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Board gender diversity and firm-level climate change exposure: A global perspective

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ABSTRACT

This study examines the association between board gender diversity and firm-level climate change exposure. Using a global sample of 14,685 firm-year observations covering 2469 firms across 63 countries from 2000–2021, we find that firms with more gender-diverse boards are likely to exhibit lower climate change exposure. The results remain after we decompose the exposure into three components: exposures to opportunity, physical (e.g., sea level rises), and regulatory shocks (e.g., carbon taxes, cap and trade markets). Our critical mass analysis further confirms that boards with at least two female directors start having such a significant effect.

1. Introduction

Over the years, we have seen an improved position for gender diversity within businesses, yet female directors are still under-represented within a firm's boardroom compared to males globally (e.g., Catalyst, 2016; Liu, 2018). Academic evidence supports the beneficial and significant roles of females in corporate leadership (Cumming et al., 2015), innovation (Torchia et al., 2011), financial and market (Campbell and Mínguez-Vera, 2008; Liu et al., 2014), environmental and social responsibility performance (Bruna et al., 2022; Jia and Zhang, 2013; McGuinness et al., 2017; Nguyen et al., 2021) as well as ecological violations/concerns (Liu, 2018). Theoretically, more gender-diverse boards are contended to bring added value, unique opinions and perspectives to boardroom discussions and meetings, improve board dynamics and enhance group decision-making (Cumming et al., 2015; Liu, 2018). In addition, female directors and executives are argued to be more community-minded and caring towards others due to the upbringing of women, which enables them to manage stakeholder relationships better (Liu, 2018). This is in line with the social role and gender socialization theories and diversity of opinion standpoint.

Most prior gender diversity-environment studies were carried out in the context of a single country (Elmagrhi et al., 2019; Liao et al., 2015; Rao et al., 2012) while few of them (Galbreath, 2010; Gull et al., 2022) use a cross-country data. They have considered environmental issues under various viewpoints and measures such as waste generation/recycling (Gull et al., 2022), ecological lawsuits (Liu, 2018), corporate philanthropic disasters (Jia and Zhang, 2013), climate change (Galbreath, 2010), and ESG (Velte, 2016). These measures can be collected by using databases such as Rakins, Bloomberg and Datastream (Elmagrhi et al., 2019; Gull et al., 2022), dummy variables (Liao et al., 2015), or content analysis (Galbreath, 2010). To date, no prior research examines whether

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and how board gender diversity is associated with firm-level climate change exposure (**FCCE** hereafter), which was recently developed by Sautner et al. (2020), who used transcripts of quarterly earnings conference calls[1] to "construct time-varying measures of how to call participants across the globe perceive firms' exposures to different facets of climate change" (pg. 1). Novel to the gender diversity and **FCCE** literature, we fill this critical void by linking corporate gender diversity to a specific value-enhancing corporate environmental concerns, **FCCE**. Our study covers the crucial climate change issues which seriously impact the human living environment and corporate activities, especially after the Paris Agreement.

Using a global sample of 14,685 firm-year observations covering 2469 firms across 63 countries from 2000 to 2021, we find that firms with more gender-diverse boards are likely to exhibit a lower level of FCCE. Results are robust after we employ different methods to treat the endogeneity and self-selection biases, such as Instrumental variable quantile regression panel data (IV-QRPD), using lagged independent variables ($t = 1,2,3$) and propensity score matching (PSM). Findings are also held after we decompose the FCCE into three components related to the exposures to opportunity, physical (e.g., sea level rises) and regulatory (e.g., carbon taxes, cap and trade markets) shocks. Our critical mass analysis further confirms that only when the board includes two or more females can make such results be significant.

2. Research background and hypotheses

Several theories have implied that female directors are more concerned about environmental issues than male peers. First, the **ecofeminism** theory states that female directors put more effort into mitigating ecological issues to protect 'nature' because they, as women, have closer relationships with 'nature' given their unique biology and social constructions (Buckingham-Hatfield, 2001). Second, **gender socialization, social role**, and **ethicality** theories also support that women are more moral, inclusive, stakeholder-oriented, and compassionate (Eagly, 2013). They are willing to respond to social expectations and recognize ethical issues more quickly than men (Bernardi et al., 2006). Hence, the presence of female directors in boardrooms encourages firms to disclose environmental performance to meet the expectations of a broader range of stakeholders (McGuinness et al., 2017).

Third, **legitimacy** and **neoinstitutional** theories argue that recruiting more female directors can improve a firm's reputation because they might pressure firms to engage more in corporate social responsibilities (CSR), such as environmental information disclosures (Suchman, 1995). Furthermore, the difference in "helping" behaviour between men and women still exists (Eagly, 2013). For example, the more women the corporate boards have, the more donations to charities the companies make (Williams, 2003). Similarly, from the **agency** perspective, female directors may improve board effectiveness because they are good at managerial monitoring skills and bring various ideas, opinions, skills and views to their corporate boards (Jensen and Meckling, 1976; McGuinness et al., 2017). Hence, a higher proportion of female directors increases environmental disclosure because they are more likely to be concerned with the environment (Liao et al., 2015). Taking all theories together, we contend that corporate boards with more female directors should be more efficient in addressing environment-related issues, particularly in reducing firm-level climate change exposures.

Prior studies have already investigated the relationships between female directors and corporate environmental performance using the single context of developed countries (e.g., Canada, UK, US) (Rao et al., 2012; Rupley et al., 2012) and developing countries (e.g., China, Libya, Malaysia) (Elmagrhi et al., 2019). Some other research offers global views on how female directors affect corporate environmental performance (Galbreath, 2010; Gull et al., 2022), which can be measured by CSR (Liao et al., 2018), greenhouse gas disclosure (Liao et al., 2015), climate change (Galbreath, 2010), waste management (Gull et al., 2022), among others. However, their results are mixed.[2] The different results can be explained by an increase in the appointment of women[3] on corporate boards. More women serving in boardrooms give them greater voices and, in turn, increase their power to influence their firm's environmental protection decisions. Based on the above-mentioned theoretical explanations and empirical evidence, we propose the following hypothesis in the alternative form:

H_1: Firms with more female directors exhibit lower level of climate change exposure

According to **tokenism** theory, the minor appointment of female directors can show gender equality but does not affect board decision-making (Torchia et al., 2011). Thus, the negligible presence of female directors may have insignificant effects on corporate environmental performance. **Critical mass** theory suggests that the minority group only impacts the group's decision-making if they reach the necessary mass size (Kanter, 1977). Therefore, the critical mass of female directors has more activities to reduce environmental issues. There are two ways to define the critical mass of women board members. First, based on the number of women directors, many previous studies (Liu et al., 2014; Torchia et al., 2011) consider that having one, two and three women directors can be considered as a (a) token, (b) presence and (c) voice, respectively. On the other hand, critical mass can be based on the ratio of female

[1] Key quarterly corporate events in which managers can share information with financial analysts who can ask questions relevant to the firm's current and future developments.

[2] Prado-Lorenzo and Garcia-Sanchez (2010) find that female directors do not affect environmental performance because they are not involved in disclosing greenhouse gas emissions. Galbreath (2010) concludes that female board members cannot address climate change. By contrast, Gull et al. (2022) find a negative relationship between the presence of more women on corporate boards and the waste generation of the firms.

[3] Specifically, the average percentage of female directors for the sample of Prado-Lorenzo and Garcia-Sanchez (2010) and Galbreath (2010) is 10 per cent, while the sample of Gull et al. (2022) has more than 15 per cent of female directors.

Table 1
Descriptive statistics.

	N	mean	sd	min	p25	p50	p75	max
CC^{Exp}	88,818	1.113	2.298	0.000	0.107	0.344	0.930	14.442
CCEXOP	88,818	0.425	1.128	0.000	0.000	0.069	0.285	7.480
CCEXRG	88,818	0.062	0.213	0.000	0.000	0.000	0.000	1.448
CCEXPH	88,818	0.010	0.044	0.000	0.000	0.000	0.000	0.313
%Female	49,355	0.157	0.127	0.000	0.059	0.143	0.250	0.500
Ln(Btenure)	47,557	1.842	0.543	0.095	1.522	1.886	2.222	2.939
#BMeeting	44,026	2.105	0.434	1.386	1.792	2.079	2.398	3.258
LnBsize	49,748	2.238	0.315	1.386	2.079	2.197	2.485	2.996
Duality	245,388	0.084	0.277	0.000	0.000	0.000	0.000	1.000
ESG	49,845	43.851	20.419	7.450	27.050	42.210	59.580	87.820
CSR committee	245,388	0.098	0.298	0.000	0.000	0.000	0.000	1.000
Sale growth	135,434	0.002	0.010	−0.010	0.000	0.001	0.002	0.075
MTB	156,666	0.028	0.054	−0.196	0.010	0.019	0.035	0.324
Ln(Assets)	146,247	13.368	2.328	6.791	11.871	13.516	14.993	18.294
Debt/Assets	142,566	0.255	0.245	0.000	0.048	0.219	0.377	1.362
Cash/Assets	140,804	0.046	0.066	0.000	0.001	0.020	0.062	0.359
PPE/Assets	144,500	0.282	0.248	0.001	0.074	0.204	0.439	0.912
EBIT/Assets	141,865	−0.023	0.341	−2.146	−0.015	0.059	0.112	0.417
RD/Assets	79,497	0.098	0.178	0.000	0.004	0.031	0.108	1.131
GDP growth	239,010	2.329	2.541	−5.694	1.550	2.289	3.483	9.551
Inflation	239,010	2.568	2.276	−1.608	1.328	1.974	3.086	11.260
RD/GDP	204,588	2.388	0.709	0.307	1.943	2.632	2.782	3.475

Notes: This table shows the descriptive statistics of all variables, which are defined in Appendix 1.

directors. Many previous studies support that a critical mass of female directors has enough power to affect corporate board decision-making (Gull et al., 2022; Nerantzidis et al., 2022). For instance, according to Nerantzidis et al. (2022), firms positively impact corporate social performance if their board has more than 25% of female members, which is considered a critical mass of women directors. Furthermore, Torchia et al. (2011) conclude that the critical mass of female directors (boards with at least three women) strongly influences corporate innovation. However, more recently, Gull et al. (2022) consider the power of two female board members. As a result, they find that firms with at least two female directors can reduce waste generation and increase their recycling activities. In this study, we share the same views as Gull et al. (2022) because the power of individual women has increased in recent years after the revolutions of females and improved equality policies worldwide. Thus, we formulate our second "critical mass" hypothesis as follows:

H_2: Two or more female directors on the board have a significantly negative impact on the firm level of climate change exposure.

3. Data and sample

We begin our global sample by employing a comprehensive list of ISIN codes for our primary dependent variable proxying firm-level climate exposure risk CC^{Exp} by Sautner et al. (2020).[4] Our initial sample includes 13,297 firms for 2001–2021, with 106,459 firm-year observations. With this comprehensive list of ISINs for international equity markets, we then extract data on corporate ESG from Refinitiv Eikon (formerly ASSET4), which is popularly used in the previous literature on ESG/CSR linked to female-related corporate governance perspectives, see sample studies by Gull et al. (2022) and Gillan et al. (2021). In line with international evidence on board gender diversity by Griffin et al. (2021), we extract data on board gender diversity (%Female), corporate governance and selected firm-level controls $(X_{k,it})$ from World Scope for the entire initial sample. We exclude financial firms with SIC codes between 6000–6999 from our initial sample for empirical analysis. We collect country-level indicators from World Development Indicators (WDI), World Bank.[5] Our final sample includes 14,685 firm-year observations covering 2469 firms across 63 countries from 2000 to 2021.

4. Methodology

We follow the estimation techniques of Bruna et al. (2022) as our study deals with similar board gender diversity and sustainability

[4] At the data processing time, we employ the yearly version as of 2021-Q4 provided by the authors via https://osf.io/fd6jq/. The version provides annual firm-level climate exposure data for a total of 13,297 firms for 2001-2021, with 106,459 firm-year observations for our initial sample.

[5] This data can be accessed via WDI - Home (worldbank.org), version as of 2021-Q4. The database is widely used in both economic and finance streams for bulk country-level data worldwide with cross-country evidence in empirical finance (e.g., Trinh et al., 2022; Gull et al., 2022).

Table 2
Board gender diversity and firm-level climate change exposure: a global perspective.

VARIABLES	Pooled OLS [1] CC^{Exp}	Fixed Effects [2] CC^{Exp}	System GMM [3] CC^{Exp}	Instrumental variable quantile regression panel data (IV-QRPD) [4] Q10 CC^{Exp}	[5] Q25 CC^{Exp}	[6] Q50 CC^{Exp}	[7] Q75 CC^{Exp}	[8] Q90 CC^{Exp}
CC^{Exp}_{t-1}	**0.806*****	**0.400*****	**0.853*****	**0.368*****	**0.550*****	**0.781*****	**0.948*****	**1.138*****
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
%Female	**−0.177****	**−0.239***	**−0.352**	**−0.026****	**−0.046****	**−0.048***	**−0.116*****	**−0.139****
	[0.037]	[0.056]	[0.568]	[0.036]	[0.015]	[0.053]	[0.001]	[0.025]
Ln(Btenure)	−0.016	0.044	0.248	−0.004	−0.003	0.005	−0.002	−0.021
	[0.425]	[0.201]	[0.410]	[0.155]	[0.523]	[0.344]	[0.770]	[0.110]
#BMeeting	0.012	0.018	1.020	0.000	0.002	0.007	0.020**	0.012
	[0.586]	[0.529]	[0.144]	[0.986]	[0.712]	[0.288]	[0.038]	[0.483]
LnBsize	0.027	−0.121*	−0.284	−0.002	−0.003	0.008	0.031	0.025
	[0.486]	[0.054]	[0.726]	[0.807]	[0.711]	[0.472]	[0.101]	[0.458]
Duality	−0.019	−0.014	−0.072	0.003	0.004	0.002	−0.018**	−0.013
	[0.291]	[0.625]	[0.583]	[0.205]	[0.354]	[0.651]	[0.032]	[0.345]
ESG	0.001	−0.001	−0.001	0.000***	0.000***	0.000*	0.000	0.001*
	[0.117]	[0.218]	[0.828]	[0.000]	[0.003]	[0.052]	[0.123]	[0.085]
CSR committee	0.009	0.034	−0.013	−0.007*	0.012**	−0.000	0.008	0.032**
	[0.702]	[0.246]	[0.933]	[0.086]	[0.032]	[0.980]	[0.473]	[0.039]
Sale growth	−0.344	−0.274	0.297	−0.226**	−0.598***	−0.075	0.054	−0.568
	[0.809]	[0.866]	[0.879]	[0.010]	[0.000]	[0.871]	[0.831]	[0.504]
MTB	−0.048	0.011	0.166	−0.021	−0.022	−0.041	−0.116***	−0.329***
	[0.738]	[0.947]	[0.528]	[0.178]	[0.389]	[0.223]	[0.007]	[0.001]
Ln(Assets)	0.007	−0.040	0.057	0.012***	0.007***	0.004	−0.001	−0.015***
	[0.446]	[0.115]	[0.517]	[0.000]	[0.001]	[0.101]	[0.876]	[0.003]
Debt/Assets	−0.013	−0.241***	−0.024	−0.006	−0.008	−0.025**	−0.014	−0.021
	[0.785]	[0.004]	[0.778]	[0.295]	[0.348]	[0.044]	[0.441]	[0.562]
Cash/Assets	0.124	0.213	0.020	0.059***	0.052*	0.036	0.144**	0.142*
	[0.436]	[0.287]	[0.955]	[0.006]	[0.082]	[0.405]	[0.015]	[0.095]
PPE/Assets	0.329***	−0.065	0.468*	0.033**	0.070***	0.144***	0.287***	0.524***
	[0.000]	[0.696]	[0.059]	[0.018]	[0.000]	[0.000]	[0.000]	[0.000]
EBIT/Assets	−0.075	−0.034	0.207	−0.001	−0.025*	0.003	−0.020	−0.092**
	[0.234]	[0.701]	[0.386]	[0.903]	[0.060]	[0.834]	[0.433]	[0.039]
RD/Assets	−0.166	−0.042	0.068	0.048***	0.019	0.016	−0.005	−0.117
	[0.201]	[0.867]	[0.804]	[0.002]	[0.296]	[0.596]	[0.898]	[0.192]
GDP growth	−0.001	−0.028***	0.001	−0.002	−0.001	−0.003	0.008	0.007
	[0.889]	[0.006]	[0.958]	[0.417]	[0.636]	[0.422]	[0.109]	[0.398]
Inflation	0.036***	0.019*	0.048*	0.009***	0.007**	0.006*	0.010*	0.020*
	[0.001]	[0.067]	[0.055]	[0.000]	[0.017]	[0.052]	[0.087]	[0.053]
RD/GDP	−0.138**	−0.402***	−0.031	−0.032**	−0.035	−0.078***	−0.126***	−0.256***
	[0.025]	[0.000]	[0.497]	[0.025]	[0.122]	[0.009]	[0.000]	[0.002]
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Constant	0.196	2.195***	−2.451	−0.374***	−0.111	0.225*	0.579**	2.278***
	[0.423]	[0.000]	[0.164]	[0.000]	[0.308]	[0.096]	[0.013]	[0.000]
Observations	14,685	14,685	14,691	14,685	14,685	14,685	14,685	14,685
R-squared	0.791	0.189						
AR(1) [p-value]			0.000					
AR(2) [p-value]			0.410					
Hansen-J test of over-identification [p-value]			0.100					
Number of instruments			62					
Number of firms	2469	2469	2469	2469	2469	2469	2469	2469
Wald Chi 2 [p-value]	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***

Notes: This table shows the regression results of the influence of Board Gender Diversity on Firm-level Climate Change Exposure using different models namely Pooled OLS, Fixed Effects, System GMM, and instrumental variable quantile regression panel data (IV-QRPD). All the variables are defined as in Appendix 1. P-value is in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

Table 3
Robustness: using lagging independent variables and propensity score matching.

	OLS	OLS	OLS	PSM [no replacement]	PSM [$n = 1$]	PSM [$n = 2$]	PSM [$n = 3$]
VARIABLES	[1] CC^{Exp}	[2] CC^{Exp}	[3] CC^{Exp}	[4] CC^{Exp}	[5] CC^{Exp}	[6] CC^{Exp}	[7] CC^{Exp}
%Female$_{[t-3]}$	**−0.440*****						
	[0.008]						
%Female$_{[t-2]}$		**−0.531*****					
		[0.000]					
%Female$_{[t-1]}$			**−0.327****				
			[0.019]				
Treated$_{\%Female}$				**−0.027**	**−0.050*****	**−0.076*****	**−0.061*****
				[0.141]	[0.001]	[0.000]	[0.001]
CC^{Exp}_{t-1}				**0.807*****	**0.860*****	**0.864*****	**0.858*****
				[0.000]	[0.000]	[0.000]	[0.000]
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	No	No	No	No
Constant	1.479***	1.428***	1.553***	0.215	−0.266	−0.434*	−0.415*
	[0.001]	[0.001]	[0.000]	[0.306]	[0.172]	[0.062]	[0.069]
Observations	10,851	12,512	14,162	11,014	19,030	13,501	14,035
R-squared	0.486	0.467	0.457	0.788	0.785	0.784	0.784
Wald Chi 2 [p-value]	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***

Notes: This table presents the results for robust tests to investigate the impact of Board Gender Diversity on Firm-level Climate Change Exposure using lagging independent variables and propensity score matching. All the variables are defined as in Appendix 1. P-value is in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

themes. Besides the pooled ordinary least square (OLS) and fixed effect (FE) models capturing individual heterogeneity, we perform treatments on endogeneity problems potentially caused by omitted variables and reverse causality,[6] through two approaches: GMM and instrumental variable quantile regression (IV-QR)[7] model. The IV-QR is more robust than the GMM as it considers the outliers' influences (Adams, 2016). The technique generally assesses quantile-specific effects, expressing the covariates' impact on both the centre and the tails of a conditional outcome distribution. Furthermore, prior literature (e.g., Bruna et al., 2022; Trinh et al., 2021) show dynamic associations among corporate governance mechanisms, the presence of female directors and corporate performance, risk and policies in nature, leading to another source of endogeneity called "dynamic endogeneity". We address this by controlling the past firm-level climate change exposure, which could affect a firm's contemporaneous exposure and corporate governance attributes, including board gender diversity.

$$CC^{Exp} = \beta_0 + \beta_1 CC^{Exp}_{t-1} + \beta_2 \%Female + \sum \beta_k X_{k,it} + \varepsilon_{it}$$

Regarding the base study by Sautner et al. (2020), the primary dependent variable presents our main variable of interest for firm-level climate exposure risk CC^{Exp}, which defines the firms' exposure to climate change. The variable CC^{Epx} is the overall exposure measure based on the machine learning (ML) approach to proxy how frequently the specified climate change bigrams appear in a transcript for each sample firm. See Footnote 20 and Appendix A by Sautner et al. (2020) for a detailed description.%Female present the percentage of women on board (e.g., Atif et al., 2021; Brieger et al., 2019). $X_{k,it}$ controls for a vector of commonly-used independent firm-level and country-level factors used in the literature. See Appendix 1 for variable definitions, and Table 1 for summary statistics. There is no multicollinearity issue (unreported correlation matrix).

5. Empirical results

5.1. Board gender diversity and firm-level climate change exposure

We test our first hypothesis by analyzing the impact of board gender diversity, measured as the proportion of female board

[6] This is in line with corporate outcomes–board diversity literature (e.g., Bruna et al., 2022) showing that the association between the female presence and outcomes can be causal. For example, our research argues that board gender diversity can reduce firm-level climate change exposure. In contrast, firms exposing such lower vulnerability can also recruit more female directors.

[7] The technique "enables a comprehensive picture between a dependent variable Y and an independent variable X at different points of a conditional distribution. Additionally, QR does not require strict assumptions regarding normality, homoskedasticity and the absence of outliers" (Bruna et al., 2022, Page 3)

Table 4
Gender critical mass.

Panel I: Gender Critical Mass			
VARIABLES	[1] CC^{Exp}	[2] CC^{Exp}	[3] CC^{Exp}
Female3 [*NumWomen>=3*]	**−0.084****		
	[0.014]		
Female2 [*NumWomen >=2*]		**−0.088*****	
		[0.002]	
Female1 [*NumWomen >=1*]			**−0.039**
			[0.287]
Constant	1.400***	1.462***	1.529***
	[0.000]	[0.000]	[0.000]
Observations	15,656	15,656	15,656
R-squared	0.447	0.447	0.446

Panel II: Industry-adjusted gender diversity and Firm-level Climate Change Exposure			
	Panel A: Firms with higher CC exposure than the industry mean [$CC^{Exp} >= CC^{Exp}_{industry}$]	Panel B: Firms with lower CC exposure than the industry mean [$CC^{Exp} < CC^{Exp}_{industry}$]	Panel C: All firms
VARIABLES	[1] Adj_CC^{Exp}	[2] Adj_CC^{Exp}	[3] Adj_CC^{Exp}
$Adj\_CC^{Exp}{}_{t-1}$	**0.626*****	**0.303*****	**0.806*****
	[0.000]	[0.000]	[0.000]
Adj_%Female	**−0.022**	**−0.016*****	**−0.017**
	[0.515]	[0.006]	[0.170]
Constant	0.985	−1.064***	−0.045
	[0.146]	[0.000]	[0.853]
Observations	4219	10,466	14,685
R-squared	0.649	0.767	0.662
Controls	**Yes**	**Yes**	**Yes**
Year-Industry-Country FE	**Yes**	**Yes**	**Yes**
Wald Chi 2 [p-value]	**0.000*****	**0.000*****	**0.000*****

Notes: This table shows the results of testing the effect of the critical mass of women directors on climate change exposure, using dummy variables to indicate one female director (Female1), two female directors (Female2), and three or more than three female directors (Female3). It also presents the results for robust tests to investigate the impact of Board Gender Diversity on Firm-level Climate Change Exposure using two sub-samples based on industry-adjusted gender diversity. All the variables are defined as in Appendix 1. P-value is in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

members (*%Female*), on the FCCE (CC^{Exp}). Column 1 of Table 2 illustrates the main results of Pooled OLS regression. Overall, the coefficient%Female is negative and significant at 5%, suggesting that female directors reduce FCCE. Economically, if a corporate board increase by 1% of board gender diversity, a firm will decrease 0.177% of climate change exposure. In other words, the more women sit on corporate boards, the less the firms have climate change exposure.

To further address the potential endogeneity problem caused by the board gender diversity, we employ a number of regression approaches such as fixed effects, system GMM, instrumental variable quantile regression panel data (IV-QRPD), using lagged independent variables ($t = 1,2,3$) and propensity score matching (PSM) regressions. The results of these analyses are reported in Table 2 (columns 2–8) and Table 3 (columns 1–7). As expected, the coefficient on female directors (*%Female* or $\text{Treated}_{\%\text{Female}}$) is still generally negative and significant, illustrating that board gender diversity decreases FCCE.

Our findings support $\mathbf{H_1}$ by providing strong empirical evidence that women have more concerns about environmental issues such as climate change. Consequently, firms with more female board members tend to exhibit lower levels of climate change exposure. Our results are consistent with prior studies (Gull et al., 2022; Nerantzidis et al., 2022), all of which argue that female directors significantly impact corporate social performance by reducing waste management and increasing waste recycling. Therefore, firms with higher board gender diversity decrease climate change exposure. In addition to board gender diversity, the FCCE in the previous year (CC^{Exp}_{t-1}) reveals significant and positive influences on the FCCE in the current year.

5.2. Testing gender critical mass

To test the impact of the critical mass of women directors on climate change exposure, we use dummy variables to indicate one female director (Female1), two female directors (Female2), and three or more than three female directors (Female3). Table 4 (Panel I)

Table 5
Decompositions of firm-level climate change exposure.

VARIABLES	[1] CC^{ExOP}	[2] CC^{ExRG}	[3] CC^{ExPH}	[CC^{ExOP} >= $CC^{ExOP}_{industry}$] [4] Adj_CC^{ExOP}	[CC^{ExOP} < $CC^{ExOP}_{industry}$] [5] Adj_CC^{ExOP}	[CC^{ExRG} >= $CC^{ExRG}_{industry}$] [6] Adj_CC^{ExRG}	[CC^{ExRG} < $CC^{ExRG}_{industry}$] [7] Adj_CC^{ExRG}	[CC^{ExPH} >= $CC^{ExPH}_{industry}$] [8] Adj_CC^{ExPH}	[CC^{ExPH} < $CC^{ExPH}_{industry}$] [9] Adj_CC^{ExPH}
%Female	**−0.085***	**0.014**	**−0.005**						
	[0.074]	[0.279]	[0.173]						
Adj_% Female				**−0.039***	**0.002**	**−0.001**	**−0.002**	**−0.001***	**0.000**
				[0.066]	[0.835]	[0.830]	[0.494]	[0.074]	[0.860]
CC^{ExOP}_{t-1}	**0.805*****								
	[0.000]								
CC^{ExRG}_{t-1}		**0.452*****							
		[0.000]							
CC^{ExPH}_{t-1}			**0.339*****						
			[0.000]						
$Adj\_CC^{ExOP}_{t-1}$				**0.613*****			**0.256*****		
				[0.000]			[0.000]		
$Adj\_CC^{ExRG}_{t-1}$					**0.291*****			**0.041*****	
					[0.000]			[0.000]	
$Adj\_CC^{ExPH}_{t-1}$						**0.275*****			**−0.002*****
						[0.000]			[0.001]
Constant	0.078	0.127***	0.007	1.124***	0.640***	0.243***	−0.449***	−0.061***	−0.002***
	[0.569]	[0.001]	[0.472]	[0.007]	[0.000]	[0.003]	[0.000]	[0.000]	[0.000]
Observations	14,685	14,685	14,685	3854	2291	1012	10,831	12,394	13,673
R-squared	0.748	0.396	0.219	0.632	0.370	0.453	0.805	0.861	0.968

Notes: This table presents the results for robust tests to investigate the impact of Board Gender Diversity on Firm-level Climate Change Exposure using alternative measure of Firm-level Climate Change Exposure. All the variables are defined as in Appendix 1. P-value is in parentheses. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

reports the results of the analysis. As predicted, the coefficient of a critical mass of board gender diversity is negative. However, the p-value of Female2 and Female 3 is less than 0.05 while the p-value of Female1 is higher than 0.1, illustrating that firms with at least two women board members will significantly reduce climate change exposure. The findings support $\boldsymbol{H_2}$ and previous studies regarding the power of the critical mass of female directors. Particularly, board gender diversity could hit the critical mass of female directors; thus, they will reduce FCCE. However, our results confirm the power of two women directors, which is consistent with the findings of Gull et al. (2022) because our sample shares the same average of board gender diversity.

5.3. *Further tests*

In this section, we re-estimate our regression model after dividing our sample into two sub-samples based on industry-adjusted gender diversity. Specifically, column 1 of Table 4 **(Panel II)** reports the results of firms with higher FCCE than the industry means, while column 2 displays the opposite findings. Furthermore, Table 5 shows the results of using an alternative measure of climate change exposure. The results are still the same as the main findings.

6. Concluding remarks

Using a global sample of 14,685 firm-year observations covering 2469 firms across 63 countries from 2000 to 2021, we find that firms with more gender-diverse boards are likely to exhibit a lower level of climate change exposure. Results are held after decomposing the FCCE into the exposures to opportunity, physical (e.g., sea level rises) and regulatory (e.g., carbon taxes, cap and trade markets) shocks. Our critical mass analysis further confirms that boards with at least two female directors start having such a significant effect. Future researchers could include ecological policies in their model and examine moderating factors such as culture and governance.

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CRediT authorship contribution statement

Vu Quang Trinh: Conceptualization, Data curation, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing. **Hai Hong Trinh:** Data curation, Writing – original draft, Writing – review & editing. **Thi Hong Hanh Nguyen:** Writing – original draft, Writing – review & editing. **Xuan Vinh Vo:** Writing – original draft, Writing – review & editing.

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Data availability

Data will be made available on request.

Appendix 1: Variables, definitions, and sources

Variable	Description	Source
CC^{Exp}	Firm-level climate risk exposure overall	Sautner et al. (2020)
CCEXOP	Firm-level climate risk exposure that captures opportunities related to climate change	Sautner et al. (2020)
CCEXRG	Firm-level climate risk exposure that captures regulatory shocks related to climate change	Sautner et al. (2020)
CCEXPH	Firm-level climate risk exposure that captures physical shocks related to climate change	Sautner et al. (2020)
%Female	Percentage of women on board	DataStream - WorldScope
Ln(Btenure)	Logarithm of board tenure	DataStream - WorldScope
#BMeeting	Number of board meetings per year	DataStream - WorldScope
LnBsize	Logarithm of board size	DataStream - WorldScope
Duality	CEO Duality	DataStream - WorldScope
ESG	Overall ESG score for a firm	Refinitiv Eikon
CSR committee	Dummy variable that is set equal to one if a firm has CSR committee	DataStream - WorldScope
Sale growth	A firm's annual sale growth rate	DataStream - WorldScope
MTB	Market-to-book value	DataStream - WorldScope
Ln(Assets)	Firm size measured by Logarithm of a firm's total assets (in millions)	DataStream - WorldScope
Debt/Assets	Leverage ratio as the ratio of debt to a firm's assets	DataStream - WorldScope
Cash/Assets	Cash to total assets	DataStream - WorldScope
PPE/Assets	Tangibility measured by the ratio of property, plants, and equipment to a firm's total assets	DataStream - WorldScope
EBIT/Assets	The ratio of Earnings Before Interest & Tax to total assets	DataStream - WorldScope
RD/Assets	Research and development expenditure to total assets	DataStream - WorldScope
GDP growth	GDP growth (annual%)	World Development Indicators (WDI) - World Bank
Inflation	Inflation, GDP deflator (annual%)	World Development Indicators (WDI) - World Bank
RD/GDP	Research and development expenditure (% of GDP)	World Development Indicators (WDI) - World Bank

Note: The data on climate exposure risk are extracted from the study by Sautner et al. (2020) that can be accessed at https://osf.io/fd6jq/. Data from DataStream - WorldScope and Refinitv Eikon are extracted using the licensed accounts offered by the School of Economics and Finance, Massey University, Private Bag 11 222 Palmerston North, 4442, New Zealand. World Development Indicators (WDI) - World Bank can be accessed publicly at https://data.worldbank.org/

References

Atif, M., Hossain, M., Alam, M.S., Goergen, M., 2021. Does board gender diversity affect renewable energy consumption? J. Corp. Finance 66, 101665.

Bernardi, R., Bosco, S., Vassill, K., 2006. Does female representation on boards of directors associate with Fortune's 100 Best companies to work for list? Bus. Soc. 45 (2), 235–248.

Brieger, S.A., Francoeur, C., Welzel, C., Ben-Amar, W., 2019. Empowering women: the role of emancipative forces in board gender diversity. J. Bus. Ethics 155, 495–511.

Bruna, M.G., Đặng, R., Houanti, L.H., Sahut, J.M., Simioni, M., 2022. By what way women on corporate boards influence corporate social performance? Evidence from a semiparametric panel model. Finance Res. Lett. 49, 103048.

Buckingham-Hatfield, S. (2001). Gender and Environment. *International Encyclopedia of the Social & Behavioral Sciences,* Pergamon, 5907–5910.

Campbell, K., Mínguez-Vera, A., 2008. Gender diversity in the boardroom and firm financial performance. J. Bus. Ethics 83 (3), 435–451.

Catalyst, 2016 *Catalyst Census: women and Men Board Directors* (2017). Access 22/01/2023 https://www.catalyst.org/research/2016-catalyst-census-women-and-men-board-directors/.

Cumming, D., Leung, T.Y., Rui, O., 2015. Gender diversity and securities fraud. Acad. Manag. J. 58 (5), 1572–1593.

Eagly, A.H., 2013. Sex Differences in Social behavior: A Social-Role Interpretation. Psychology Press.

Elmagrhi, M.H., Ntim, C.G., Elamer, A.A., Zhang, Q., 2019. A study of environmental policies and regulations, governance structures and environmental performance: the role of female directors. Bus. Strat. Environ. 28 (1), 206–220.

Galbreath, J., 2010. Corporate governance practices that address climate change: an exploratory study. Bus. Strat. Environ. 19 (5), 335–350.
Gillan, S.L., Koch, A., Starks, L.T., 2021. Firms and social responsibility: a review of ESG and CSR research in corporate finance. J. Corp. Finance 66, 101889.
Griffin, D., Li, K., Xu, T., 2021. Board gender diversity and corporate innovation: international evidence. J. Financ. Quant. Anal. 56 (1), 123–154.
Gull, A.A., Atif, M., Hussain, N., 2022. Board gender composition and waste management: cross-country evidence. Br. Account. Rev., 101097
Jia, M., Zhang, Z., 2013. Critical mass of women on BODs, multiple identities, and corporate philanthropic disaster response: evidence from privately owned Chinese firms. J. Bus. Ethics 118 (2), 303–317.
Jensen, M.C., Meckling, W.H., 1976. Theory of the firm: managerial behavior, agency costs and ownership structure. J. Financ. Econ. 3 (4), 305–360.
Kanter, R.M., 1977. Some effects of proportions on group life: skewed sex ratios and responses to token women. Am. J. Sociol. 82 (5), 965–990.
Liao, L., Lin, T., Zhang, Y., 2018. Corporate board and corporate social responsibility assurance: evidence from China. J. Bus. Ethics 150 (1), 211–225.
Liao, L., Luo, L., Tang, Q., 2015. Gender diversity, board independence, environmental committee and greenhouse gas disclosure [Article]. Br. Account. Rev. 47 (4), 409–424.
Liu, C., 2018. Are women greener? Corporate gender diversity and environmental violations. J. Corp. Finance 52, 118–142.
Liu, Y., Wei, Z., Xie, F., 2014. Do women directors improve firm performance in China? J. Corp. Finance 28, 169–184.
McGuinness, P.B., Vieito, J.P., Wang, M., 2017. The role of board gender and foreign ownership in the CSR performance of Chinese listed firms [Article]. J. Corp. Finance 42, 75–99.
Nerantzidis, M., Tzeremes, P., Koutoupis, A., Pourgias, A., 2022. Exploring the black box: board gender diversity and corporate social performance. Finance Res. Lett., 102987
Nguyen, T.H., Elmagrhi, M.H., Ntim, C.G., Wu, Y., 2021. Environmental performance, sustainability, governance and financial performance: evidence from heavily polluting industries in China. Bus. Strat. Environ. 30 (5), 2313–2331.
Prado-Lorenzo, J.-.M., Garcia-Sanchez, I.-.M., 2010. The role of the board of directors in disseminating relevant information on greenhouse gases. J. Bus. Ethics 97 (3), 391–424.
Rao, K.K., Tilt, C.A., Lester, L.H., 2012. Corporate governance and environmental reporting: an Australian study [Article]. Corp. Govern. Int. J. Bus. Soc. 12 (2), 143–163.
Rupley, K.H., Brown, D., Marshall, R.S., 2012. Governance, media and the quality of environmental disclosure. J. Account. Public Policy 31 (6), 610–640.
Sautner, Z., van Lent, L., Vilkov, G., & Zhang, R. (2020). Firm-level climate change exposure. *European Corporate Governance Institute–Finance Working Paper*, (686).
Suchman, M.C., 1995. Managing legitimacy: strategic and institutional approaches. Acad. Manage. Rev. 20 (3), 571–610.
Torchia, M., Calabrò, A., Huse, M., 2011. Women directors on corporate boards: from tokenism to critical mass [Article]. J. Bus. Ethics 102 (2), 299–317.
Trinh, H.H., Sharma, G.D., Tiwari, A.K., Vo, D.T.H., 2022. Examining the heterogeneity of financial development in the energy-environment nexus in the era of climate change: novel evidence around the world. Energy Econ. 116, 106415.
Trinh, V.Q., Cao, N.D., Dinh, L.H., Nguyen, H.N., 2021. Boardroom gender diversity and dividend payout strategies: effects of mergers deals. Int. J. Financ. Econ. 26 (4), 6014–6035.
Velte, P., 2016. Women on management board and ESG performance. J. Glob. Responsib. 7 (1), 2041–2056.
Williams, R.J., 2003. Women on corporate boards of directors and their influence on corporate philanthropy. J. Bus. Ethics 42 (1), 1–10.