20.01)	-33.76* (19.70)	-14.94 (18.68)	-9.13 (20.04)	-3.29 (19.12)	206.02 (127.47)
ROA	-115.91 (82.61)	-45.47*** (14.97)	-40.64*** (15.36)	-34.39** (14.15)	-18.29 (15.26)	-4.04 (14.85)	0.36 (16.96)	4.78 (16.15)	163.29* (92.36)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

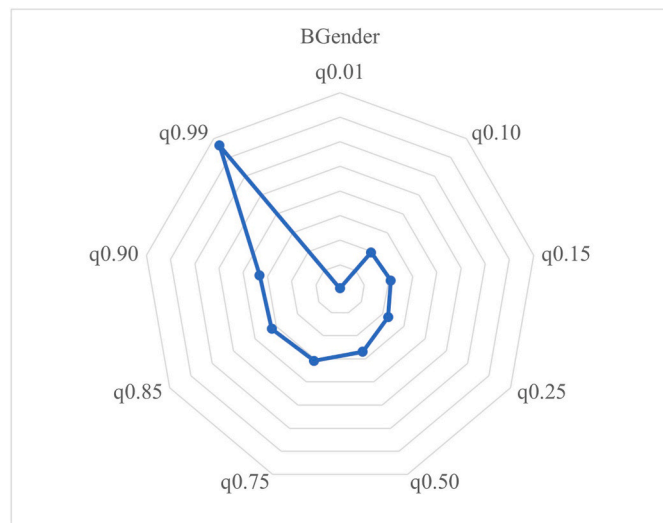


Fig. 2. Tendency arising from the results.

4.3. Robustness analysis

Table 7 contains several additional analyses performed to ensure that the results for the relation between board gender diversity and environmental innovation are not biased by the design of the measures for dependent and independent variables and due to endogeneity issues.

First, the main analysis was replicated for an alternative measure regarding board gender diversity (Column 1), the BLAU index (Blau gender), which is regularly used in the literature (He and Jiang, 2019). It was calculated as $1 - \sum P^2$, where P is the proportion of individuals in a category (fraction of female and male directors), and i is the number of categories (two in this case) (Blau, 1977). This index takes into account both the number of gender categories and the evenness of the distribution of board members among them.

Another approach implied a change in the measure for environmental innovation by employing a rank regression analysis (Column 2). The original variable for environmental innovation was ranked (Env_rank) by sorting the values in ascending order so that the resulting variable includes the rankings. Rank transformation has been used in the literature because it yields distribution-free data, and mitigates the impact of measurement errors, outliers and residual heteroskedasticity on the regression results (Reguera-Alvarado and Bravo, 2017).

Furthermore, two endogeneity tests were conducted to discard the existence of unobserved variables or inverse causality relations. First, the two-step dynamic panel data model Generalized Method of Moments (GMM) (Column 3), which overcomes the latent endogeneity problem by adopting the lagged variables as instruments (Blundell and Bond, 1998), was applied. Second, a two-stage least squares method (2SLS) was applied (Column 4). This method is based on the use of instrumental variables, which might explain the independent variable (BGender), but must be unrelated to the dependent one (Env_inno) (Larcker and Rusticus, 2010). In our empirical study, we use as the instrumental variable: programme to increase workforce diversity. The instrument obeys the above-mentioned conditions, whose validity is confirmed by the Sargan test. Results from these tests confirm the lack of endogeneity issues in our sample.

4.4. Discussion

Our study reinforces the idea that an aggregate measure of female directors might be positively related to an overall effect on environmental innovation (Galia et al., 2015; Horbach and Jacob, 2018; Nadeem et al., 2020), but this can mask the actual effect of women in the boardroom. We definitively need to have a closer look to unravel the effect of female directors on environmental innovation. In this regard, our paper questions the one-size-fits-all approach and adopts a critical standpoint in the study of the influence of female directors, thus contributing to the literature in several additional ways.

First, in line with recent studies (Kirsch, 2018; Bolourian et al., 2021; Weck et al., 2021), we advocate the need to go beneath the surface and to consider non-traditional regression approaches as well as the board context in order to really understand whether and how women directors make a difference when it comes to environmental decisions. Our results emphasize that considering these methodological issues may prove crucial in empirical studies to attain more conclusive evidence to inform practice. From an academic standpoint, in light of our findings, gender studies must be aware that the effect of female directors on organizational outcomes may differ depending on certain conditions.

Second, our study aligns with the literature concerning critical mass (Torchia et al., 2011; Cook and Glass, 2018; Yarram and Adapa, 2021). Environmental innovation is costly and risky, and requires long-term commitment. As a result, when women are an important minority, they find it difficult to encourage boards to implement environmentally innovative actions. In particular, the presence of only one woman in the board tends to make male directors to view her as a token, making ineffective her participation in the board (Cook and Glass, 2018).

Table 6
Moderation analysis.

Variables	(1)	(2)	(3)	(4)	(5)
BGender	0.09 (0.12)	0.59*** (0.21)	0.59** (0.28)	0.52*** (0.16)	0.36** (0.17)
BGender*CSR_Committee	0.22* (0.13)				
BGender*BSize		-0.04* (0.02)			
BGender*BIndep			-0.01 (0.00)		
BGender*BTenure				-0.05* (0.03)	
BGender*BMeetings					-0.01 (0.02)
CSR_Committee	2.512 (3.19)	6.31*** (1.99)	7.02*** (1.96)	6.73*** (1.96)	6.92*** (1.96)
BSize	-0.49 (0.37)	0.20 (0.58)	-0.58 (0.37)	-0.52 (0.37)	-0.53 (0.37)
BIndep	0.12* (0.06)	0.12* (0.06)	0.23** (0.11)	0.13** (0.06)	0.12* (0.06)
BTenure	1.58*** (0.52)	1.44*** (0.52)	1.57*** (0.52)	2.44*** (0.73)	1.49*** (0.52)
BMeetings	0.19 (0.24)	0.18 (0.24)	0.15 (0.24)	0.18 (0.24)	0.40 (0.45)
Asset	-43.38*** (2.07)	-39.22** (2.07)	-41.74*** (2.07)	-41.49*** (2.07)	-42.11*** (2.07)
Leverage	(15.17) -22.59**	(15.19) -21.62**	(15.15) -23.45**	(15.12) -20.98**	(15.19) -23.22**
ROA	10.55 (2.07)	10.58 (2.07)	10.57 (2.07)	10.60 (2.07)	10.59 (2.07)
Year dummies	Yes	Yes	Yes	Yes	Yes
Observations	923	923	923	923	923
R-squared	0.21	0.21	0.21	0.21	0.20
F-Test	11.56***	11.52***	11.42***	11.57***	11.34***
Fixed/Random effect (FE/RE)	FE	FE	FE	FE	FE

Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 7
Robustness analysis.

Variable	Env_inno	Env_rank	Env_inno	Env_inno
	(1)	(2)	GMM (3)	2SLS (4)
Blau gender	20.000*** (6.412)			
BGender		0.003*** (0.001)	0.533* (0.305)	0.188* (0.099)
CSR_Committee	7.428*** (1.953)	0.072*** (0.022)	9.566*** (2.578)	3.734* (2.260)
BSize	-0.583 (0.367)	-0.005 (0.004)	-0.590 (0.410)	0.804*** (0.299)
BIndep	0.122* (0.064)	0.001** (0.001)	0.014 (0.079)	0.159* (0.095)
BTenure	1.448*** (0.518)	0.018*** (0.006)	1.163 (0.711)	3.965 (2.979)
BMeetings	0.172 (0.243)	0.001 (0.003)	0.421 (0.256)	0.178 (0.386)
Asset	13.138*** (2.076)	0.144*** (0.023)	6.659** (3.274)	0.674 (0.960)
Leverage	-40.657*** (15.213)	-0.514*** (0.167)	-10.645 (19.558)	1.700 (6.872)
ROA	-23.036** (10.607)	-0.270** (0.117)	0.825 (14.751)	-4.130 (5.763)
Sector_CSR	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	923	923	627	637
R-squared	0.198	0.224	0.134	n.a.
F-test/Wald chi2	11.69***	13.71***	5.31***	281.96***
Sargan test	n.a.	n.a.	0.023	8.88
Fixed/Random effect (FE/RE)	FE	FE	FE	n.a.

Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

Indeed, the board becomes a homogeneous group, which is likely to inhibit creativity and exchange of ideas, thus reducing the inclination towards innovation (Torchia et al., 2011). However, when boards contain at least three female directors, these women are more likely to raise their voice towards environmental concerns and push boards to decisions related to environmental innovation.

Third, consistent with a new stream of research on the impact of corporate governance mechanisms (Chi et al., 2020), our study supports the notion that the effects of boards on organizational outcomes may depend on the level of the latter. In this regard, we find that female directors exert an influence on environmental innovation only in high environmentally innovative firms that display the right conditions to favor this kind of innovation. However, firms with lower levels of this environmental innovation do not benefit from board gender diversity. Decisions on environmental innovation require for boards an adequate exchange of information and level of cohesion (Bhuiyan et al., 2021). This is likely to be difficult in low environmentally innovative firms as, in line with the theoretical expectations, boards from those firms can be subject to greater pressures, and tend to restrict information and centralize complex decisions, which may increase rigidity in innovative decisions (Conyon and He, 2017). Thus, this is a handicap for female directors' environmental perspective to prevail. Therefore, our evidence sheds important light on this new approach in gender studies, since the distribution of the values of organizational outcomes proves decisive in terms of understanding what actual influence female directors have.

Fourth, recent studies advocate a contextual approach to expand current understanding of how board gender diversity affects environmental decisions (Bolourian et al., 2021), especially considering how board characteristics might interact with each other and vis-à-vis their connections with CSR (Endrikat et al., 2020). In this regard, our findings show that the positive effect of gender diversity on environmental innovation is intensified by the presence of a CSR committee. This

committee helps to overcome uncertainty concerning environmental decisions and to implement environmental initiatives (Arena et al., 2018), which can strengthen the influence of female directors. The expected orientation of women towards environmental innovation is thus supported in the presence of CSR committees. However, board size and board tenure negatively moderate the relation between board gender diversity and environmental innovation. On the one hand, larger boards may face coordination and communication problems and have difficulty reaching a consensus about complex decisions (Zona et al., 2013; Arayssi et al., 2016). This may be a greater handicap in more diverse boards, which are more likely to present factions and coalitions. In this scenario, our findings suggest that women are unable to assert their environmental inclination. On the other hand, regardless of gender, board tenure seems to be a key factor, as longer tenures make boards more reluctant to undertake strategic changes and new ideas concerning environmental decisions in an effort to avoid risk (Golden and Zajac, 2001; Khan et al., 2021). Regarding board independence and board meetings, neither attribute has any moderating effect on the relation between gender diversity and environmental innovation. Independent directors may possess insufficient knowledge and expertise about a firm to promote complex environmental initiatives (Guerrero-Villegas et al., 2018). Additionally, an increase in the number of board meetings may not add enough value to intensify environmental orientation since many meetings include routines and may not actually improve directors' efficacy in their functions (Lin et al., 2014).

5. Conclusion

Our paper has important theoretical implications. First, our evidence brings into question the validity of the one-size-fits-all perspective vis-à-vis revealing the role of female directors. Second, we reinforce the arguments from stakeholder theory and upper echelons theory in the explanation of the influence of board gender diversity on environmental outcomes. Third, we contribute critical mass theory and threat-rigidity theory by expanding the existing evidence to the environmental dimension of firms. Fourth, we advocate that no single theory can fully explain the role of female directors in environmental innovation. Particularly, our paper highlights that different theories should be simultaneously considered to obtain more comprehensive theoretical frameworks, which would allow a better understanding of the effects of board gender diversity.

Given the ever-increasing attention of environmental innovation and female board representation, our paper also has practical implications for firms, regulators, and researchers.

Our evidence allows firms to understand how female directors impact environmental innovation. We provide guidance in terms of understanding the specific conditions in which female directors can have an effect on this type of innovation. A growing number of companies are concerned about their environmental practices and may be interested in business cases that can actually help them to improve their accountability in this field. At the same time, the evidence from the moderation analysis provides a roadmap for firms that aim at enhancing environmental innovation, highlighting the value added by the creation of CSR committees and the importance of the configuration of boards. Certain board attributes are proven decisive in the promotion of environmental initiatives and, in this regard, our findings offer advice against an excessive board size and board tenure, and suggest that increasing board independence and the number of board meetings may be ineffective.

Moreover, board gender diversity has lain at the centre of corporate governance reforms and recommendations issued by international professional bodies and policy-makers. Likewise, the integration of environmental policies into corporate strategies has also been discussed in the business and political arena. In this regard, our study provides valuable evidence to inform such bodies about the value added by female directors in terms of environmental innovation, thus offering

important insights in terms of refining legislation and recommendations concerning board gender diversity from regulators and practitioners. Other board attributes have been actively debated by regulators and professionals, leading to inconclusive discussions about the optimal board size, degree of board independence, and number of board meetings, as well as the need for directors' refreshment to reduce board tenure. Our evidence adds new insights for future policy regarding these board attributes.

From an academic standpoint, our results point to the need for scholars to consider board-related variables as potential drivers of environmental innovation. Particularly, we encourage employing measures of female critical mass. In addition, our paper has implications for researchers by highlighting the relevance of methodological techniques in the study of the influence of board gender diversity. Firstly, quantile regression is seen to prove effective in offering a comprehensive view of the circumstances in which women directors have an actual impact on environmental outcomes. Furthermore, our findings emphasize the importance of moderation analyzes that specifically bear in mind the context in which directors make decisions.

This paper evidences certain limitations. First, our study focuses on a particular country, which might affect the behavior of firms in terms of board gender diversity and environmental practices. Moreover, our sample is limited to large listed firms. In addition, our analysis only considers a limited number of factors that may shape the influence of female board members. These limitations may be considered with a view to pursuing future research opportunities. In this regard, future studies could explore this topic in different legal and/or institutional contexts in order to obtain more conclusive evidence about the relationship between gender diversity and environmental decisions. At the same time, research on this topic might also look at small and medium enterprises, which are pivotal in many economies. Furthermore, further studies might employ a different view, employing a personal-level approach and focus on specific characteristics of women, such as their expertise, tenure, education, self-esteem, or power within the board. Beyond the interactions of female directors with other board members, it could be interesting to analyze how the influence of women in the boardroom is moderated by firm characteristics that are likely to shape corporate decisions, such as the firm size, leverage, growth opportunities, and by CEO features.

CRedit authorship contribution statement

Elena Moreno-Ureba: Data curation, Investigation, Methodology, Software, Visualization, Writing – original draft. **Francisco Bravo-Urquiza:** Conceptualization, Investigation, Supervision, Writing – review & editing. **Nuria Reguera-Alvarado:** Data curation, Methodology, Software, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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