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Board gender diversity, feminine culture, and innovation for environmentalsustainability

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ABSTRACT

The environmental crisis is one of global society's most extreme grand challenges. One of the supply-side factors that can help cope with it is corporate environmental innovation. Based on the upper echelon and value belief theory and with significant empirical analyses, our results strongly support that the presence of women on the board positively impacts innovation aimed at environmental sustainability. The results are based on a sample of 19,800 firm-year observations of 2,966 unique firms in 54 industry groups domiciled in 52 countries for the 2003-2019 period. The global distribution of the firms means that the sample is diverse enough to examine our main hypotheses. In addition, we show that culturally masculine societies, as captured by their grammatical gender marking, have a negative impact on such innovation. The masculine culture also moderates the impact of gender board diversity on innovation for environmental sustainability. Our results are robust to a battery of empirical tests and definitions, including instrumental variable approach and propensity score matching causality tests. We further explored firms' attitudes towards innovation for environmental sustainability by adding a qualitative case study research design to our quantitative analysis. That was based on Semi-structured interviews with board members and executives. The case studies provided additional support to the results in the quantitative analysis part. This study's empirical results have various broad theoretical and practical implications for board composition, taking into account the linguistic environment of thefirm.

Keywords: Grand challenges, Environmental innovation, Board Gender diversity, Upperechelons theory, Grammatical gender marking

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Practitioner Points:

- A significant number of women on the board will positively impact the environmentalinnovation of the firm.
- Shareholders who want to increase the environmental innovation of the firm shouldnominate more women to the board.
- Women on the board in masculine value societies have the most significant impact on thefirm actions related to environmental innovation.

1. INTRODUCTION

Our world finds itself increasingly grappling with an array of grand challenges spanning societal, economic, and scientific issues, such as refugees (Guo et al., 2020), poverty (Berrone et al., 2016), diseases, including COVID-19 pandemic and antibiotic resistance (Vakili & McGahan, 2016; Olsen et al., 2016; Noble & Spanjol, 2020; Laxminarayan et al., 2013), and environmental sustainability (Wright & Nyberg, 2017). Doh et al.(2019) claim that a grand challenge is a situation that creates massive disruptions to organizational and societal systems that transcend the interests or influence of individual firms. Grand challenges are big-scale problems that affect society with urgently needed solutions that are even more complex than the problem (Grodal & O'Mahony, 2017; Venugopal & Viswanathan, 2019). Successful adaptation to these challenges will also require innovative solutions that leverage the resources and capabilities of all relevant actors, therefore involving cross-sectoral solutions.

Among and unlike other grand challenges, environmental sustainability is considered more critical because the impact of degradation in the ecological environment and climate change is universal. The actions required to address this issue are considered non-negotiable (Goodland, 1995; Goodland & Daly, 1996). In this backdrop, this article focuses on innovation undertakenfor environmental sustainability by for-profit organizations.

The sixth (2021) governmental Panel on Climate Change[i]concluded that human activity in the last 50 years warmed the climate to unprecedented temperatures, resulting in an increased chance of extreme compound events like heatwaves, floods, and droughts. Climate change is already affecting every inhabited region across the globe and may impact the survival of humanity. It leads to the straightforward conclusion that the global environmental crisis is one of the most demanding grand challenges. It requires a collective mass action, especially for

for-profit firmscontrolling humanity's manufacturing side.

The solutions to the environmental crisis could evolve from the demand or/and the supply side. The demand-side solutions are based on impacting/changing consumption, individuals' behavior, lifestyles, and generally reducing consumption or reducing/substituting the specific type of polluting consumption (Creutzig et al., 2018). But dealing with the demand side could be inefficient if not all countries cut the polluted consumption. The outcome could be that the "sinners" would consume at lower prices (Sinn, 2008).

The supply side is based on reducing pollution during production (Gaulin & Billon, P, 2020). It could be done by policy (Harstad, 2012). However, one of the leading supply-side solutions is achieved by the corporations' initiatives for environmental innovation (EI) (Sinn, 2012). EI leads to lower pollution during production (Konadu et al., 2022) and provides substitute products for consumption that have lower pollution during production. For example, Hartmann, Inkpen, and Ramaswamy (2021) show that firms in the oil and gas industry invest in renewable energy technology and processes.

Due to its vast scale and complexity, there is no one solution to the grand challenge of the global environmental crisis. But understanding mechanisms that can promote EI worldwide through a globally available resource could be an essential part of the solution. For supply-side solutions, we argue scrutiny of corporate boards is imperative because the board of directors has a significant impact on the strategic choices made by a firm (Judge & Zeithaml, 1992; Forbes & Milliken, 1999), like the level and resources allocated to EI. This makes the board composition an essential factor in determining the EI of the corporation. The comprehensive literature in different disciplines highlights the impact on company policies and outcomes of board diversity, particularly board gender diversity (Farrell & Hersch, 2005;

Adams & Ferreira, 2009; Shoham et al., 2020).

However, a significant tension relates to the direction of the impact of board gender diversity (BGD) on the EI of the corporation. On the one hand, the literature provides extensive support that females have higher risk aversion than males (Croson & Gneezy, 2009). Innovation processes are very risky, expecting females on the board to decrease EI. On the other hand, the literature supports the argument that women in general and females on the board have higher social responsibility than males. Females tend to be more empathetic and engaged in responding to the needs of others (Jaffee & Hyde, 2000). They are generally more sensitive to societal issues and conduct themselves morally and ethically better than men (McInerney-Lacombe et al., 2008). This leads to an opposite expectation that females on the board will positively impact EI.

Using echelons theory and institutional theory, we propose that BGD, gendered culture, and their interaction impact the firm's EI. We find support for our propositions through a sequential mixed- method explanatory research design. Our main empirical inquiry is based on a quantitative analysis of 19,800 cross-firm-year observations from 52 countries for 17 years, obtained from the Thomson Reuters Refinitiv ESG database. This database is a credible source of firm-level data widely used in empirical ESG research. The supplementary analysis is based on a quantitative comparative case study approach (Eisenhardt, 1989; Eisenhardt & Garbner, 2006; Wiewel & Hunter, 1985; Yin, 1989).

Our empirical examination revealed that having women on the board significantly encourages a firm’s decision to engage in EI. This effect positively correlates with a critical mass of women in boardrooms. A battery of robustness tests, including propensity-score matched (PSM) and an instrumental variable (IV) analysis, are performed. We further found that

local culture emphasizing masculinity plays a detrimental effect on corporate EI activities, while the outperforming EI observed in greater gender-diverse boards tends to be moderated by masculine local culture in societies. Overall, we capture the femininity of the local culture using the intensityof gender marking embedded in a dominant language of local societies.

Our study contributes to the literature in three ways. First, as George et al. (2016) argued, more management research is needed as grand challenges are ubiquitous and collective action is required at various levels to tackle them (Watson et al., 2018). Our academic understanding of this vital aspect is still very sparse. This article adds to our knowledge of a supply-side solution to the major grand challenge of our time by exploring how board configuration affects a firm's engagement in innovation to mitigate environment-related challenges. BGD is a human capital resource available in all societies and environments to deal with the environmental crisis effectively. However, the body of literature dealing with the impact of BGD on environment-related challenges in general and EI is nascent and small (e.g., Galia et al., 2015; Nadeem et al., 2020), especially in a multi- environment of cross-country analysis. The contribution is significant because most of the prior research on corporate boards is limited to examining two vital issues: a) the impact of board composition on environment-related corporate disclosure and reporting (Fernandez-Feijoo et al., 2014; Naciti, 2019) and b) the impact of board composition on the establishment of strategic alliances (Post et al., 2015) aimed at enhancing corporate environmental performance (Ortiz-de- Mandojana & Aragon-Correa, 2015; Post et al., 2011). This is somewhat surprising because: (i) EI is regarded as a vital area of research (Mazzucato, 2018); and (ii) recent studies have recommended that, besides increasing their activities for R&D and creating new systems of innovation, firms should implement transformative changes in their leadership and structure (Schot & Steinmueller, 2018; Singh et al., 2020).

Second, our study contributes to the theory of the informal social institution of culture, namely the value belief theory. It advances our knowledge of the direct impact of gendered culture on EI. The study also provides theoretical and empirical support for the moderating effect of culture on BGD outcomes. Our theoretical conjecture is based on a cross-cultural analysis of gendered culture, as captured by the grammatical gender marking enacted in society. The institutions embody sets of societal expectations and values that trickle down to a firm's level through its most influential actors, promoting fundamental changes to a firm's behaviors and actions and providing meaning to any changes made to gain social legitimization (Scott, 1987; Meyer & Jepperson, 2000). It indicates that feminine values provide an additional pillar capable of strengthening feminine beliefs and actions in a given environment (Brooks, 2002). We embedded the upper echelons theory within the value belief theory and showed how informal institutions such as culture moderate the predictions.

Third, this article also includes an empirical contribution by using the linguistic structure as a proxy for gendered culture. We use the linguistic structure to explain the conditions under which environmental innovation is enhanced or hampered by BGD. We specifically investigate the interlink between BGD and the influences of linguistic structure—such as gender grammatical marking (e.g., Gay et al., 2013; Santacreu-Vasut et al., 2014)—in relation to the EI of firms in the societies in which they operate. There is a lack of research on the impact of gendered culture on innovation, even when using traditional cultural dimensions. In the specific case of grammatical gender marking, no prior study (at least to our knowledge) has analyzed its influences on firm EI.

Based on the contributions presented above, we also contribute directly to the micro and meso perspectives on the role of innovation in tackling the grand challenge of the environmental

crisis from the supply side. Providing strong theoretical and empirical support for the positive impact of female directors on EI in the context of the gendered cultural environment helps better understand the following questions often raised by scholars, for instance: a) What are the internal drivers for using innovation to tackle grand challenges? b) What governance structures for for-profit organizations increase innovation to tackle grand challenges?

The following section examines the theoretical framework and presents hypotheses. Section 3 explains our research methods and data sources. Section 4 presents our results, followed by a discussion section that includes practical and theoretical implications. Finally, we conclude by presenting our work's limitations and future research.

2. THEORY AND HYPOTHESES

We propose to theorize that internal aspects of higher echelons within the firm via board gender diversity and the external impact of informal societal institutions affect firm decision-making. From the theory perspective, the upper echelons theory (Hambrick & Mason, 1984) suggests that board and higher management composition relates to a firm's decision-making (internal factor). We also build on the value belief theory (Hofstede, 1980; Triandis, 1995) perspectives of the informal institution as part of the greater institutional theory to link the impact of the society in which firms exist on EI (external factor). The following sections present the upper echelons theory as represented by the BGD (internal) with the institutional environment as reflected by the value belief theory regarding gendered culture (external) and their impact on the firm concerning EI.

Over the last three and a half decades, upper echelons theory has influenced management research in many ways (Neely et al., 2020). The theory suggests that the composition and characteristics of top management teams, such as the board of directors, shape a firm's

decision-making. The fundamental idea behind this proposition lies in the fact that, in a complex organization, decision- making is a shared activity, and any decisions made are based on the collective experience, values, personalities, and demographics of its board members. The board's collective characteristics and composition reflect the firm's cognitive frame. This affects the board's *vision* (the directions in which it looks and what it listens to), *perception* (what it actually sees and hears), and *interpretation* (how it attaches meaning to what it sees and hears) in tackling the strategic situationsfacing the firm (Hambrick & Mason, 1984).

Given its more comprehensive application and ability to explain organizational action, the plethora of research conducted in the strategy and OB domain has widely relied upon analyzing the upper crust to predict organizational behaviors and strategies. The central idea of upper echelons theory has proved to be influential in explaining organizational outcomes (Bantel & Jackson, 1989; Carpenter & Fredrickson, 2001; Hodgkinson & Sparrow, 2002) and the strategic actions taken by a firm (Gupta et al., 2017; Wright & Nyberg, 2017; Eisenhardt & Bourgeois, 1988; Simons et al., 1999). This is because the firm outcomes are affected by its top administration, like the board (Sciascia Mazzola et al., 2013; Bromiley & Rau, 2016; Wang et al., 2016).

The firm's decision to engage in EI is partly a function of the configuration of its board. The Upper Echelons theory (Hambrick & Mason, 1984) and the extant literature on corporate boards propose that the board provides strategic direction and shapes the managerial philosophy (Forbes & Milliken, 1999). Upper Echelons theory has "served as a catalyst" by providing a solid foundation for examining the relationship between a firm's executives and its actions (Neely et al., 2020:1030). The theory suggests that what an organization does and how it does it reflects its board's "biases and dispositions"—the most powerful actor in any

organization. In fact, a firm's decisions reflect its board members' collective experiences, knowledge, and values (Hambrick, 2007). He also suggests an interrelationship between managerial action and societal configuration embedded in the firm. In response to the impact of the external institutional environment on a firm's decision-making, even Hambrick (2007) updated the upper echelons theory by acknowledging that its predictions are affected by the institutional environment in which a firm operates.

The institutional theory deals with the configuration of the environment of the firm. The theory mainly argues that organizational actions and their associated outcomes are affected by the external institutional forces that provide the 'rules of the game' (North, 1991) according to which an organization has to play. Scott (2008:48) provides a clear, logical grounding that "*institutions are social structures that have attained a high degree of resilience*." Because of their durability and importance, institutions are regarded as valuable mechanisms that provide "*stability and meaning to social life*." In other words, institutions provide a structure—including rules, regulations, norms, schemes, and routines—that defines the guidelines for social behaviors (Scott, 1987). Given these powerful explanations of institutions and their relevance for the society in which an organization is embedded, scholars have started to use them as significant predictors of organizational behaviors. According to DiMaggio and Powell (1983), a firm faces pressures from external institutional forces and thus needs to conform to institutional demands in order to legitimize its actions. This legitimization behavior brings isomorphism into the organizational response.

One of the main informal institutions is culture. The Value-Belief Theory (Hofstede, 1980; Triandis, 1995) suggests that the values and beliefs held by members of a culture influence how the members of the society behave and the degree to which behaviors are seen as

legitimate and acceptable, and effective. Cultural aspects shape how business is conducted (Freytag & Thurik, 2007). Hofstede (2001) states that culture is collectively programmed early in life, leading to lasting behavioral patterns and shaping the institutional environment (Barnouw, 1979; Hofstede, 1980; Mueller & Thomas, 2001). Indeed, culture and the gender dimension of culture have influenced multiple economic behaviors (e.g., Guiso et al., 2006) and outcomes (Nollenberger et al., 2016; Almor et al., 2019). The seminal studies on cultural dimensions (e.g., Hofstede 1980; House et al., 2004; Hofstede et al., 2010) include a dimension for a gendered culture of the society.

At the same time, the literature on innovation in corporate/for-profit organizations has grown and attracted attention due to the importance of innovation in those types of organizations (He & Tian 2018). But successful corporate innovation is complicated to achieve (Kuratko et al., 2014). One of the essential factors impacting innovation in for-profit firms is the executive and the decision- makers in the corporation (Chen et al., 2014). The executives' background influences the many aspects of innovation in the corporation (Zhang et al., 2022). In this context, a nascent body of literature supports the idea that BGD impacts corporate innovation (e.g., Almor et al., 2019). The above paragraphs provided literature on the general topic. In the following subsections, we develop specific hypotheses based on those theories and literature presented earlier.

2.1. Female board members and environmental innovation

The extant literature on gender diversity in corporate boards provides evidence that women consider their decisions' effect on multiple corporate stakeholders, not just the shareholders (Nadeem et al., 2020; Konrad & Kramer, 2006). For example, a higher degree of gender diversity positively impacts a firm's charitable actions (Wang & Coffey, 1992; Williams,

2003; Marquis & Lee, 2013). When looking into any broad impact on stakeholders, one of the effects considered by gender-diverse boards is corporate social responsibility (CSR) (McGuinness et al., 2017; Nadeem et al., 2017; Cumming et al., 2015; Jain & Zaman, 2020; Bear et al., 2010; Boulouta, 2013).

Prior research indicates that BGD positively impacts a firm's environmental ratings (Post et al., 2011). recent studies by Shoham et al. (2017) and Nadeem et al. (2020). Show that female member on board positively affects organizational concerns towards environmental sustainability. BGD may lead the firm to devise novel ways and processes to deal with environment-related challenges (Nadeem et al., 2020). This suggests that female board members may push organizations' efforts to undertake innovation for environmental upgrading.

However, innovation projects, especially environmental sustainability ones, are highly risky and capital-intensive. The higher risk aversion attitude usually exhibited by women (Adams & Funk, 2012) can give rise to the assumption that females on the board might negatively impact R&D investments and innovation due to the associated high risks. But Almor et al. (2019) show that gender-diverse boards encourage more effective R&D investments that are better aligned with the corporate goals. Other researchers found that BGD impacts the ability of a firm to innovate (Galia & Zenou, 2012; Talke et al., 2010; Zahra et al., 2000). In the context of employees, Østergaard et al. (2011) reported a positive correlation between gender diversity and the likelihood of innovationbeing introduced in the firm.

In sum, these insights from the literature suggest that women on the board are likely to impact the organizational efforts for environmental innovation. While arguing in favor of BGD, our work acknowledges that the mere presence of women on a board may not yield adequate

action because men usually dominate corporate boards. Women members often carry a subdued, minority voice (Elstad & Ladegard, 2012) as they are inducted as board members for tokenism (Duguid et al., 2012). Critical mass theory (Kanter, 1977) claims that the impact of women is quite limited when they belong to a minority group. The critical mass theory has been tested and supported for various outcomes (e.g., Konrad et al., 2008; Schwartz-Ziv, 2017; Torchia et al., 2011). Prior literature considered boards that include three or more women members or more than thirty percent of women board members as boards with a critical mass of females (Konrad et al., 2008; Schwartz- Ziv, 2017; Torchia et al., 2011). However, Shoham et al. (2017) argue that the presence of even one female on a board may yield a positive effect on organizational action. Therefore, we propose two hypotheses—pertaining to the positive effect of BGD on environmental innovation—that are mutually exclusive regarding the extent of gender diversity required to elicit an impact.

Hypothesis 1a (H1a). The presence of at least one woman on the board of directors of a firm willpositively impact innovation related to environmental sustainability.

Hypothesis 1b (H1b). The presence of a critical mass of women on the board of directors of a firm will positively impact innovation related to environmental sustainability.

2.2. Masculine/feminine culture and innovation for environmental sustainability

As we presented earlier, The Value-Belief Theory (Hofstede, 1980, Triandis, 1995) argues that culture influences individuals and business behavior (Freytag & Thurik, 2007). The influence is due to the fact that culture is "the collective programming of the mind" (Hofstede, 2001:9). Husted (2005) argues that a discussion of environmental sustainability is inadequate if it does not addressculture.

The cultural dimension of masculinity/femininity (e.g., Hofstede 1980) is associated with the degree of gender-based roles in society, but it is also associated with societies that contain

higher masculine values compared to societies that include higher degrees of feminine values. In the words of Hofstede et al. (2010:140), "*A society is called masculine when emotional gender roles are clearly distinct: men are supposed to be assertive, tough, and focused on material success, whereas women are supposed to be more modest, tender, and concerned with the quality of life. A society is called feminine when emotional gender roles overlap both men and women are supposed to be modest, tender, and concerned with the quality of life.*" The authors also claimed that one of the three main differences between masculine and feminine cultures is the degree to which the environment is protected. Governments in masculine cultures prioritize growth over the environment, while those in feminine cultures are more likely to do the opposite (Schumacher, 1973; Hofstede, 2001). Husted (2005) concluded that feminine cultures favor 'green' or 'sustainable' values. Also, Gallén and Peraita (2017) showed that countries with more feminine cultures provide a higher quantity of sustainability reports, while masculine cultures have a negative impact on the corporate adoption of costly environmental technology (Palmer et al., 1995).

Based on Hofstede et al. (2010) argument presented above—i.e., that gender-based culture is associated with masculine/feminine values—we would expect a higher masculine (feminine) culture found in a society to have a negative (positive) impact on EI.

Hypothesis 2 (H2). Societies with feminine cultures will positively affect the tendency of their firms to engage in innovation related to environmental sustainability than those with masculine ones.

2.3. Moderating the impact of masculine/feminine culture

As presented above, Hambrick (2007) updated the upper echelons theory by acknowledging that its predictions are affected by the institutional environment in which a firm operates. He argued that external institutions act as 'moderators,' affecting the relationship between board

composition and characteristics and firm decision-making —put simply, external institutions condition the decisions made by a firm. Thus, while diversity in a firm's decision-making may be affected by the characteristics and composition of its board, the institutional environment brings some degree of coherence to such decision-making as it guides the firm in what it can and cannot do.

Among institutional variables, cultural dimensions have been found to be a strong moderator of activities and decisions at the individual and organizational levels (Probst & Lawler, 2006; Thompson et al., 2014; Chen et al., 2016; Wulani & Junaedi, 2021). Prior research also suggests that the cultural orientation of a society affects the firm's orientation toward innovation. Based on a study of over 700,000 firms from 62 countries, Turró et al. (2014) concluded that cultural values moderate corporate innovation. Morris et al. (1993) showed that individualism in a society affects corporate entrepreneurship. The cultural dimension of collectivism has been found to moderate outcomes related to environmental decisions (Lee, 2017). Societies which nurture such traits are likely to promote corporate entrepreneurial actions for innovation, and societies that lack exhibit weaker thrust.

A recent study by Xie et al. (2020) showed that the R&D team's gender diversity moderates the effect of the market structure on the firm's innovation efficiency. Attah-Boakye et al. (2020) analyze a dataset from an emerging market to illustrate that gendered culture moderates BGD on corporate innovation. Taking ques from the literature, we argue that the presence of women on the board is also likely to affect the relationship between BGD and the firm's initiatives for EI. More specifically, the marginal effect of women board members will be positive within a masculine societal culture and negative within a feminine society. Our conjecture regarding moderating effect is based on the supposition that women members can

sensitize boardroom discussion, especially in a masculine society where the scope for undertaking EI is higher. This is in comparison to feminine societies, which may be already promoting environmental innovation, where the additional impact of female board members is likely to be smaller.

Hypothesis 3 (H3). Societies with feminine (masculine) culture negatively (positively) moderatethe impact of BGD on environmental innovation.

Figure 1 presents and summarizes the theoretical framework as suggested by the hypotheses.

"Place Figure 1 approximately here."

3. RESEARCH DESIGN

The empirical analysis is based on a mixed-method design, specifically, the sequential explanatory design that consists of two distinct phases: first, quantitative secondary data analysis; second, qualitative case study approach (Creswell et al., 2003). We use the mixed-method approach for our research following the work of Shoham et al. (2017). They suggest that the best empirical approach for research of BGD and environmental issues is using both quantitative and qualitative methods. The purpose of using cases is to understand better the interplay between individual board members, their gender, and their support of environmental sustainability. It allows extracting corroborative and substantive evidence, especially regarding differences in cultural values between a firm embedded in a masculine society against a firm embedded in a feminine society, which helps to explicate the results of the quantitative analysis. In-depth comparative cases are particularly advocated cross-cultural comparison are to be scrutinized (Yan and Gray, 2017; Welch et al., 2011).

This empirical strategy allowed us to explore the relationship between dependent and

independent variables, as hypothesized in H1-H3, with the help of quantitative analysis. Then substantiate the relationships with the use of qualitative data analysis. Scholars (Rossman & Wilson, 1985; Tashakkori & Teddlie, 1998) argue that the role of subsequent qualitative data analysis is critical as it is not just intended to provide confirmatory results but to a) enhance the credibility of quantitative analysis by validating the initial findings generate; and b) generate theoretical insights behind the relationship explored in the first stage. Below we have provided details of both methodologies. In section 4, where we present our results, we have triangulated the corroborative results obtained using qualitative analysis with the results of the quantitative analysis. This has enabled us to enrich our discussion by comparing and contrasting the results of two analysis sets and presenting a converging story.

3.1. Quantitative secondary data analysis

3.1.1. Sample selection

The data for our study was obtained mainly from the Thomson Reuters Refinitiv ESG database (Refinitiv ESG, formerly known as ASSET4), one of the most widely used in empirical ESG research over the last decades. Using the Refinitiv ESG dataset, we captured the various aspects associated with gender diversity in the boardrooms of firms and their EI activities. The final sample is an unbalanced panel with 19,800 firm-year observations of 2,966 unique firms in 54 industry groups domiciled in 52 countries (see Appendix 1) for the 2003-2019 period. The global distribution of the firms means that the sample is diverse enough to examine the effect of BGD on the degree of corporate EI activities in terms of ESG EI scores and their related R&D investment levels[ii].

3.1.2. Empirical model

To test our hypotheses, we employed multivariate ordinary linear squared (OLS) regression models as our baseline, as specified in Equations (1) for hypotheses 1a and 1b, Equation (2) for

hypothesis2, and Equation (3) for hypothesis 3, respectively.

(1) $$Environmental\ Innovation\ Activities_{i,t} = \alpha + \beta_1 Board\ Gender\ Diversity_{i,t-1} + \beta_2 Company\ Level\ Controls_{i,t-1} + \beta_3 Country\ Level\ Controls_{i,t-1} + \sum_{t=2003}^{2019} \gamma_t Year_t + \sum_{j=1}^{54} \delta_j Industry_j + \sum_{c=1}^{52} \emptyset_c Country_c$$

(2) $$Environmental\ Innovation\ Actitivies_{i,t} = \alpha + \beta_1 Local\ masculine\ culture_c + \beta_2 Company\ Level\ Controls_{i,t-1} + \beta_3 Country\ Level\ Controls_{i,t-1} + \sum_{t=2003}^{2019} \gamma_t Year_t + \sum_{j=1}^{54} \delta_j Industry_j$$

(3) $$Environmental\ Innovation\ Activities_{\ i,t} = \alpha + \beta_1 Board\ Gender\ Diversity_{i,t-1} \times Local\ masculine\ culture_c + \beta_2 Board\ Gender\ Diversity_{i,t-1} + \beta_3 Local\ masculine\ culture_c + \beta_4 Company\ Level\ Controls_{i,t-1} + \beta_5 Country\ Level\ Controls_{i,t-1} + \sum_{t=2003}^{2019} \gamma_t Year_t + \sum_{j=1}^{54} \delta_j Industry_j$$

Where i, j, c, and t denote firm, industry, country, and year, respectively. All explanatory and control variables are lagged by one year[iii] to deal with any potential reverse causality (Liu, 2018). In Equations (1) to (3), to capture the EI activities of firm *i* in year *t* as a dependent variable, we used *Environmental Innovation Scores*, as described in the Dependent Variable subsection. To identify a different aspect of corporate EI activities, we used corporate investment in environmental R&D as an alternative robustness dependent variable. We measured BGD using female directors' percentages and the total number of directors on our sample firms' boards, as detailed in equations (1) to (3) in the independent variable subsection.

In Equation (2)—whereby we examined the effect of local masculine culture on corporate EI activities—we used a gender intensity index (GIIv2) (Gay et al., 2013) to capture the degrees to which the local culture is gendered. A high GIIv2 reflected a masculine society, and a low one a feminine society. In Equation (3), the interaction term between BGD and GIIv2 is used as an explanatory variable of interest in estimating their interplay in corporate EI activities.

All Equations include year dummies to account for any systematic variations in corporate environmental performance over time, while industry dummies are included to account for possible similarities across the same industries. We had country dummies in Equation (1) to

control for time-invariant country-level omitted variables[iv]. The robust standard errors are used to control for the possibility of the error terms not having constant variance (heteroscedasticity).

3.1.3. Dependent variable

ESG EI Category score (hereafter Environmental Innovation Score) measures corporate EI as a dependent variable. This reflects a firm's capacity to reduce its customers' environmental costs and burdens and thereby create new market opportunities through new environmental technologies and processes or eco-designed products. The *Environmental Innovation Score* ranges from 0 to 100, with a higher value representing better environmental innovation.

As an alternative measure of corporate EI activities, we used the log of the firm's total amount of environmental R&D expenditures[v]. The log is used to mitigate the possible impact of outliers. Some firms do not report information on R&D because they either engage in no R&D expenditure or choose not to disclose it for strategic reasons (Koh & Reeb, 2015). To deal with firms that do not report information on R&D, we followed customary practice (Lewis & Tan, 2016) and allocated a value of 0 to Environmental R&D expenditures if the data is missing.

3.1.4. Independent variables

We first measured the degree to which female directors are present on corporate boards using the percentages of female directors available in the Refinitiv ESG dataset and constructed our *Female director ratio* variable. We next constructed the *Number of female directors* variable as a product of the *Female director ratio* and *Board size*, as available in the Refinitiv ESG dataset.

Using the *Number of female directors*, we further constructed three binary variables to capture the incidence of female presence on the board. To test hypothesis 1a, we created a variable—*Female_director>= (yes/no)*—to which we assigned a value of 1 if a firm had at least one

woman director and, 0 otherwise. To test hypothesis 1b, we followed prior studies and considered boards that included more than three or more than 30% women (Konrad et al., 2008; Schwartz-Ziv, 2017; Torchia et al., 2011) test critical mass theory and constructed two critical mass variables. The first is *Female_director>=3 (Yes/No)*, to which we assigned a value of 1 if a firm had at least three women directors on the board, and 0 otherwise. The other was *Gender critical mass (Yes/No)*, to which we assigned a value of 1 if a firm had at least three and/or at least 30% of women directorson the board, and 0 otherwise.

North (1990, 1993) pointed out that language serves as a vehicle for cultural transmission. As stated by the Sapir-Whorf hypothesis, the principle of linguistic relativity claims that language shapes thought (Sapir, 1929; Whorf, 1956). Also, Hofstede (2001) backed Sapir-Whorf linguistic relativity. In addition, Triandis (1995) supported the idea that shared values can be identified among individuals who speak the same language. Recent years have seen the emergence of a new body of literature capturing the gender-related roles found in society via the latter's grammatical gender marking (e.g., Santacreu-Vasut. et al., 2014; see Shoham, 2019 for a detailed explanation of grammatical gender marking). Grammatical gender marking captures a society's ancestral culture, reinforced by cognition (Shoham et al., 2017; Drori et al., 2020; Bazel-Shoham et al., 2020).

To capture the femininity/masculinity of the local culture, we used the GIIv2 index, which is based on the intensity of gender marking found in the language spoken in a country. It incorporates values that account for the presence of the number of genders (NG) (Corbett, 2011b [WALS chapter 30]), a Sex-Based (SB) gender system (Corbett, 2011a [WALS chapter 31]), and Gender Pronouns (GP) (Siewierska, 2011 [WALS chapter 44]) in the following expression: GIIv2 = NG + SB + GP, where GIIv2 $\in$ {0; 1; 2; 3}. Grammatical structures are validated as empirical tools in prior studies (Hicks et al., 2015; Santacreu- et al., 2014); a

detailed explanation may be found in Gay et al. (2013). Given that, by design, GIIv2 is open to criticism for assuming a linear effect when summing the individual gender markings to create the index, we formed a single GIIv2 factor by performing a principal component factor analysis of the three individual language indices (NG, SB, and GP). All three individual language indices uploaded positively to the GIIv2, suggesting that the GIIv2 factor does indeed provide a satisfactory description of the commonality of all three individual indices.

3.1.5. Control variables

In the finance and economics literature (Shoham et al., 2017), the board is regarded as one of the paramount governance mechanisms of a firm; as such, it plays a critical role in formulating various firm policies, including those on CSR. In this regard, we first controlled for the unique characteristics of the board by adding three board-related variables to all regression models: (1) *Board size*, (2) *Independent director ratio*, and (3) *Dual CEO (Yes/No)*. *Board size* represented the total number of board members at the end of each year and was log-transformed to mitigate the possible impact of outliers. The *Independent director ratio* is measured as the percentage of independent board members, as reported by the firm. *Dual CEO (Yes/No)* is assigned a value of 1 if the CEO had simultaneously chaired the board and had been the firm's CEO and 0 otherwise. Lastly, we controlled for firm size by including *Log (Number of employees)*, a log-transformed value of the total number of employees included in its CSR reporting.

Each country's *sovereign credit rating* (from S&P Global Rating) is added as a composite indicator of its creditworthiness. Following Klock et al. (2005) and Pandej et al. (2020), we computed the credit ratings through a conversion process in which AAA-rated bonds are assigned a value of 22 and D-rated ones a value of 1. We further controlled each country's overall economic health by including *Log (GDP)* and *GDP per capita*.

As corporate EI may be subject to business cycles and other inter-temporal macroeconomic changes, we added *year fixed effect* in all regression. We also added *industry-fixed effects* to control industry-wide shock to firms' environmental activities in the same industry. We used the TRBC industry group classification system adopted by Refinitiv ESG, which enabled us to identify the 54 unique industry groups in the sample. Considering that the EI of firms domiciled in the same country can be related to common country-level factors that cannot be controlled empirically, we added a *country-fixed effect* whenever deemed necessary. Detailed definitions of all the variablesused in the study are presented in Appendix 2.

3.2. Qualitative case study research design

As discussed above, we further explored firms' attitudes towards innovation for environmental sustainability by supplementing our quantitative analysis with a qualitative case study research design. The qualitative case study method allows for generating rich insights for developing theoretical explanations (Eisenhardt & Graeber, 2007; Van Maanen et al., 2007; Fisher & Aguinis, 2017; Munjal et al., 2021) as it provides a deeper understanding of the phenomenon under study (Eisenhardt, 1989; Yin, 2009; Ozcan et al., 2017) in its natural setting (O'Connor, 1998). For our research propositions, the case study approach allowed us to dig down into the firm's decision-making in its natural settings and gain a substantive understanding of the factors that influence its attitude and choices for mitigating environmental sustainability.

Within the case study approach, scholars (Esienhardt, 1989) prefer multiple case studies (againstsingle case studies) as it allows for generalization wherever empirical context drives the phenomenon under investigation. Multiple case studies also allow for within-case and cross-case comparisons (Koners & Goffin, 2007), which is essential for our study, especially

for examininghow differences in cultural values (feminine vs. masculine) affect the adoption of innovation forenvironmental sustainability.

We used a theoretical sampling approach to select suitable cases for our study (Coyne, 1997). This allowed us to choose cases that are theoretically fit for the purpose, i.e., the firm has gender diversity in its corporate board and has been engaged in innovation for meeting environmental sustainability. In addition, to fulfill our requirement of comparative evaluation of the impact of cultural values on the firm's impact on environmental sustainability, we picked one firm embedded in a masculine society (India) and another firm embedded in a feminine society (The United Kingdom). In addition to the comparative case studies, additional qualitative data were collected from individuals with extensive board-level crossvergence experience working in bothmasculine and feminine cultures.

Semi-structured interview was carried out with the board members of both firms virtually over the internet. Ten individuals were interviewed, consisting of 7 board members (4 from the firm from a masculine society and three from the firm from a feminine society) across both firms and three independent directors with crossvergence experience. The interviews allowed respondents to explain the internal dynamics of the firm's decision-making and the effect BGD and the cultural values had on the firm (King, 2004; Kvale & Brinkmann, 2008). The authors had permission to go back to respondents for clarifications. To maintain ethical integrity and to protect the interest of participants, quotes are disguised.

Questions were derived from the literature to capture corroborative evidence for quantitative analysis. These questions captured the impact of BGD on the firm's sensitivity towards environment-related grand challenges. Emphasis is placed on exploring how and to what extent BGD, and external socio-cultural milieu, specifically feminine and masculine values in

the society where the firm is embedded, affected the firm's outlook towards environmental sustainability issues. During the primary data collection process, there was a continuous interchange between empirical data and theories to explore theoretical nuances affecting the firm's decision-making (Snow & Anderson, 1991). The results of the interviews are incorporatedin section 4.7.

4. QUANTITATIVE ANALYSIS AND FINDINGS

4.1. Summary statistics

Table 1 reports the summary statistics for the variables used in quantitative analysis. The firms in our sample are awarded an average *Environmental Innovation Score* of 37.252. Most firms had noticeably improved their EI over time. We found very similar increasing time trends in the *environmental R&D expenditure* made by the firms. In relation to BGD, the mean *Female director ratio* of 15.665% showed that, on average, about 1.773 out of 11.318 board directors were women across the sample. However, we also observed significant variation: from 0 for some firms to 71.430% (most directors on the board being women) for others. The mean value of *Female_director>= (Yes/No)* of 0.769 showed that most of our sample firms had at least one female director, while the mean value of *Female_director>=3 (Yes/No)* of 0.269 indicated that less than a third of our sample firms had at least three women directors on the average board of eleven members[vi], suggesting that BGD is still far from reaching parity. Gender inequality was also manifest when we measured it using *Gender critical mass (Yes/No)*, which is found to have amean value of 0.277.

"Place Table 1 approximately here."

The correlations among the variables of our interest are reported in Table 2. First, the very strong and positive correlation between our two dependent variables suggests that firms with more environmental R&D expenditure are more likely to be awarded higher

environmental innovation scores. As hypothesized, each BGD measure is positively correlated with the key-dependent variable. The statistical significance of the positive correlation (*p-value* <0.100) of *Female director>=1 (Yes/No)* is relatively smaller than those (*p-value* < 0.010) of *Female director>=3 (Yes/No)* and *Gender critical mass (Yes/No)*, providing unilateral evidence that refuted hypothesis 1a but supported hypothesis 1b. However, we found a negative correlation between all BGD measures and corporate environmental R&D investments. It might be premature to link this negative correlation with female directors on boards being more reluctant than their male counterparts to increase investments in environmental R&D; rather, this negative correlation calls for conducting an in-depth investigation aimed at checking whether BGD is endogenously associated with a firm's decisions to engage in environmental R&D investments. While firms with larger boards are found to tend to have a positive attitude toward EI activities, those with more independent boards seemed to exhibit a negative one. Lastly, larger firms with more employees are found to have more resources available to improve their EI generally.

"Place Table 2 approximately here."

4.2. Testing hypotheses 1a & 1b: Effect of BGD on environmental innovation activities

To test our hypotheses 1a and 1b, we first estimated Equation (1), where *Environmental Innovation Scores* is used as a dependent variable. The baseline OLS regression models in Panel A of Table 3 show that the coefficients of most BGD measures are significantly positive, generally supporting the assumption that gender-diverse boards tend to be perceived and recognized as being more EI. However, the coefficient of *Female director>=1 (Yes/No)* is insignificant, implying that the presence of just one female director might not be enough to exert a significant influence on corporate decision-making on EI, which refutes hypothesis 1a. Conversely, the positive coefficients found for the two critical mass variables—*Female*

director>=1 (Yes/No) and *Gender critical mass (Yes/No)*—strongly support hypothesis 1b, which is an alternative to hypothesis 1a.

Concerning robustness, we replaced *Environmental Innovation Scores* with *Log (Environmental R&D expenditure)* in Equation (1). As reported in Panel B of Table 3, the results are very similar to those reported in Panel A, confirming the rejection of hypothesis 1a and supporting hypothesis 1b.

"Place Table 3 approximately here."

4.3. Testing hypothesis 2: Effect of masculine/feminine local cultures on EI activities

To test our hypothesis 2, Equation (2) is employed, where the *GIIv2 factor* was used as an explanatory variable of interest to capture the degree of core masculinity/femininity found in the local culture. As reported in Model (1) in Table 4, the *GIIv2 factor* carries a strongly negative coefficient, suggesting that those firms domiciled in strongly masculine countries in their dominant languages tend to be awarded lower environmental innovation scores. We further found that a masculine culture also discourages local firms from spending more on environmental R&D expenditures, as reported in Model (2) Table 4. To summarize, firms operating in more masculine societies tend to perform poorly than their feminine-society counterparts in terms of EI.

"Place Table 4 approximately here."

4.4. Testing hypothesis 3: Moderating role played by masculine/feminine local cultures

Hypothesis 3 is tested by employing Equation (3), where the *GIIv2 factor* interacts with BGD. The interaction variable captures the effect of BGD in various masculine/feminine local cultures. As reported in all regressions of Table 5 panel A, the interaction variable of *GIIv2*

factor and BGD is positive and significant, suggesting females on the board have a more considerable effect on the environmental innovation score of firms domiciled in countries with strongly masculine features in their dominant languages. In other words, the presence of women on the board helps firms mitigate the observed poor EI presented in Table 4. Also, the GIIV2 factor and BGD are significant and maintain their signs from the regressions introduced in Tables 3 and 4. We obtained the same results in the robust regression conducted using environmental R&D expenditures, as shown in Table 5 panel B. To summarize, the marginal effect of the presence of women on the board on a firm's EI is more substantial in masculine societies.

"Place Table 5 approximately here."

4.5. Endogeneity tests for hypothesis 1

4.5.1. Propensity score matching (PSM) analyses

Although many relevant control variables—along with the country-, industry-, and year-fixed effect—had been deliberately included in the regression analyses, we might not have been free from any endogeneity concerns, including a time-changing omitted variables bias, which might not have been included in the regression analysis, but might have affected both BGD and corporate EI at the same time. Critics could also argue that the one-year lagging of all explanatory variables of interest and control variable—to deal with potential reverse causality (Liu, 2018)—might not have been sufficient because any eligible women, who are a scarce human resource available for corporate leadership positions, may find it more optimal to self-select more EI firms. Although such arguments are unlikely to cope rigorously with any endogeneity concerns in line with prior studies (Dhaliwal et al., 2016; Shoham et al., 2020). we executed a propensity score matching (PSM) to re-test hypothesis 1b. First, we regarded those firms which had at least three or 30% women directors on their boards—or both—as

our 'treatment' group. Then, using the predicted likelihood estimated in the first-stage logit model, we one-to-one matched each firm in our treatment group with a board that failed to reach critical mass. More specifically, our matching procedures are based on all seven firm- and country-level control variables plus the year-fixed effect[vii]. Therefore, our treatment and control firms were virtually identical in their characteristics. The only difference was in the critical mass in terms of BGD. To evaluate the validity of our matching procedure, we followed Dhaliwal et al. (2016) and conducted the matching diagnostic tests provided in online Appendix 3. When combined, all three diagnostic tests strongly demonstrated that our matching procedure had been successful, and the two groups essentially differed only on one dimension, i.e., their degree of BGD.

Table 6 re-estimated Equation (1) using the PSM subsample. The results still show that the coefficients of *Gender critical mass (Yes/No)* are statistically positive for all models, regardless of how EI was measured, providing re-confirming evidence supporting hypothesis 1b.

"Place Table 6 approximately here."

4.5.2. Instrumental variable (IV)

To provide further empirical evidence supporting hypothesis 1b, instrumental variable (IV) analysis is conducted. Following DeBoskey et al. (2020), the IV is the industry average of a lagged value of *the number of female directors* in the country where a firm was operating. The IV is employed in a 2SLS estimation[viii]. The logic is that a firm would be more likely to achieve a critical mass if operating in an industry with a larger pool of women available for corporate leadership positions, including seats in the boardroom (thus satisfying the relevance condition). At the same time, the larger female director pool did not directly affect corporate EI (thus satisfying the exclusion condition).

In the first-stage IV estimation, *Gender critical mass (Yes/No)$_{t-1}$* is regressed on its corresponding industry average along with the same control variables used in Equation (1), including dummies. As shown in Model 1 of Table 7, the industry average exhibited a positive and highly significant relation with *Gender critical mass (Yes/No) $_{t-1}$*, satisfying the relevance condition. Model 2 presents the results of the second-stage IV estimations, in which the Environmental Innovation Score is regressed on the fitted *Gender critical mass (Yes/No)$_{t-1}$*. As evidenced by the significantly positive coefficient of the fitted *Gender critical mass (Yes/No)$_{t-1}$*, the results remain robust, confirming that greater BGD had led to better corporate EI—and not vice versa—even after controlling for possible endogeneity concerns. When we used *Log (Environmental R&D expenditure)* as the dependent variable in Model 3, we continued to find robust results supporting hypothesis 1b. The high IV F- statistics confirmed that our IVs were not weak. The significant Durbin P-value in Models 2 and 3 also suggested that there might be an endogenous relationship between BGD and corporate EI, supporting the validity of employing the IV estimations.

"Place Table 7 approximately here."

4.6. Additional tests

4.6.1. Environment-related technologies as an alternative proxy for corporate EI

There might be a concern that the dependent variables (*Environmental Innovation Score* and *Environmental R&D expenditure*) cannot fully capture the degree to which a firm engages in corporate environmental innovation activities. For example, an environmental patent application[ix] might be a better measure for it because a patent application can be the final outcome of corporate innovation activities. To address this concern at least partly, we identify from the Refinitive ESG dataset four indicator variables that are related to the environmental patent application as follows: (1) Hybrid technology which is assigned a value of 1 if the

company develops hybrid technology, and 0 otherwise; (2) Clean technology which assigned a value of 1 if the company develops clean technology (wind, solar, hydro and geothermal and biomass power), and 0 otherwise; (3) Water technology which assigned a value of 1 if the company develops products or technologies that are used for water treatment, purification or that improve water use efficiency, and 0 otherwise; (4) lastly, Environmental product (*Env_product*) which is assigned a value of 1 if the company reports on at least one product line or service that is designed to have a positive effect on the environment or which is environmentally labeled and marketed, and 0 otherwise. Given that the first three environment-related technologies and one environment-related product can be the intended ultimate outcomes of corporate environmental innovation activities via environmental R&D expenditure, we believe them to be well related to corporate environmental innovation activities. By using the first three environment-related technology indicators, a new variable is created, *Env_tech,* which is assigned a value of 1 if the company develops at least one of the three technologies above and 0 otherwise.

Additionally, as done for the GIIv2, we formed *Env_tech_factor* using a principal component factor analysis of the three environment-related technology indicators. Using new alternative proxies for environment-related innovation activities, we re-estimated Equations (1) and (3) to retest H1, H2, and H3. LOGIT regression is performed for the two indicator variables Env_tech and Env_product, and OLS regression for *Env_tech_factor*. As reported in Online Appendix 4 (Panels A to C for H1, Panel D for H2, and Panels E to G for H3), the results are consistent withour primary regressions providing additional support to our hypotheses.

4.6.2. Treatment of missing environmental R&D expenditure through imputation

A concern might arise regarding the corporate environmental R&D expenditure variable. Unlike the main dependent variable of *Environmental Innovation Score*, we followed the

customary practice of assigning a value of 0 to *Environmental R&D expenditure* if the data is missing. Additional robustness tests are conducted to mitigate the concern that this approach for missing environmental R&D expenditures might not be optimal for treating missing data. First, as described in section 4.6.1, the *Env_tech*, *Env_tech_factor*, and *Env_product* are used as new alternative measures for environment-related innovation activities and find very consistent evidence. Second, after limiting the subsample to companies with reported environmental R&D expenditure (those companies which reported annual environmental R&D expenditure at least once in our sample period of 2003 to 2019), we imputed missing data using average environmental R&D expenditures in the same industry from a country where each company belongs. As reported in Online Appendix 5, we find robust evidence supporting that corporate environmental innovation activities are driven by the rising number of women on board, especially when the critical mass is achieved in boardrooms. Lastly, we performed the PSM analysis as follows. We identified company-year pairs which reported zero environmental R&D expenditures and designated those as the treatment group. Next, company-year pairs whose environmental R&D expenditures are missing are grouped into a control group. Using the predicted propensity score estimated in the first-stage logit model, we used the k-Nearest neighbors matching approach to match each pair in the treatment group to ten pairs in the control group, using the same control variables and year- fixed effect as in the baseline regression. The logic behind this matching strategy is that companies in the treatment group which actually reported zero environmental R&D expenditures are virtually identical to companies in the control group that do not report their environmental R&D expenditures in terms of contemporaneously observable company- and country-level control variables. This identification strategy allows us to identify companies in the control group who might report zero environmental R&D expenditures if they decided to do so. Next, we

filled in missing environmental R&D expenditures using zero for those identified companies in the control group and re-estimated Equations (1), (2), and (3) to retest H1, H2, and H3, respectively. As shown in Online Appendix 6, we found consistent results supporting our primary findings.

4.7 Qualitative analysis outcomes

The results of the quantitative analysis are also confirmed in the qualitative analysis. In both case studies, respondents suggested female board members have somewhat stronger attitudes and feelings toward environmental issues, which is why they are likely to influence their organizational actions toward environmental sustainability. In both companies studied, the difference between the gender mindset is clearly articulated. Our in-depth discussion with the board of directors of a British firm, which represent our case study for a feminine society, explicitly revealed that "*female have a different sensitivity to males, no doubt about it…they raise more concerns towards such [environmental sustainability] issues…*" and are more likely to suggests how it can be addressed. Similarly, a discussion with the board members of an Indian firm, which represents our second case study from a masculine society, confirmed that female board members have a different attitude towards environmental issues. The board members suggest that women associate more with environmental causes because environment and nature are generally considered feminine issues, "*we add the prefix 'mother' to nature, called 'Mother Nature' which automatically gives a feminine or feminist bend to the nature and associated issues of environment and sustainability, environmental sustainability in particular*."

Differences in personality traits also seem to emerge from women's empathetic attitude towards people and a general sense of inequality towards women in society, which naturally motivates them to seek equity and fairness in the system. The other respondents (herein

referred to as Independent Director) have extensive board-level crossvergence experience from both masculine and feminine cultures. They confirmed that female board members push more for environmental sustainability mandates. An independent director, 'A,' a British national, who has extensive board- level experience in the UK and US firms, suggested that "*there is far more concerted effort to push this [environmental sustainability] mandate from female senior leaders than I have seen from male senior leaders. Male perspective is centered around the short term, the deliverable of profit, the impact to bottom line, and to share price. In contrast, female perspective is more empathetic to things that are longer term, and people related either directly or more broadly around corporate social responsibility*". Another independent director, 'B,' a Brazilian national, who has crossed borders into Europe, said that "*as a female, you have already seen a lot of attitude [inequality] and females want to redeem this…they want to do things in a fair way…environmental sustainability is about equality, it is about to be more fair with the world and with actions… having a gender balance… it's already, an example of a fairness [in corporate culture]...from a maternal side, females in general are more concerned more aware about what's better for the group for the society for the environment. They want to have a better world for their kids, a good world to live in…".*

This effect of a woman board member having a subdued voice is apparent in the second case study based in a masculine society, i.e., India, with native board members. In-depth discussions with the company board revealed the importance of critical mass, i.e., more female board members, which was considered important for strengthening their opinion. One of the female board members revealed that "*if you have just one single voice, it is very easy to be lost at times… at the board level when decisions are taken, often they are majority votes right, you have to convince the majority of the board…. even if you're not able to hit an absolute*

[majority] you know number then definitely having a critical mass is very, very important… our female board members used to echo each other and then that became you know a wider voice" that was not easy to be ignored.

The independent director 'B,' who had worked in Brazil, a masculine society, compared her experience with her current experience and confirmed that female voice finds it harder to get traction in a masculine society. She said, "*in Brazil, Brazilian company tends to be more masculine I do see many more high-level managers men, much more than I do see here in Belgium and Netherlands…whenever you have high managers and just what few females it's harder for them to support their point to support the value. Normally people don't tend to realize that the gender affect power, the final decisions.*"

Discussion with the British firm with largely British white board members suggests that "their board have ethos" and gender does not really matter, "*what matters is the idea*." With regard to innovation, the company has already made significant progress, to which the board does not attribute any of its female board members. On further substantiation, the managing director suggested that "*we have got no hang-ups about person [race and gender]…we are only interested in the intellectual approach the views and values as far as people are concerned*".

Similar narratives are also provided by other independent directors who shared their experiences. For instance, the independent director 'B,' who crossed borders from Latin America into Europe, suggested, "*in Netherland, for example, I don't see the big impact being as a woman, considering that the entire quarter is already emerging in sustainability*." Another independent director, 'C,' a British national who has worked in Chinese, British, and US firms, reflected on his experience from a US-based firm where he had an intensive

discussion on an innovation project with a female member. He said, "*based on our discussion, one female member extrapolated the idea and proposed a solution that could address three sustainability development goals. Subsequently, a few of us discussed it over the before lunch and saw the merit*". However, the board did not take it forward because they were already doing enough about it. The decision was "*well we don't need to go any further.*"

In contrast, deliberations with the board of our second case study (India) revealed that female board members provided food for thought and made the board sensitive to environmental issues. This subsequently led to serious discussions and undertaking investments for innovation projects. The managing director of the Indian firm said that "*my own experience has been that women bring that diversity of conversations, the breadth, and depth of conversations, and I think that makes a lot of difference in the decision making at the board level…in the processes and actions and activities"*. In a separate conversation, the executive director also acknowledged how women directors in this firm had transformed organizational practices regarding environmental sustainability. He stated, "with them, it has helped immensely in accentuating the [champions for environmental sustainability in India] character their organization is known for."

5. DISCUSSION

Our findings provide strong theoretical and empirical evidence supporting the critical role played by women directors in making corporate decisions aimed at innovating for environment-related grand challenges, especially when firms achieve critical mass in their BGD. These findings are grounded in the upper echelons theory (Hambrick & Mason, 1984), which, in our case, refers to the board's impact on the firm innovation for the environment-related grand challenges. Specifically speaking, the inclusion of female board members changes the cognitive frame of the corporate board, making the firm more sensitive toward

societal issues, such as environmental challenges (McInerney et al., 2010).

However, it is worth reiterating that our findings show that the presence of one female board member is not sufficient to shift the cognitive frame of a corporate board toward tackling environment-related grand challenges. Some degree of gender diversity—i.e., a critical mass of female board members—is necessary to form an opinion/voice that the organization cannot easily ignore. We argue that this is an important finding because women's voices are sometimes ignored, suppressed (McInerney-Lacombe et al., 2010), and/or included as tokenism (Duguid etal., 2012).

Further results showed that masculine culture, as presented by grammatical gender marking (Santacreu-Vasut et al., 2014; Shoham et al., 2020), has a negative impact on corporate EI. This result is aligned with the value belief theory (Hofstede, 1980, Triandis, 1995) understanding of feminine vs. masculine cultures (Hofstede et al., 2010). As postulated, we also found that the supportive role played by women board members in organizational efforts to innovate for environmental sustainability gains importance and becomes more effective when firms are domiciled in masculine societies. Because in a feminine society, the effectiveness of female board members in pushing for innovation aimed at dealing with environment-related grand challenges is limited because companies domiciled in feminine society, irrespective of their BGD, are generally concerned about the environment.

5.1. Theoretical implications

Our work provides an important contribution to the evolving literature on grand challenges. There is a considerable body of literature on BGD (e.g., Farrell & Hersch, 2005; Adams & Ferreira, 2009), but the current literature does not deal with the impact of BGD on EI, especially in the international contacts that include culture. Scholars (e.g., George et al., 2016)

suggest that more management research is needed to find parsimonious solutions to prevent broader societal issues encountered by all, irrespective of nationality, race, and creed. But more importantly, our theoretical insight on solutions to grand challenges in general and the environmental crisis adds to the nascent literature on the topic. We combine the external factor based on the value belief theory regarding the gender cultural dimension with the internal factor based on the upper echelons theory as represented by the BGD and their impact on the firm EI outcomes. By combining two theories that explain the firm decision and outcomes, we are able to advance the theoretical knowledge of a supply-side solution to the environmental crisis.

The impact of the BGD on EI is a sophisticated topic, as presented in the article but very important for the grand challenge of the environmental crisis. The theoretical effect of females, especially women on the board, on EI is unclear. As we presented, females have higher risk aversion than males (Croson & Gneezy, 2009), leading to the expectation of a negative impact of BGD on EI due to the high risk of R&D expenditures. But the literature also provides evidence that women have superior social responsibility than males (Jaffee & Hyde, 2000, McInerney-Lacombe et al., 2008), resulting in the argument that a stronger voice of females on the board will positively impact EI. Our research advances the upper echelon theory by providing preliminary evidence that women, especially women in the board room, are much more affected by their social responsibility values than the risk eversion, at least regarding corporate EI activity.

In this way, the research also advances the value belief theory. Because the results provide new insight into how gendered culture impacts EI directly and moderates BGD impact on outcomes like EI. It indicates that feminine values provide an additional pillar capable of strengthening feminine beliefs and actions in a given environment (Brooks, 2002). Finally, our

research advances the value belief theory by directly replacing the survey-based cultural dimensions with grammatical markings. The GII can substitute the survey-based dimensions as a proxy for the values they represent. This is an important advance due to the endogeneity problems associated with survey-based cultural dimensions. This means that survey-based cultural dimensions are polluted by current socioeconomic events/cycles when conducting the survey (Shoham, 2023). At the same time, grammatical structures like GII are exogenous to current events because they are stable and do not change over long time periods.

5.2. Practical implications

Williams & Shepherd (2016) conclude that management scholars should contribute in a meaningful way to deal with grand challenges. Even more, Czakon (2019:21) claims that practical implications for grand challenges such as environmental challenges "offer a unique opportunity to take management scholarship to the next level of social legitimacy" by helping the global society tackle its significant problems. EI is categorized as part of the responsible innovation category (Rindfleisch et al., 2020). By definition, any research on the topic should include major practical implications.

Policymakers and firms could use our research to increase EI in for-profit firms. The straightforward implication is that a significant number of women on the board will positively impact EI. On the one hand, shareholders who want to increase EI could nominate more women. This action, on average, will promote policies by the board related to increased EI of the firm.

Also, policymakers could affect the EI of the nation by increasing the number of women on the boards. This could be achieved in different ways, such as quotas of women on boards of directors, like those implemented in the EU.

The empiric of the article shows that women on the board in masculine value societies have the most significant impact on the firm related to environmental innovation. But masculine cultures have high gender roles that lead to low female participation on the board of directors, which means that market forces of masculine societies would not increase the number of women on the board. Increasing the BGD in masculine societies can be achieved mainly through an intervention like regulation.

6. CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

Based on a battery of empirical examinations utilizing panel data of 19,800 firm-year observations (2,966 unique firms domiciled in 52 countries) available from the Refinitiv ESG database, our research presents the causal impact BGD has on environmental innovation. Specifically, we found that a critical mass, not a mere presence of a woman on board, should be attained to make a meaningful influence on corporate decision-making on EI. We further found that local masculine culture plays a detrimental effect on corporate EI activities while the observed positive influence on corporate EI activities of greater presence of women on its board tends to be positively moderated by local masculine culture. Finally, we also emphasize that our results are robust to possible endogeneity concerns between gender diversity on the board and a firm's innovation for environmental challenges and hold true to a battery of robustness tests that included different variables to capture EI and BGD, propensity score matching, instrumental variable approaches among others. With the additional help of substantive qualitative analysis, we argue that our results are buoyant.

With its focus on gendered cultural values, our work considered social institutions' impact on corporate decision-making. While this is an important contribution to the literature, our

quantitative analysis has some inherent limitations. This leaves a gap in our understanding regarding the impact of many other types of institutions like cognitive, normative domains of institutions, and formal regulative institutions, especially with regard to climate change and the policies introduced by governments to promote equality and diversity in organizations. In addition, we use proxies for environmental innovation based on variables provided by the Refinitiv ESG dataset. Although the Refinitiv ESG dataset is a validated source for the environmental sustainability of the corporation (Shoham et al., 2017), using patent applications could be a valuable proxy for environmental innovation. Future research could use patent applications to solidify the results presented above. Also, the simple correlation shown in Table 2 for BGD and environmental R&D expenditures exhibits a negative correlation. Although a simple correlation includes many omitted variables, future research might focus entirely on understanding just the impact of BGD on R&D expenditures for environmental sustainability by the for-profit firm.

BGD literature has been a fast-growing field in the last decade. This is due to the changing social environment that led to a few seminal academic articles (e.g., Adams & Ferreira, 2009) that stimulated academic discussion. But mainly, the field evolved because the body of literature provided evidence that BGD affects board decisions and firm outcomes (Croson & Gneezy, 2009; Delis et al., 2020). The literature, like the current article, mainly focuses on the impact of BGD on corporate outcomes/ governance. But future research should take the BGD the extra mile in understanding two additional issues. The first is a better understanding of the channel that causes women to be influential on the board, like impacting EI. On the one hand, the channel could be that because women have different characteristics like risk aversion, they lead to different outcomes than men on the board. On the other hand, it might be just the direct impact of diversity on the board that leads to different outcomes. In other words, any

type of diversity that changes the dynamic of the "old boys club" will lead to those different outcomes. The second issue is moving from the one poll of women to understanding the impact of women with different characteristics/backgrounds on outcomes like the EI of the firm.

To conclude, the theoretical and empirical highlight two crucial factors (BGD and gendered culture) that impact environmental innovation by the for-profit firm. This is an important contribution to academic discussion and combating our greatest grand challenge, the global environmental crisis.

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Appendix 1. List of Countries in the Sample

Country of Domicile	Freq.	Country of Domicile	Freq.
Australia	887	Luxembourg	21
Austria	109	Malaysia	251
Belgium	238	Mexico	142
Brazil	488	Morocco	18
Canada	968	Netherlands	348
Chile	135	New Zealand	53
China	351	Norway	165
Colombia	68	Oman	9
Cyprus	5	Peru	8
Czechia	27	Philippines	105
Denmark	212	Poland	137
Egypt	11	Portugal	89
Finland	254	Qatar	4
France	940	Russian Federation	237
Germany	620	Saudi Arabia	12
Greece	97	Singapore	195
Hong Kong	625	South Africa	794
Hungary	39	Spain	380
India	483	Sri Lanka	1
Indonesia	190	Sweden	381
Ireland	68	Switzerland	469
Israel	64	Thailand	154
Italy	355	Turkey	134
Japan	2,170	United Arab Emirates	10
South Korea	492	United Kingdom	2,179
Kuwait	17	USA	3,591
Total	**19,800**		

Appendix 2. Definitions of Variables of Interest

	Variable	Definition	Data source
(1)	Environmental Innovation Score	The Thomson Reuter Refinitiv ESG EI category score that reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby create new market opportunities through new environmental technologies and processes or eco-designed products.	Refinitiv ESG
(2)	Log (Environmental R&D expenditure)	The natural log of the total amount of environmental R&D costs (without clean up and remediation costs) plus 1.	Refinitiv ESG
(3)	Female director ratio	Percentage of female directors on the board.	Refinitiv ESG
(4)	Number of female directors	Total number of female directors on board	Refinitiv ESG
(5)	Female director>=1 (Yes/No)	Has a value of 1 if a board has at least one female director on board	Refinitiv ESG
(6)	Female director>=3 (Yes/No)	Has a value of 1 if a board has at least three female directors on board	Refinitiv ESG
(7)	Gender critical mass (Yes/No)	Has a value of 1 for boards with either at least 3 or at least 30% female directors, or both.	Refinitiv ESG
(8)	Log (Board size)	The natural log of the total number of board members at the end of the fiscal year plus 1.	Refinitiv ESG
(9)	Independent director ratio	The percentage of independent board members, as reported by the company	Refinitiv ESG
(10)	Dual CEO (Yes/No)	Has a value of 1 if the CEO simultaneously chaired the board or the chairman of the board was the CEO of the company, and zero otherwise.	Refinitiv ESG
(11)	Log (GDP)	Gross Domestic Product of a host country in current US$ 10 millions	World Bank
(12)	GDP per capita	Gross Domestic Product per capita of a host country measured at current US$ 10 thousands	World Bank
(13)	Sovereign credit rating	The entity rating for long-term foreign currency denominated debt issues. Following Klock, Mansi, and Maxwell (2005) and Pandej, Sirimon, Pornsit, and Lee (2020), we computed credit ratings using a conversion process in which AAA-rated bonds were assigned a value of 22 and D-rated ones a value of 1. Unrated firms were assigned a value of 0.	Compustat Capital IQ
(14)	Log (Number of employees)	The total number of employees, as declared by the company in its CSR reporting	Refinitiv ESG

Appendix 3. Alternative Measures of Corporate Environmental Innovation Activities.

Panel A: Hypothesis 1	(1) LOGIT	(2) LOGIT	(3) LOGIT	(4) LOGIT	(5) LOGIT
VARIABLES			Env_tech		
Female director ratio $_{t-1}$	0.002				
	(0.799)				
Number of female directors $_{t-1}$		0.032*			
		(1.648)			
Female director>=1 (Yes/No) $_{t-1}$			-0.050		
			(-0.789)		
Female director>=3 (Yes/No) $_{t-1}$				0.102*	
				(1.854)	
Gender critical mass (Yes/No) $_{t-1}$					0.126**
					(2.309)
Log (Board size) $_{t-1}$	0.467***	0.414***	0.489***	0.431***	0.427***
	(5.012)	(4.109)	(5.098)	(4.498)	(4.484)
Independent director ratio $_{t-1}$	0.004***	0.004***	0.004***	0.004***	0.004***
	(3.078)	(2.993)	(3.263)	(3.027)	(2.994)
Dual CEO (Yes/No) $_{t-1}$	-0.168***	-0.168***	-0.167***	-0.169***	-0.170***
	(-3.312)	(-3.325)	(-3.299)	(-3.338)	(-3.347)
Log (GDP) $_{t-1}$	1.080***	1.085***	1.086***	1.091***	1.094***
	(3.069)	(3.082)	(3.084)	(3.097)	(3.105)
GDP per capita $_{t-1}$	-0.173**	-0.173**	-0.175**	-0.177**	-0.177**
	(-1.967)	(-1.974)	(-1.995)	(-2.013)	(-2.015)
Sovereign credit rating $_{t-1}$	-0.039	-0.038	-0.040	-0.038	-0.038
	(-1.368)	(-1.324)	(-1.410)	(-1.345)	(-1.331)
Log (Number of employees) $_{t-1}$	0.479***	0.478***	0.481***	0.477***	0.476***
	(24.935)	(24.820)	(25.033)	(24.746)	(24.717)
Constant	-17.339***	-17.247***	-17.391***	-17.282***	-17.287***
	(-7.581)	(-7.541)	(-7.596)	(-7.552)	(-7.553)
Observations	19,539	19,539	19,539	19,539	19,539
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Pseudo R-squared	0.346	0.346	0.346	0.346	0.346

Panel B: Hypothesis 1	(1) LOGIT	(2) LOGIT	(3) LOGIT	(4) LOGIT	(5) LOGIT
VARIABLES			Env_product		
Female director ratio $_{t-1}$	0.006***				
	(2.698)				
Number of female directors $_{t-1}$		0.080***			
		(4.192)			
Female director>=1 (Yes/No) $_{t-1}$			0.120**		
			(2.003)		
Female director>=3 (Yes/No) $_{t-1}$				0.166***	
				(3.178)	
Gender critical mass (Yes/No) $_{t-1}$					0.184***
					(3.572)
Log (Board size) $_{t-1}$	0.530***	0.393***	0.509***	0.478***	0.478***
	(6.037)	(4.142)	(5.649)	(5.298)	(5.342)
Independent director ratio $_{t-1}$	0.003**	0.003**	0.003**	0.003**	0.003**
	(2.245)	(2.138)	(2.384)	(2.315)	(2.296)
Dual CEO (Yes/No) $_{t-1}$	-0.038	-0.036	-0.036	-0.037	-0.037
	(-0.797)	(-0.756)	(-0.756)	(-0.767)	(-0.782)
Log (GDP) $_{t-1}$	0.706**	0.712**	0.688**	0.722**	0.724**
	(2.044)	(2.061)	(1.986)	(2.092)	(2.097)
GDP per capita $_{t-1}$	-0.247***	-0.247***	-0.246***	-0.254***	-0.254***
	(-2.959)	(-2.954)	(-2.944)	(-3.045)	(-3.039)
Sovereign credit rating $_{t-1}$	0.009	0.012	0.008	0.010	0.010
	(0.317)	(0.416)	(0.275)	(0.325)	(0.327)
Log (Number of employees) $_{t-1}$	0.457***	0.455***	0.459***	0.455***	0.454***
	(26.099)	(25.960)	(26.245)	(25.935)	(25.908)
Constant	-7.613***	-7.417***	-7.427***	-7.484***	-7.504***
	(-3.545)	(-3.454)	(-3.450)	(-3.490)	(-3.498)
Observations	18,317	18,317	18,317	18,317	18,317
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Pseudo R-squared	0.315	0.315	0.314	0.315	0.315

Panel C: Hypothesis 1	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
VARIABLES			Env_tech_factor		
Female director ratio $_{t-1}$	0.001				
	(1.139)				
Number of female directors $_{t-1}$		0.012*			
		(1.884)			
Female director>=1 (Yes/No) $_{t-1}$			-0.016		
			(-0.758)		
Female director>=3 (Yes/No) $_{t-1}$				0.033*	
				(1.704)	
Gender critical mass (Yes/No) $_{t-1}$					0.041**
					(2.180)
Log (Board size) $_{t-1}$	0.130***	0.111***	0.139***	0.120***	0.119***
	(4.172)	(3.274)	(4.287)	(3.749)	(3.736)
Independent director ratio $_{t-1}$	0.001**	0.001**	0.001***	0.001***	0.001**
	(2.576)	(2.528)	(2.762)	(2.579)	(2.552)
Dual CEO (Yes/No) $_{t-1}$	-0.021	-0.021	-0.021	-0.021	-0.021
	(-1.152)	(-1.146)	(-1.149)	(-1.145)	(-1.149)
Log (GDP) $_{t-1}$	0.270**	0.271**	0.274**	0.273**	0.273**
	(2.431)	(2.433)	(2.464)	(2.451)	(2.452)
GDP per capita $_{t-1}$	-0.029	-0.029	-0.030	-0.030	-0.030
	(-1.059)	(-1.048)	(-1.112)	(-1.098)	(-1.093)
Sovereign credit rating $_{t-1}$	-0.012	-0.011	-0.012	-0.012	-0.011
	(-1.280)	(-1.216)	(-1.338)	(-1.252)	(-1.241)
Log (Number of employees) $_{t-1}$	0.156***	0.156***	0.157***	0.156***	0.155***
	(27.678)	(27.545)	(27.788)	(27.448)	(27.404)
Constant	-2.608***	-2.555***	-2.657***	-2.586***	-2.577***
	(-7.799)	(-7.614)	(-7.921)	(-7.731)	(-7.705)
Observations	19,174	19,174	19,174	19,174	19,174
R-squared	0.355	0.356	0.355	0.356	0.356
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Adjusted R-squared	0.351	0.351	0.351	0.351	0.351

Panel D: Hypothesis 2	(1) LOGIT	(2) LOGIT	(3) OLS
VARIABLES	Env_tech	Env_product	Env_tech_factor
GIIv2 factor	-0.158***	-0.173***	-0.078***
	(-4.487)	(-5.089)	(-5.889)
Log (Board size) $_{t-1}$	0.545***	0.671***	0.177***
	(6.704)	(8.668)	(6.128)
Independent director ratio $_{t-1}$	-0.002**	-0.003***	-0.002***
	(-2.157)	(-4.038)	(-4.456)
Dual CEO (Yes/No) $_{t-1}$	-0.058	0.084*	0.007
	(-1.235)	(1.904)	(0.393)
Log (GDP) $_{t-1}$	-0.028	-0.073***	-0.007
	(-1.519)	(-4.071)	(-0.934)
GDP per capita $_{t-1}$	0.070***	0.091***	0.038***
	(3.856)	(5.033)	(5.455)
Sovereign credit rating $_{t-1}$	0.001	0.039***	-0.003
	(0.131)	(3.822)	(-0.752)
Log (Number of employees) $_{t-1}$	0.424***	0.426***	0.149***
	(24.085)	(25.726)	(26.469)
Constant	-10.824***	-3.879***	-2.024***
	(-10.228)	(-11.212)	(-14.220)
Observations	18,727	17,475	18,344
R-squared			0.337
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Country FE	NO	NO	NO
Adjusted/Pseudo R-squared	0.322	0.281	0.334

Panel E: Hypothesis 3	(1) LOGIT	(2) LOGIT	(3) LOGIT	(4) LOGIT	(5) LOGIT
VARIABLES			Env_tech		
Interaction	0.010***	0.086***	0.193**	0.200***	0.167**
	(3.684)	(4.155)	(2.548)	(2.616)	(2.189)
GIIv2 factor	-0.274***	-0.283***	-0.267***	-0.209***	-0.202***
	(-5.215)	(-5.536)	(-4.064)	(-4.933)	(-4.771)
Female director ratio $_{t-1}$	-0.001				
	(-0.296)				
Number of female directors $_{t-1}$		0.004			
		(0.231)			
Female director>=1 (Yes/No) $_{t-1}$			-0.143**		
			(-1.975)		
Female director>=3 (Yes/No) $_{t-1}$				0.105*	
				(1.852)	
Gender critical mass (Yes/No) $_{t-1}$					0.115**
					(2.039)
Log (Board size) $_{t-1}$	0.555***	0.589***	0.629***	0.526***	0.518***
	(6.715)	(6.434)	(7.408)	(6.063)	(6.020)
Independent director ratio $_{t-1}$	-0.000	-0.001	-0.000	-0.002*	-0.002**
	(-0.384)	(-0.648)	(-0.173)	(-1.832)	(-1.971)
Dual CEO (Yes/No) $_{t-1}$	-0.068	-0.070	-0.075	-0.064	-0.064
	(-1.448)	(-1.486)	(-1.595)	(-1.371)	(-1.358)
Log (GDP) $_{t-1}$	-0.048**	-0.043**	-0.042**	-0.031	-0.029
	(-2.495)	(-2.241)	(-2.204)	(-1.604)	(-1.507)
GDP per capita $_{t-1}$	0.070***	0.066***	0.071***	0.067***	0.067***
	(3.792)	(3.596)	(3.875)	(3.632)	(3.649)
Sovereign credit rating $_{t-1}$	0.004	0.004	0.004	0.001	0.001
	(0.404)	(0.379)	(0.425)	(0.130)	(0.086)
Log (Number of employees) $_{t-1}$	0.429***	0.429***	0.429***	0.425***	0.424***
	(24.228)	(24.157)	(24.203)	(23.965)	(23.929)
Constant	-10.848***	-10.941***	-10.961***	-10.699***	-10.663***
	(-10.262)	(-10.285)	(-10.350)	(-10.093)	(-10.063)
Observations	18,661	18,661	18,661	18,661	18,661
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Pseudo R-squared	0.322	0.322	0.323	0.322	0.322

Panel F: Hypothesis 3	(1) LOGIT	(2) LOGIT	(3) LOGIT	(4) LOGIT	(5) LOGIT
VARIABLES			Env_product		
Interaction	0.026***	0.183***	0.698***	0.474***	0.468***
	(8.844)	(8.042)	(9.271)	(6.127)	(6.078)
GIIv2 factor	-0.499***	-0.466***	-0.645***	-0.294***	-0.295***
	(-9.812)	(-9.303)	(-9.905)	(-7.316)	(-7.335)
Female director ratio $_{t-1}$	0.013***				
	(5.958)				
Number of female directors $_{t-1}$		0.095***			
		(5.168)			
Female director>=1 (Yes/No) $_{t-1}$			0.197***		
			(2.844)		
Female director>=3 (Yes/No) $_{t-1}$				0.334***	
				(5.865)	
Gender critical mass (Yes/No) $_{t-1}$					0.357***
					(6.341)
Log (Board size) $_{t-1}$	0.609***	0.558***	0.689***	0.567***	0.560***
	(7.705)	(6.462)	(8.454)	(6.931)	(6.916)
Independent director ratio $_{t-1}$	-0.002***	-0.003***	-0.002**	-0.003***	-0.003***
	(-2.613)	(-2.879)	(-2.075)	(-3.790)	(-3.880)
Dual CEO (Yes/No) $_{t-1}$	0.067	0.067	0.061	0.074*	0.074*
	(1.497)	(1.492)	(1.371)	(1.663)	(1.666)
Log (GDP) $_{t-1}$	-0.091***	-0.086***	-0.096***	-0.075***	-0.074***
	(-4.959)	(-4.691)	(-5.299)	(-4.166)	(-4.088)
GDP per capita $_{t-1}$	0.080***	0.079***	0.083***	0.082***	0.082***
	(4.352)	(4.331)	(4.577)	(4.510)	(4.488)
Sovereign credit rating $_{t-1}$	0.036***	0.037***	0.042***	0.038***	0.037***
	(3.480)	(3.593)	(4.030)	(3.646)	(3.602)
Log (Number of employees) $_{t-1}$	0.429***	0.429***	0.435***	0.425***	0.424***
	(25.596)	(25.571)	(25.890)	(25.438)	(25.397)
Constant	-3.848***	-3.723***	-4.115***	-3.651***	-3.631***
	(-11.041)	(-10.377)	(-11.801)	(-10.335)	(-10.306)
Observations	17,441	17,441	17,441	17,441	17,441
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Pseudo R-squared	0.286	0.286	0.287	0.284	0.284

Panel G: Hypothesis 3	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES			Env_tech_factor		
Interaction	0.007***	0.056***	0.126***	0.175***	0.164***
	(6.400)	(7.259)	(4.275)	(6.107)	(5.725)
GIIv2 factor	-0.159***	-0.164***	-0.159***	-0.123***	-0.122***
	(-7.966)	(-8.467)	(-6.271)	(-7.794)	(-7.674)
Female director ratio $_{t-1}$	0.001				
	(0.705)				
Number of female directors $_{t-1}$		0.004			
		(0.670)			
Female director>=1 (Yes/No) $_{t-1}$			-0.040		
			(-1.630)		
Female director>=3 (Yes/No) $_{t-1}$				0.062***	
				(2.840)	
Gender critical mass (Yes/No) $_{t-1}$					0.067***
					(3.087)
Log (Board size) $_{t-1}$	0.181***	0.202***	0.213***	0.172***	0.168***
	(6.142)	(6.211)	(6.999)	(5.620)	(5.534)
Independent director ratio $_{t-1}$	-0.001**	-0.001**	-0.001**	-0.001***	-0.001***
	(-2.274)	(-2.410)	(-2.289)	(-3.602)	(-3.705)
Dual CEO (Yes/No) $_{t-1}$	0.001	-0.001	0.000	0.002	0.002
	(0.064)	(-0.031)	(0.000)	(0.118)	(0.135)
Log (GDP) $_{t-1}$	-0.016**	-0.014*	-0.012*	-0.009	-0.009
	(-2.205)	(-1.940)	(-1.717)	(-1.286)	(-1.227)
GDP per capita $_{t-1}$	0.038***	0.036***	0.038***	0.036***	0.036***
	(5.330)	(5.150)	(5.388)	(5.157)	(5.155)
Sovereign credit rating $_{t-1}$	-0.002	-0.002	-0.002	-0.003	-0.003
	(-0.619)	(-0.532)	(-0.455)	(-0.811)	(-0.841)
Log (Number of employees) $_{t-1}$	0.151***	0.151***	0.151***	0.150***	0.150***
	(26.656)	(26.704)	(26.650)	(26.471)	(26.422)
Constant	-2.060***	-2.125***	-2.125***	-2.026***	-2.010***
	(-14.252)	(-14.268)	(-14.712)	(-13.789)	(-13.735)
Observations	18,270	18,270	18,270	18,270	18,270
R-squared	0.339	0.339	0.339	0.339	0.339
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Adjusted R-squared	0.336	0.337	0.336	0.336	0.336

Appendix 4. Imputing Missing Environmental R&D using average value by county and industry

Panel A: H1	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Female director ratio $_{t-1}$	0.004				
	(0.491)				
Number of female directors $_{t-1}$		0.033			
		(0.469)			
Female director>=1 (Yes/No) $_{t-1}$			-0.159		
			(-0.835)		
Female director>=3 (Yes/No) $_{t-1}$				0.461***	
				(2.780)	
Gender critical mass (Yes/No) $_{t-1}$					0.541***
					(3.236)
Log (Board size) $_{t-1}$	1.490***	1.455***	1.524***	1.392***	1.398***
	(4.997)	(4.845)	(5.102)	(4.694)	(4.730)
Independent director ratio $_{t-1}$	0.016***	0.016***	0.016***	0.015***	0.015***
	(3.711)	(3.705)	(3.852)	(3.598)	(3.580)
Dual CEO (Yes/No) $_{t-1}$	-0.542***	-0.542***	-0.530***	-0.547***	-0.542***
	(-3.342)	(-3.365)	(-3.297)	(-3.400)	(-3.369)
Log (GDP) $_{t-1}$	0.611	0.606	0.655	0.521	0.499
	(0.603)	(0.597)	(0.649)	(0.515)	(0.494)
GDP per capita $_{t-1}$	0.136	0.138	0.125	0.136	0.136
	(0.546)	(0.553)	(0.503)	(0.547)	(0.549)
Sovereign credit rating $_{t-1}$	-0.148**	-0.148**	-0.158**	-0.143**	-0.141**
	(-2.235)	(-2.231)	(-2.376)	(-2.203)	(-2.175)
Log (Number of employees) $_{t-1}$	0.597***	0.596***	0.602***	0.588***	0.584***
	(8.313)	(8.312)	(8.426)	(8.268)	(8.200)
Constant	8.054*	8.169*	7.873	8.847*	8.980*
	(1.663)	(1.680)	(1.631)	(1.822)	(1.852)
Observations	3,101	3,101	3,101	3,101	3,101
R-squared	0.577	0.577	0.577	0.578	0.578
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Adjusted R-square	0.563	0.563	0.564	0.564	0.564

Robust t-statistics in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Panel B: H2	(1)
	OLS
VARIABLES	Log (Environmental R&D expenditure)
GIIv2 factor	-2.540***
	(-19.357)
Log (Board size) $_{t-1}$	1.430***
	(5.126)
Independent director ratio $_{t-1}$	-0.002
	(-0.832)
Dual CEO (Yes/No) $_{t-1}$	-0.184
	(-1.182)
Log (GDP) $_{t-1}$	-0.049
	(-0.839)
GDP per capita $_{t-1}$	0.340***
	(4.600)
Sovereign credit rating $_{t-1}$	-0.017
	(-0.456)
Log (Number of employees) $_{t-1}$	0.420***
	(7.405)
Constant	7.209***
	(5.309)
Observations	3,082
R-squared	0.537
Year FE	YES
Industry FE	YES
Country FE	NO
Adjusted R-square	0.527

Panel C: H3	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Interaction	0.025***	0.283***	-0.565***	1.199***	1.161***
	(3.082)	(4.065)	(-2.589)	(5.079)	(4.892)
GIIv2 factor	-2.679***	-2.798***	-2.008***	-2.860***	-2.860***
	(-15.705)	(-15.339)	(-10.799)	(-17.517)	(-17.494)
Female director ratio $_{t-1}$	-0.019**				
	(-2.337)				
Number of female directors $_{t-1}$		-0.115*			
		(-1.719)			
Female director>=1 (Yes/No) $_{t-1}$			-1.187***		
			(-4.764)		
Female director>=3 (Yes/No) $_{t-1}$				0.479***	
				(2.681)	
Gender critical mass (Yes/No) $_{t-1}$					0.520***
					(2.893)
Log (Board size) $_{t-1}$	1.442***	1.716***	1.660***	1.402***	1.387***
	(5.065)	(5.915)	(5.782)	(4.950)	(4.904)
Independent director ratio $_{t-1}$	0.003	0.003	0.000	-0.001	-0.001
	(1.066)	(1.049)	(0.127)	(-0.221)	(-0.289)
Dual CEO (Yes/No) $_{t-1}$	-0.206	-0.218	-0.172	-0.217	-0.215
	(-1.324)	(-1.407)	(-1.107)	(-1.388)	(-1.372)
Log (GDP) $_{t-1}$	-0.135**	-0.123**	-0.055	-0.069	-0.065
	(-2.149)	(-2.010)	(-0.950)	(-1.133)	(-1.066)
GDP per capita $_{t-1}$	0.384***	0.360***	0.393***	0.313***	0.311***
	(5.179)	(4.888)	(5.264)	(4.288)	(4.261)
Sovereign credit rating $_{t-1}$	0.009	0.016	-0.007	0.004	0.002
	(0.237)	(0.420)	(-0.204)	(0.103)	(0.064)
Log (Number of employees) $_{t-1}$	0.436***	0.438***	0.435***	0.415***	0.414***
	(7.673)	(7.734)	(7.678)	(7.331)	(7.294)
Constant	7.897***	7.015***	7.901***	8.157***	8.223***
	(6.894)	(5.946)	(6.850)	(7.091)	(7.150)
Observations	3,066	3,066	3,066	3,066	3,066
R-squared	0.540	0.540	0.540	0.539	0.539
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Adjusted R-square	0.529	0.529	0.529	0.529	0.529

Appendix 5. Imputing Missing Environmental R&D using zero after PSM matching

Panel A: H1	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Female director ratio $_{t-1}$	0.067***				
	(3.382)				
Number of female directors $_{t-1}$		0.584***			
		(3.574)			
Female director>=1 (Yes/No) $_{t-1}$			0.484		
			(1.080)		
Female director>=3 (Yes/No) $_{t-1}$				1.305***	
				(2.697)	
Gender critical mass (Yes/No) $_{t-1}$					1.701***
					(3.636)
Log (Board size) $_{t-1}$	1.231*	0.616	1.084	0.958	0.960
	(1.869)	(0.882)	(1.606)	(1.418)	(1.440)
Independent director ratio $_{t-1}$	0.102***	0.102***	0.106***	0.104***	0.104***
	(10.865)	(10.881)	(11.255)	(11.136)	(11.084)
Dual CEO (Yes/No) $_{t-1}$	0.240	0.244	0.329	0.279	0.280
	(0.580)	(0.589)	(0.795)	(0.675)	(0.678)
Log (GDP) $_{t-1}$	0.960	0.911	1.010	1.050	1.067
	(0.354)	(0.337)	(0.369)	(0.386)	(0.394)
GDP per capita $_{t-1}$	-0.190	-0.175	-0.115	-0.201	-0.210
	(-0.247)	(-0.228)	(-0.148)	(-0.260)	(-0.273)
Sovereign credit rating $_{t-1}$	-0.147	-0.148	-0.150	-0.152	-0.156
	(-0.740)	(-0.747)	(-0.761)	(-0.773)	(-0.793)
Log (Number of employees) $_{t-1}$	0.279*	0.258	0.282*	0.272	0.264
	(1.679)	(1.553)	(1.700)	(1.633)	(1.585)
Constant	10.991	12.904	9.854	10.922	11.248
	(0.826)	(0.969)	(0.734)	(0.817)	(0.846)
Observations	2,440	2,440	2,440	2,440	2,440
R-squared	0.417	0.417	0.415	0.416	0.417
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Adjusted R-square	0.388	0.389	0.386	0.387	0.388

Robust t-statistics in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Panel B: H2	(1)
	OLS
VARIABLES	Log (Environmental R&D expenditure)
GIIv2 factor	-3.789***
	(-11.509)
Log (Board size) $_{t-1}$	1.262**
	(1.983)
Independent director ratio $_{t-1}$	0.032***
	(4.186)
Dual CEO (Yes/No) $_{t-1}$	0.804**
	(1.962)
Log (GDP) $_{t-1}$	-1.271***
	(-6.350)
GDP per capita $_{t-1}$	0.698***
	(2.960)
Sovereign credit rating $_{t-1}$	-0.212*
	(-1.876)
Log (Number of employees) $_{t-1}$	0.169
	(1.021)
Constant	20.955***
	(5.563)
Observations	2,415
R-squared	0.336
Year FE	YES
Industry FE	YES
Country FE	NO
Adjusted R-square	0.315

Panel C: H3	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Interaction	0.090***	0.842***	1.378**	3.402***	3.231***
	(3.754)	(4.698)	(2.279)	(5.623)	(5.321)
GIIv2 factor	0.028				
	(1.199)				
Female director ratio $_{t-1}$		0.290			
		(1.612)			
Number of female directors $_{t-1}$			0.732		
			(1.126)		
Female director>=1 (Yes/No) $_{t-1}$				1.530***	
				(2.776)	
Female director>=3 (Yes/No) $_{t-1}$					1.629***
					(3.022)
Gender critical mass (Yes/No) $_{t-1}$	-4.752***	-4.928***	-4.672***	-4.579***	-4.572***
	(-9.830)	(-10.592)	(-8.103)	(-11.686)	(-11.627)
Log (Board size) $_{t-1}$	1.125*	1.139*	1.265*	0.904	0.870
	(1.743)	(1.656)	(1.924)	(1.347)	(1.313)
Independent director ratio $_{t-1}$	0.039***	0.039***	0.034***	0.035***	0.035***
	(4.791)	(4.831)	(4.414)	(4.560)	(4.479)
Dual CEO (Yes/No) $_{t-1}$	0.738*	0.705*	0.784*	0.712*	0.715*
	(1.782)	(1.708)	(1.912)	(1.730)	(1.739)
Log (GDP) $_{t-1}$	-1.435***	-1.378***	-1.330***	-1.336***	-1.323***
	(-6.877)	(-6.742)	(-6.580)	(-6.660)	(-6.620)
GDP per capita $_{t-1}$	0.645***	0.629***	0.657***	0.617***	0.616***
	(2.713)	(2.661)	(2.779)	(2.605)	(2.600)
Sovereign credit rating $_{t-1}$	-0.170	-0.174	-0.192*	-0.177	-0.184
	(-1.473)	(-1.497)	(-1.685)	(-1.555)	(-1.608)
Log (Number of employees) $_{t-1}$	0.171	0.171	0.184	0.152	0.148
	(1.029)	(1.032)	(1.108)	(0.913)	(0.893)
Constant	18.124***	17.906***	17.734***	18.721***	18.931***
	(5.795)	(5.445)	(5.624)	(5.840)	(5.917)
Observations	2,407	2,407	2,407	2,407	2,407
R-squared	0.338	0.340	0.337	0.340	0.340
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Adjusted R-square	0.316	0.318	0.315	0.319	0.318

Figure 1. Theoretical framework

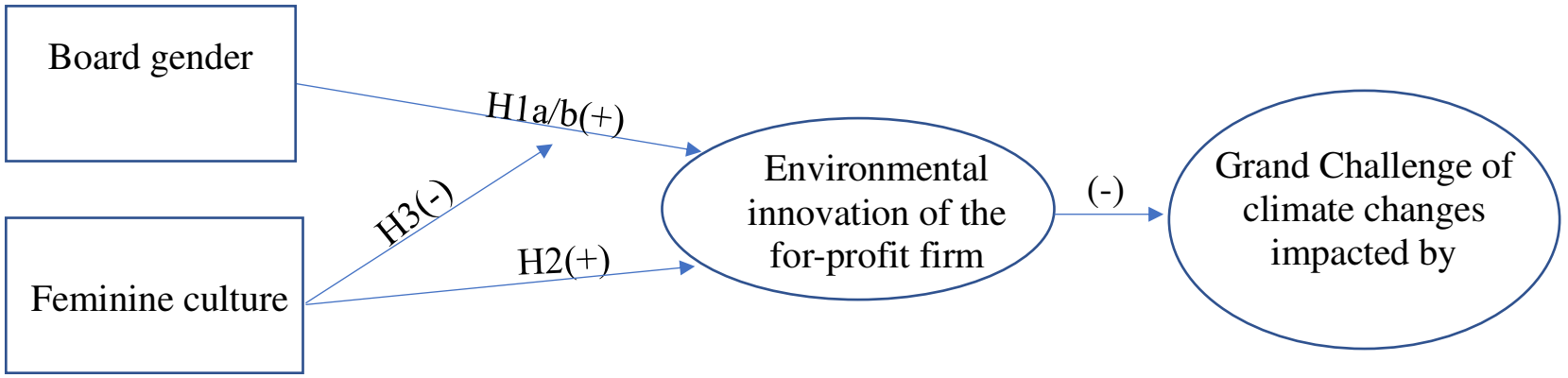

Table 1. Summary Statistics

variable	N	Mean	Median	Std Dev	Min	Max
Environmental Innovation Score	19,088	37.25	35.88	33.42	0.00	99.84
Log (Environmental R&D expenditure)	19,800	1.43	0.00	5.16	0.00	26.70
Female director ratio	19,800	15.67	14.29	12.60	0.00	71.43
Number of female directors	19,800	1.77	2.00	1.55	0.00	13.00
Female director>=1 (Yes/No)	19,800	0.77	1.00	0.42	0.00	1.00
Female director>=3 (Yes/No)	19,800	0.27	0.00	0.44	0.00	1.00
Gender critical mass (Yes/No)	19,800	0.28	0.00	0.45	0.00	1.00
Log (Board size)	19,800	2.46	2.48	0.30	0.69	3.69
Independent director ratio	19,800	55.97	57.14	26.96	0.00	100.00
Dual CEO (Yes/No)	19,800	0.34	0.00	0.48	0.00	1.00
Log (GDP)	19,800	5.39	5.51	1.34	1.18	7.63
GDP per capita	19,800	3.96	4.25	1.88	0.10	11.88
Sovereign credit rating	19,800	19.33	21.00	3.38	3.00	22.00
Log (Number of employees)	19,800	9.48	9.55	1.61	0.00	14.65

Table 2. Correlation Matrix

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1)	Environmental Innovation Score	1.000						
(2)	Log (Environmental R&D expenditure)	0.232***	1.000					
(3)	Female director ratio	0.060***	-0.152***	1.000				
(4)	Number of female directors	0.126***	-0.128***	0.896***	1.000			
(5)	Female director>=1 (Yes/No)	0.018*	-0.167***	0.681***	0.625***	1.000		
(6)	Female director>=3 (Yes/No)	0.125***	-0.076***	0.727***	0.809***	0.332***	1.000	
(7)	Gender critical mass (Yes/No)	0.125***	-0.076***	0.747***	0.804***	0.339***	0.980***	1.000
(8)	Log (Board size)	0.192***	0.082***	0.044***	0.359***	0.183***	0.295***	0.259***
(9)	Independent director ratio	-0.036***	-0.233***	0.360***	0.264***	0.327***	0.191***	0.197***
(10)	Dual CEO (Yes/No)	0.027***	0.022**	-0.017*	0.027***	0.005	0.018**	0.012
(11)	Log (GDP)	0.076***	0.095***	-0.003	0.027***	0.050***	0.010	0.003
(12)	GDP per capita	0.089***	0.001	0.240***	0.156***	0.169***	0.116***	0.124***
(13)	Sovereign credit rating	0.023**	-0.046***	0.177***	0.106***	0.135***	0.064***	0.072***
(14)	Log (Number of employees)	0.259***	0.090***	0.046***	0.173***	0.061***	0.164***	0.153***

	Variables	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(8)	Log (Board size)	1.000						
(9)	Independent director ratio	-0.172***	1.000					
(10)	Dual CEO (Yes/No)	0.123***	0.070***	1.000				
(11)	Log (GDP)	0.081***	0.210***	0.316***	1.000			
(12)	GDP per capita	-0.143***	0.361***	0.126***	0.288***	1.000		
(13)	Sovereign credit rating	-0.149***	0.348***	0.077***	0.281***	0.795***	1.000	
(14)	Log (Number of employees)	0.347***	-0.003	0.166***	0.196***	-0.039***	-0.014*	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table 3. H1: Effect of Board Gender Diversity on Environmental Innovation Performance

Panel A	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Environmental Innovation Score				
Female director ratio $_{t-1}$	0.030				
	(1.374)				
Number of female directors $_{t-1}$		0.689***			
		(3.605)			
Female director>=1 (Yes/No) $_{t-1}$			-0.008		
			(-0.014)		
Female director>=3 (Yes/No) $_{t-1}$				1.566***	
				(2.762)	
Gender critical mass (Yes/No) $_{t-1}$					1.813***
					(3.254)
Log (Board size) $_{t-1}$	8.710***	7.556***	8.824***	8.203***	8.187***
	(9.686)	(7.843)	(9.532)	(8.919)	(8.976)
Independent director ratio $_{t-1}$	0.041***	0.039***	0.043***	0.040***	0.040***
	(3.330)	(3.152)	(3.501)	(3.302)	(3.273)
Dual CEO (Yes/No) $_{t-1}$	-1.374***	-1.372***	-1.367***	-1.371***	-1.374***
	(-2.777)	(-2.774)	(-2.761)	(-2.770)	(-2.778)
Log (GDP) $_{t-1}$	8.404**	8.400**	8.434**	8.508**	8.512**
	(2.520)	(2.520)	(2.527)	(2.552)	(2.553)
GDP per capita $_{t-1}$	-2.820***	-2.792***	-2.843***	-2.864***	-2.858***
	(-3.471)	(-3.439)	(-3.497)	(-3.526)	(-3.519)
Sovereign credit rating $_{t-1}$	-0.108	-0.069	-0.121	-0.093	-0.090
	(-0.388)	(-0.248)	(-0.436)	(-0.333)	(-0.323)
Log (Number of employees) $_{t-1}$	6.096***	6.055***	6.111***	6.064***	6.055***
	(35.444)	(35.158)	(35.585)	(35.199)	(35.138)
Constant	-99.278***	-96.885***	-99.542***	-98.219***	-98.137***
	(-6.827)	(-6.656)	(-6.835)	(-6.755)	(-6.750)
Observations	19,088	19,088	19,088	19,088	19,088
R-squared	0.343	0.344	0.343	0.343	0.343
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Adjusted R-square	0.339	0.339	0.339	0.339	0.339

Panel B	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Female director ratio $_{t-1}$	0.011***				
	(3.879)				
Number of female directors $_{t-1}$		0.086***			
		(3.194)			
Female director>=1 (Yes/No) $_{t-1}$			-0.062		
			(-0.573)		
Female director>=3 (Yes/No) $_{t-1}$				0.265***	
				(3.565)	
Gender critical mass (Yes/No) $_{t-1}$					0.281***
					(3.860)
Log (Board size) $_{t-1}$	0.519***	0.402**	0.583***	0.456***	0.463***
	(3.290)	(2.298)	(3.572)	(2.783)	(2.852)
Independent director ratio $_{t-1}$	0.000	0.001	0.001	0.001	0.001
	(0.232)	(0.332)	(0.671)	(0.386)	(0.383)
Dual CEO (Yes/No) $_{t-1}$	0.129	0.131	0.131	0.131	0.131
	(1.547)	(1.568)	(1.567)	(1.564)	(1.560)
Log (GDP) $_{t-1}$	1.711***	1.719***	1.734***	1.735***	1.734***
	(4.000)	(4.019)	(4.039)	(4.050)	(4.048)
GDP per capita $_{t-1}$	-0.144	-0.147	-0.156*	-0.157*	-0.156*
	(-1.568)	(-1.598)	(-1.693)	(-1.711)	(-1.695)
Sovereign credit rating $_{t-1}$	-0.053	-0.052	-0.059	-0.054	-0.054
	(-1.457)	(-1.414)	(-1.608)	(-1.461)	(-1.462)
Log (Number of employees) $_{t-1}$	0.192***	0.191***	0.198***	0.190***	0.189***
	(7.852)	(7.818)	(8.120)	(7.729)	(7.700)
Constant	-7.880***	-7.648***	-8.048***	-7.751***	-7.756***
	(-4.107)	(-4.001)	(-4.169)	(-4.049)	(-4.051)
Observations	19,800	19,800	19,800	19,800	19,800
R-squared	0.278	0.278	0.277	0.278	0.278
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Adjusted R-square	0.273	0.273	0.273	0.273	0.273

Robust t-statistics in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Table 4. H2: Effect of Local Language on Environmental Innovation Performance

VARIABLES	(1) OLS Environmental Innovation Score	(2) OLS Log (Environmental R&D expenditure)
GIIv2 factor	-1.184*** (-3.053)	-1.503*** (-23.838)
Log (Board size) $_{t-1}$	11.467*** (13.588)	0.562*** (3.846)
Independent director ratio $_{t-1}$	-0.043*** (-4.814)	-0.043*** (-24.256)
Dual CEO (Yes/No) $_{t-1}$	-0.727 (-1.491)	-0.011 (-0.127)
Log (GDP) $_{t-1}$	-1.424*** (-7.304)	0.248*** (8.324)
GDP per capita $_{t-1}$	2.135*** (10.576)	0.355*** (13.114)
Sovereign credit rating $_{t-1}$	0.332*** (2.815)	-0.150*** (-9.036)
Log (Number of employees) $_{t-1}$	5.926*** (35.036)	0.244*** (9.210)
Constant	-82.327*** (-24.362)	-0.672 (-1.195)
Observations	18,258	18,948
R-squared	0.306	0.186
Year FE	YES	YES
Industry FE	YES	YES
Country FE	NO	NO
Adjusted R-square	0.303	0.183

Table 5. H3: Moderating Role of Language on Environmental Innovation Scores

Panel A.	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Environmental Innovation Score				
Interaction	0.308***	2.272***	7.671***	6.036***	5.860***
	(9.899)	(9.840)	(9.026)	(7.031)	(6.853)
GIIv2 factor	-5.107***	-4.883***	-6.256***	-2.806***	-2.800***
	(-8.769)	(-8.739)	(-8.571)	(-6.039)	(-6.011)
Female director ratio $_{t-1}$	0.125***				
	(5.156)				
Number of female directors $_{t-1}$		1.006***			
		(5.298)			
Female director>=1 (Yes/No) $_{t-1}$			1.416*		
			(1.859)		
Female director>=3 (Yes/No) $_{t-1}$				3.996***	
				(6.197)	
Gender critical mass (Yes/No) $_{t-1}$					4.248***
					(6.669)
Log (Board size) $_{t-1}$	11.186***	10.737***	12.253***	10.525***	10.435***
	(13.078)	(11.536)	(14.047)	(11.796)	(11.832)
Independent director ratio $_{t-1}$	-0.024**	-0.028***	-0.019**	-0.040***	-0.041***
	(-2.507)	(-2.990)	(-2.030)	(-4.345)	(-4.467)
Dual CEO (Yes/No) $_{t-1}$	-0.998**	-1.041**	-1.023**	-0.923*	-0.917*
	(-2.046)	(-2.134)	(-2.093)	(-1.891)	(-1.879)
Log (GDP) $_{t-1}$	-1.660***	-1.551***	-1.673***	-1.412***	-1.395***
	(-8.282)	(-7.809)	(-8.488)	(-7.171)	(-7.078)
GDP per capita $_{t-1}$	2.032***	2.012***	2.059***	2.039***	2.036***
	(10.032)	(9.947)	(10.193)	(10.060)	(10.040)
Sovereign credit rating $_{t-1}$	0.308***	0.311***	0.372***	0.306***	0.300**
	(2.608)	(2.629)	(3.153)	(2.592)	(2.541)
Log (Number of employees) $_{t-1}$	5.925***	5.919***	5.986***	5.887***	5.877***
	(34.891)	(34.815)	(35.229)	(34.641)	(34.559)
Constant	-81.336***	-80.555***	-85.518***	-79.261***	-78.860***
	(-23.974)	(-22.664)	(-25.147)	(-22.767)	(-22.770)
Observations	18,184	18,184	18,184	18,184	18,184
R-squared	0.310	0.310	0.310	0.308	0.308
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Adjusted R-square	0.307	0.307	0.308	0.305	0.305

Panel B	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
VARIABLES	Log (Environmental R&D expenditure)				
Interaction	0.040***	0.380***	0.942***	1.159***	1.144***
	(8.457)	(11.111)	(6.323)	(9.555)	(9.451)
GIIv2 factor	-1.971***	-2.034***	-2.088***	-1.782***	-1.784***
	(-20.868)	(-22.373)	(-16.668)	(-24.000)	(-23.981)
Female director ratio $_{t-1}$	-0.001				
	(-0.516)				
Number of female directors $_{t-1}$		-0.074***			
		(-3.007)			
Female director>=1 (Yes/No) $_{t-1}$			-0.377***		
			(-3.962)		
Female director>=3 (Yes/No) $_{t-1}$				0.217**	
				(2.551)	
Gender critical mass (Yes/No) $_{t-1}$					0.248***
					(2.978)
Log (Board size) $_{t-1}$	0.560***	0.902***	0.798***	0.574***	0.542***
	(3.754)	(5.374)	(5.264)	(3.621)	(3.461)
Independent director ratio $_{t-1}$	-0.038***	-0.037***	-0.038***	-0.041***	-0.041***
	(-21.933)	(-21.459)	(-20.741)	(-23.271)	(-23.311)
Dual CEO (Yes/No) $_{t-1}$	-0.023	-0.039	-0.041	-0.018	-0.017
	(-0.275)	(-0.456)	(-0.483)	(-0.217)	(-0.203)
Log (GDP) $_{t-1}$	0.182***	0.177***	0.202***	0.219***	0.219***
	(6.209)	(6.016)	(6.823)	(7.378)	(7.359)
GDP per capita $_{t-1}$	0.349***	0.343***	0.348***	0.340***	0.339***
	(13.030)	(12.795)	(12.987)	(12.622)	(12.593)
Sovereign credit rating $_{t-1}$	-0.142***	-0.134***	-0.138***	-0.146***	-0.146***
	(-8.547)	(-8.126)	(-8.369)	(-8.832)	(-8.834)
Log (Number of employees) $_{t-1}$	0.253***	0.261***	0.253***	0.252***	0.251***
	(9.561)	(9.882)	(9.515)	(9.495)	(9.454)
Constant	-0.706	-1.750***	-1.222**	-0.748	-0.654
	(-1.228)	(-2.881)	(-2.147)	(-1.250)	(-1.100)
Observations	18,874	18,874	18,874	18,874	18,874
R-squared	0.190	0.192	0.192	0.189	0.189
Year FE	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES
Country FE	NO	NO	NO	NO	NO
Adjusted R-square	0.187	0.189	0.189	0.186	0.186

Table 6. H1: Robustness Using Propensity Score Matched (PSM) Sub-Sample

Panel A: PSM diagnostic Logit regression	(1)	(2)
Sample	Full sample (pre-matched)	PSM subsampl (post-matched
Variables	*Treated group*	
Log (Board size) $_{t-1}$	2.973***	-0.093
	(37.199)	(-0.987)
Independent director ratio $_{t-1}$	0.025***	0.000
	(31.539)	(0.486)
Dual CEO (Yes/No) $_{t-1}$	-0.221***	-0.030
	(-5.641)	(-0.617)
Log (GDP) $_{t-1}$	-0.211***	0.008
	(-14.695)	(0.471)
GDP per capita $_{t-1}$	0.232***	-0.015
	(14.266)	(-0.808)
Sovereign credit rating $_{t-1}$	-0.047***	-0.001
	(-5.419)	(-0.059)
Log (Number of employees) $_{t-1}$	0.120***	0.005
	(9.409)	(0.321)
Constant	-9.861***	0.203
	(-38.800)	(0.663)
Observations	19,800	8,692
Year FE	YES	YES
Pseudo R2	0.146	0.000243

Robust z-statistics in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

Panel B: Summary statistics of the propensity score between the treated group and control group

	Obs.	mean	Std. dev	min	p25	p50	p75	max
Treated group	4,346	0.376	0.185	0.000	0.234	0.371	0.507	0.927
Control group	4,346	0.376	0.186	0.000	0.234	0.371	0.508	0.928
Difference	0	0.000	0.000	0.000	0.000	0.000	0.000	-0.001

Panel C: Mean difference tests of the control variables between the treatment and control group

	Treated Group	Control group	Mean Difference	t-statistic
Log (Board size) $_{t-1}$	2.547	2.552	-0.882	0.882
Independent director ratio $_{t-1}$	62.033	61.757	0.515	-0.515
Dual CEO (Yes/No) $_{t-1}$	0.352	0.358	-0.65	0.65
Log (GDP) $_{t-1}$	5.364	5.362	0.076	-0.076
GDP per capita $_{t-1}$	4.217	4.249	-0.803	0.803
Sovereign credit rating $_{t-1}$	19.585	19.625	-0.575	0.575
Log (Number of employees) $_{t-1}$	9.698	9.697	0.03	-0.03

Panel D: PSM Models	(1) OLS	(2) OLS
VARIABLES	Environmental Innovation Score	Log (Environmental R&D expenditure)
Gender critical mass (Yes/No) $_{t-1}$	1.394**	0.191**
	(1.974)	(2.134)
Log (Board size) $_{t-1}$	11.071***	0.406
	(6.944)	(1.645)
Independent director ratio $_{t-1}$	0.078***	0.005
	(3.903)	(1.590)
Dual CEO (Yes/No) $_{t-1}$	0.239	0.019
	(0.309)	(0.171)
Log (GDP) $_{t-1}$	5.671	2.291***
	(0.961)	(3.342)
GDP per capita $_{t-1}$	-2.263*	-0.266**
	(-1.723)	(-2.305)
Sovereign credit rating $_{t-1}$	0.013	-0.018
	(0.028)	(-0.313)
Log (Number of employees) $_{t-1}$	6.473***	0.192***
	(23.280)	(5.574)
Constant	-107.964***	-10.573***
	(-4.194)	(-3.309)
Observations	8,360	8,692
R-squared	0.327	0.235
Year FE	YES	YES
Industry FE	YES	YES
Country FE	YES	YES
Adjusted R-square	0.317	0.223

Table 7. H1: Robustness Using 2LSL IV Estimation

	(1)	(2)	(4)
Stage	IV first	IV second	IV second
VARIABLES	Gender critical mass (Yes/No) $_{t-1}$	Environmental Innovation Score	Log (Environmental R&D expenditure)
Average of number of female directors $_{-1}$ by industry and country	0.166***		
	(30.832)		
Fitted Gender critical mass (Yes/No) $_{t-1}$		11.366***	0.989**
		(4.509)	(2.472)
Log (Board size) $_{t-1}$	0.288***	4.847***	0.218
	(25.422)	(3.919)	(1.118)
Independent director ratio $_{t-1}$	0.002***	0.025**	-0.000
	(10.177)	(2.009)	(-0.171)
Dual CEO (Yes/No) $_{t-1}$	0.011*	-1.411***	0.127
	(1.806)	(-2.860)	(1.636)
Log (GDP) $_{t-1}$	-0.080*	8.932**	1.763***
	(-1.786)	(2.571)	(3.200)
GDP per capita $_{t-1}$	0.016	-2.940***	-0.163
	(1.447)	(-3.460)	(-1.216)
Sovereign credit rating $_{t-1}$	-0.015***	0.074	-0.042
	(-4.075)	(0.264)	(-0.934)
Log (Number of employees) $_{t-1}$	0.026***	5.761***	0.167***
	(12.055)	(31.146)	(5.699)
Constant	-0.500**	-15.260	-6.233**
	(-2.063)	(-0.805)	(-2.259)
Observations	19,088	19,088	19,800
R-squared	0.387	0.333	0.275
Year FE		YES	YES
Industry FE		YES	YES
IV F-stat		950.6	969.5
Durbin pval		9.08e-05	0.0696

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1