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Board gender diversity and environmental emissions

Khine Kyaw[1] | Sirimon Treepongkaruna[2,3] | Pornsit Jiraporn[4]

[1]NTNU Business School, Norwegian University of Science and Technology, Trondheim, Norway, Norway

[2]Sasin School of Management, Chulalongkorn University, Bangkok, Thailand

[3]UWA Business School, The University of Western Australia, Perth, WA, Australia

[4]Great Valley School of Graduate Professional Studies, Pennsylvania State University, State College, Pennsylvania, USA

Correspondence
Sirimon Treepongkaruna, Sasin School of Management, Chulalongkorn University, Bangkok 10330, Thailand.
Email: sirimon.treepongkaruna@sasin.edu

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Abstract

The recent climate emergency declaration by many nations around the world signifies the severity of the impact of climate change. As an entity which consumes a large quantity of resources ranging from material to human, corporations have a responsibility to seriously tackle climate change. As a company's board of directors is typically responsible for developing business strategies, including environmental strategies, this paper explores whether gender diversity on corporate boards affect firms' emission performance. Consistent with diversity theory, we find that board gender diversity is positively associated with firms' emission reduction performance. The likelihood that a firm with a gender diverse board reduces environmental emission is 9% higher than its industry peers. To ensure that our results are robust to endogeneity, we conduct additional analyses including propensity score matching (PSM), entropy balancing, and instrumental-variable analysis.

KEYWORDS
emission, environment, gender diversity

1 | INTRODUCTION

Climate crisis has led over 2,000 jurisdictions and local governments, comprising 1 billion citizens, to acknowledge that humanity is facing a climate emergency. Collective efforts to fight global warming and climate change have been put forward by many organizations including the United Nations (UN). Recently, at the 2021 UN climate change conference (COP26), which finally took place in Glasgow, many countries made bold collective commitments to curb methane emissions, halt and reverse forest losses, and align the finance sector with net-zero by 2050. However, they still failed to agree on certain issues such as the phasing out of coal and ending international financing for fossil fuels.

At COP26, governments settled on rules for the global carbon market under Article 6 of the Paris Agreement to ensure that the climate ambition will not be undermined and that environmental and social integrity are preserved. Recognizing this climate emergency, corporations should do more to reduce environmental emissions. Corporate environmental strategies are usually developed and decided at the board level. As such, boards of directors are in a position to guide and prioritize climate change solutions. High quality boards are expected to do more for the environment. Gender diversity on corporate boards is found to improve board quality (Chatjuthamard et al., 2021). We contribute to the literature on environmental emissions by investigating the effect of female board representation on US firms' emission performance, measured by the emission performance score (EP) from Refinitiv.

Gender diversity on corporate boards is important, not just for academics, but also for investors, shareholders, regulators, and lawmakers. In practice, many countries such as Australia, Belgium, France, Germany, Norway, Spain, Iceland, and Italy have enacted legislation mandating the inclusion of women on corporate boards of directors (Li & Chen, 2018). On the academic front, studies on the impact of board gender diversity continue to grow substantially (Adams & Ferreira, 2009; Arun et al., 2015; Campbell & Minguez Vera, 2009; Carter et al., 2003; Erhardt et al., 2003; Kim &

Starks, 2016; Reguera-Alvarado et al., 2015; Sabatier, 2015). This highlights the importance of gender diversity on corporate boards. One strand of literature on board gender diversity explores the magic number of women on a board. It has been shown that at least three women constitute the critical mass on a corporate board (Kramer et al., 2007).

Our findings suggest that female representation on the board improves firms' emission reduction performance. In particular, the likelihood that a firm with a gender diverse board reduces environmental emissions is 9% higher than its industry peers. When using critical mass as a proxy for board gender diversity, we confirm that companies with at least three females on their board of directors have better emission performance. To ensure that our results are not driven by endogeneity, we execute a variety of robustness checks, including propensity score matching (PSM), entropy balancing (EB), and instrumental-variable analysis (IV). Our findings survive all the robustness checks, suggesting that they are unlikely tarnished by endogeneity and hence probably reflect causation rather than mere correlation.

The results of our study contribute to several important areas of the literature. First, we contribute to the debate on gender diversity on corporate boards. The literature suggests that board gender diversity (hereafter, BGD) does not always translate to financial performance (Adams & Ferreira, 2009; Erhardt et al., 2003). However, BGD is positively associated with improved corporate social performance (Bruna et al., 2021; McGuinness et al., 2017) and fewer incidences of unethical conducts (Kyaw et al., 2015) or environmental violations (Liu, 2018). Diversity theory postulates that female directors bring different perspectives to boardroom discussions, which consequently improves the board's advisory function (Cumming et al., 2015; Erhardt et al., 2003). This together with women's disposition towards the welfare of society and community (Adams et al., 2011; Gilligan, 1977) posits that gender diverse boards will execute their advisory role well on environmental issues. Liu (2018) finds that firms with a gender diverse board experience relatively fewer environmental lawsuits. Furthermore, Liao et al. (2015) show that firms with BGD not only exhibit greater propensity to disclose their greenhouse gas emission information but also make more extensive disclosures. However, there is still scant research on whether BGD has any actual impact on environmental welfare, such as emission reductions.[1]

Second, we contribute to the body of knowledge about climate change and carbon emissions. Excessive carbon emissions, according to a growing body of empirical research, reduce business value (Chapple & Humphrey, 2013; Clarkson et al., 2014; Griffin et al., 2017; Luo & Tang, 2014; Matsumura et al., 2013). As a result, the significance of carbon emissions cannot be denied. We contribute to literature in this area by demonstrating that board gender diversity is a main driver of corporate carbon emission performance, in addition to being an essential feature of board governance.

Finally, our research adds to an important body of literature that investigates the critical mass theory (Dobija et al., 2022; Nuber & Velte, 2021; Redor, 2018; Torchia et al., 2011; Wiley & Monllor-Tormos, 2018; Yarram & Adapa, 2021). This is the first research to apply this theory to the relationship between female directors and corporate emission performance.

Our findings offer a few important practical implications. First, our results support the view that female board representation matters, consistent with the recent changes that attempt to increase board gender diversity. Second, carbon emissions regulators should take into account board and corporate governance when designing regulations, as it has been shown that board gender diversity is one of the most significant determinants of corporate carbon emission performance. Finally, investors who are mindful of their environmental responsibility and carbon emissions can take into consideration board gender diversity when making investment decisions.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the data and method. Section 4 presents the results. Section 5 concludes.

2 | LITERATURE REVIEW

2.1 | Board gender diversity

This literature has offered various reasons to support the notion that board gender diversity improves the quality of board governance. Greater gender diversity on a board of directors brings about a larger range of perspectives, which assists in the correction of informational biases during strategy development and problem solving (Dewatripont et al., 1999; Francoeur et al., 2008; Westphal & Milton, 2000). Likewise, the resource dependence theory establishes a theoretical basis for the board of directors' role as a strategic resource (Hillman et al., 2000). Thus, it can be argued that female board members contribute to enhanced corporate governance by bringing a variety of qualities, abilities, and views to the table, and infusing board meetings with new dynamics (Jamali et al., 2007). According to the resource dependence theory, board gender diversity is a fundamental component of board governance and is expected to increase board performance (Chatjuthamard et al., 2021).

In an agency framework, the board's duty is to manage agency conflicts between managers and shareholders. According to this view, external and internal directors would not conspire to exploit shareholders' interests, as they have incentives to establish a reputation as competent monitors. Board independence is essential to protecting the interests of shareholders. One may argue that diversity improves board independence by allowing members of different genders, ethnicities, and cultural backgrounds to raise concerns that directors from more traditional backgrounds would not. As a result, board gender diversity should be beneficial to the board and improve its

[1] An important way in which female directors improve board effectiveness and ultimately corporate performance is that they offer unique perspectives. These disctinct perspectives are considered important resources according to the resource dependence theory. Moreover, gender diversity allows the board to connect to various stakeholders more effectively, according to the stakeholder theory. Additional recent research on board gender diversity can be found in Chen et al. (2018, 2019) and Amorelli and García-Sánchez (2019).

functioning (Carter et al., 2003; Chatjuthamard et al., 2021). Furthermore, Ongsakul et al. (2022) demonstrate that board gender diversity plays a more effective governance role than board independence.

Based on the stakeholder theory, stakeholder engagement is crucially important for firms to justify the legitimacy of their operations. Webb (2004) and Francoeur et al. (2008) argue that appointing female directors on boards can be viewed as the commitment of companies to satisfy a wider range of stakeholders' needs by allowing for more heterogeneous and inclusive views. Jimeno and Redondo (2008) suggest that board gender diversity may also offer diverse perspectives and encourage an efficient monitoring role in managing relationships among various stakeholders.

2.2 | Corporate environmental performance

Existing literatures define corporate environmental performance differently depending on the applied attributes and notions. For example, corporate environmental performance can be referred to as firm performance concerning its environmental responsibility (Yang et al., 2011), the outcome of a firm's strategic activities that manage its impact on the natural environment (Walls et al., 2012), or as a multidimensional concept with at least two interrelated dimensions such as activities addressing environmental concerns or the outcomes of such activities (Trumpp et al., 2013). As such, one could measure corporate environmental performance as the emission reduction performance (outcome-oriented). A growing number of studies rely on carbon disclosure scores and participation from Bloomberg, the carbon disclosure index (Hahn et al., 2015), or greenhouse gas emissions (Haque, 2017; Qian & Schaltegger, 2017).

One crucial strand of literature focuses on the effect of board governance on corporate environmental performance. Relying on agency, resource dependence, stakeholder, and institutional theories, various studies document positive relations between board governance and corporate environmental performance. For example, Rao et al. (2012) use agency and stakeholder theories to explore the relationship between different board characteristics and environmental disclosures in Australia, while Liao et al. (2015) rely on the stakeholder theory to examine the effect of governance on greenhouse gas disclosures in the UK. Both document that board gender diversity, board size, and board independence positively affect corporate environmental performance.

2.3 | Corporate environmental performance and board gender diversity

Existing studies on the relation between corporate environmental performance and gender diversity on boards provide mixed evidence as different proxies for environmental performance are used in different countries, time periods, and methods. Proxies for corporate environmental performance used by these studies include environmental performance from KLD, CIS, Asset4, RKS rating and CSRHub (outcome oriented), biodiversity disclosure, environmental disclosure or lawsuits, and green product patents. Positive relations between board gender diversity and environmental performance are documented by Rao et al. (2012) for companies in Australia; Galia et al. (2015), Baalouch et al. (2019), and Burkhardt et al. (2020) for those in France; Haque (2017) in the UK; Garcia Martin and Herrero (2020), Nuber and Velte (2021), and Haque and Jones (2020) in Europe; Kassinis et al. (2016), Liu (2018), and Lu and Herremans (2019) in the US; and Elmagrhi et al. (2018) in China. Hussain et al. (2018) recently explored which corporate governance mechanisms affect corporate environmental performance in the US through the lens of the agency and stakeholder theories. However, they fail to find any significant relationship between board gender diversity and corporate environmental performance. Given the mixed evidence, we contribute to existing literature by exploring the effect of the board gender diversity on emission performance score from Refinitiv for US firms.

2.4 | The critical mass theory

Furthermore, we analyze the prediction of the critical mass theory, which contends that the impact of female director representation may not be apparent until a specific number is reached (Kanter, 1977). Prior research reveals that the board should include at least three female directors in order for them to have a sufficient collective voice (Brahma et al., 2021; Joecks et al., 2012; Liu et al., 2014). Several other studies have considered the critical mass theory with respect to female board representation (Dobija et al., 2022; Nuber & Velte, 2021; Redor, 2018; Torchia et al., 2011; Wiley & Monllor-Tormos, 2018; Yarram & Adapa, 2021). While earlier studies have investigated the critical mass theory, this is the first time it has been applied to carbon emission performance.

3 | DATA, VARIABLES AND METHODOLOGY

We collect financial, governance, and emission performance data of US firms from 2002 through 2018 from Refinitiv. We exclude financial and utilities firms (SIC 6,000–6,999 and 4,900–4,999). The final sample consists of 6,764 firm-year observations. The emission performance score (*EP*) from Refinitiv indicates the percentile rank score of a firm's commitment and effectiveness towards reducing environmental emission in its production and operational processes relative to its industry. Board gender diversity (*bgd*) is the percentage of female directors on the board. As various studies document a positive impact of at least three female directors on board (Kramer et al., 2007), we create a dummy variable (*critical mass*) set to one if there are at least three women on the board and zero otherwise. We use this dummy variable as an alternative measure for board gender diversity.

We also include control variables for firm characteristics such as firm profitability (*roa*, the ratio of net income to total assets), size

TABLE 1 Descriptive statistics

Panel A: Descriptive Statistics						
	(1) *bgd* > 0 (*N* = 5,823)		(2) *bgd* = 0 (*N* = 955)		Difference in mean	
	Mean	Std. dev.	Mean	Std. dev.	(1)–(2)	
EP	0.3498	0.3340	0.1428	0.2277	0.2070	***
bgd	0.1839	0.0855	0.0000	0.0000	0.1839	***
roa	0.0612	0.0873	0.0550	0.1240	0.0061	**
size	15.807	1.1824	15.161	0.9905	0.6457	***
ln_age	4.4154	1.6163	4.2490	1.7609	0.1664	***
mkt2book	5.1561	12.181	3.9819	7.6465	1.1742	***
td_ta	0.2053	0.1711	0.1747	0.1641	0.0306	***
boardsize	2.3286	0.1995	2.0920	0.2766	0.2366	***
indep	0.8031	0.1277	0.7350	0.1577	0.0681	***
roledual	0.7027	0.4571	0.6869	0.4640	0.0158	
shrhdg	0.0515	0.0638	0.0375	0.0557	0.0140	***

Panel B: Correlation matrix										
	EP	*bgd*	*roa*	*size*	*ln_age*	*mkt2book*	*td_ta*	*boardsize*	*indep*	*roledual*
bgd	0.3081$^{\xi}$									
roa	0.0437$^{\xi}$	0.0519$^{\xi}$								
size	0.5140$^{\xi}$	0.2115$^{\xi}$	−0.0356$^{\xi}$							
ln_age	0.0541$^{\xi}$	0.0497$^{\xi}$	0.0157	0.0238						
mkt2book	0.0375$^{\xi}$	0.0711$^{\xi}$	0.1259$^{\xi}$	−0.0083	−0.0036$^{\xi}$					
td_ta	0.0431$^{\xi}$	0.0344$^{\xi}$	−0.4164$^{\xi}$	0.2532$^{\xi}$	−0.0352$^{\xi}$	−0.0724$^{\xi}$				
boardsize	0.3075$^{\xi}$	0.2522$^{\xi}$	0.0306$^{\xi}$	0.3978$^{\xi}$	0.0416$^{\xi}$	0.0239$^{\xi}$	0.1021$^{\xi}$			
indep	0.2152$^{\xi}$	0.2105$^{\xi}$	0.0289$^{\xi}$	0.1253$^{\xi}$	0.0682$^{\xi}$	0.0332$^{\xi}$	0.0198	0.1592$^{\xi}$		
roledual	0.0473$^{\xi}$	0.0149	0.0475$^{\xi}$	0.0754$^{\xi}$	0.0320$^{\xi}$	0.0169	−0.0295$^{\xi}$	0.0833$^{\xi}$	0.0186	
shrhdg	0.0445$^{\xi}$	0.0382$^{\xi}$	0.0469$^{\xi}$	0.0318$^{\xi}$	0.1715$^{\xi}$	−0.0049	−0.0479$^{\xi}$	0.1260$^{\xi}$	0.0221	0.0773$^{\xi}$

Note: *EP* measures a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes. *bgd* is percentage of female directors on board; *roa* is return on assets; *size* is natural logarithm of total assets; *ln_age* is natural logarithm of firm's age; *mkt2book* is market to book value of equity; *td_ta* is the ratio of total debt to total assets; *boardsize* is size of the board; *indep* is proportion of independent directors on the board; *roledual* takes a value 1 if the CEO simultaneously chairs the board or the chairman of the board has been the CEO of the company, and 0 otherwise; *shrhdg* is the percentage shareholding of large shareholders.

*Significance at 10% on mean difference test.

**Significance at 5% on mean difference test.

***Significance at 1% on mean difference test.

$^{\xi}$Significance at 5% level.

(*size*, natural logarithm of total assets), age (*ln_age*, natural logarithm of firm's age), opportunities (*mkt2book*, market to book value of equity), and leverage (*td_ta*, the ratio of total debt to total assets). Variables *td_ta* and *mkt2book* are winsorized at the top and bottom 1%. Additionally, control variables for governance are also included. These are board size (*boardsize*, natural logarithm of the number of directors on the board), board independence (*indep*, the proportion of independent directors on the board), role separation (*roledual*, indicator variable that takes a value of 1 if the CEO is also the chairman), and large shareholding (*shrhdg*, the percentage of shares owned by large shareholders, i.e., shareholding in excess of 3%). The variable definitions are available in Table A1.

To explore the effect of board gender diversity on emission performance, we first estimate the OLS regression below where standard errors are clustered by firms.[2]

$$EP_{it} = \alpha + \beta_1 bgd_{it} + \sum \beta_n Controls_{it} + \sum Year\ effect + \sum Industry\ effect + \varepsilon_{it}, \quad (1)$$

where subscripts *i* and *t* refer to firm and year, respectively. Beside the governance and firm controls, we also control for year and

[2]We also estimate with standard error that is robust to misspecifications. The results are similar and available upon request.

TABLE 2 Effect of board gender diversity on emission reduction performance

Panel A	(1) OLS	(2) OLS	(3) OLS	(4) Lagged-OLS	(5) IV 1st stage	(5) IV 2nd stage
bgd	**0.936*** **	**0.560*** **	**0.491*** **	**0.532*** **		**0.601*** **
	−0.0962	**−0.0807**	**−0.0795**	**−0.125**		**−0.102**
Firm controls						
size		0.138***	0.128***	0.126***	0.0008	0.126***
		−0.00734	−0.00861	−0.0111	−0.00063	−0.0093
roa		0.0491	0.042	0.123	−0.000505	0.0619
		−0.0514	−0.0508	−0.0857	−0.00775	−0.0595
ln_age		0.00818	0.00663	0.00101	−0.000153	0.00665
		−0.00516	−0.00513	−0.00791	−0.00036	−0.00536
mkt2book		0.000398	0.000357	0.000468	0.00003	0.000238
		−0.000378	−0.000366	−0.000617	−0.00005	−0.000352
td_ta		−0.146***	−0.145***	−0.229***	0.0029	−0.134**
		−0.0498	−0.0493	−0.0799	−0.00426	−0.0528
Governance controls						
boardsize			0.115**	0.170***	0.01235***	0.118*
			−0.0546	−0.0544	−0.0038	−0.0614
indep			0.117**	0.225***	0.0290***	0.116
			−0.0594	−0.0788	−0.00653	−0.0763
roledual			−0.000511	−0.00839	0.0012	−0.00409
			−0.0153	−0.0251	−0.00137	−0.0163
shrhdg			0.0923	0.124	0.0124	0.0799
			−0.116	−0.176	−0.01057	−0.121
Constant	−0.419***	−2.264***	−2.409***	−2.500***	−0.0112	−2.130***
	−0.0263	−0.103	−0.123	−0.196	−0.01051	−0.179
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,764	6,764	6,764	3,087		5,954
R-squared	0.258	0.439	0.446	0.499		0.432

Panel B	(1) OLS	(2) OLS	(3) OLS	(4) Lagged-OLS	(5) IV 1st stage	(5) IV 2nd stage
Critical mass	**0.164*** **	**0.0741*** **	**0.0527*** **	**0.0363** **		**0.138*** **
	(0.0200)	**(0.0166)**	**(0.0170)**	**(0.0178)**		**(0.0184)**
size		0.148***	0.136***	0.0147	0.0374	0.0431
		(0.00780)	(0.00889)	(0.0487)	(0.0405)	(0.0371)
roa		0.0698	0.0611	0.118***	0.0261***	0.128***
		(0.0446)	(0.0433)	(0.00821)	(0.00353)	(0.00332)
ln_age		0.00972	0.00737	0.00754	−0.00298	0.00756***
		(0.00599)	(0.00592)	(0.00504)	(0.00213)	(0.00195)
mkt2book		0.000229	0.000179	3.52e-05	0.000236	0.000343
		(0.000399)	(0.000384)	(0.000312)	(0.000294)	(0.000269)
td_ta		−0.0893*	−0.0826	−0.163***	−0.0551**	−0.132***
		(0.0511)	(0.0504)	(0.0449)	(0.0251)	(0.0231)

(Continues)

TABLE 2 (Continued)

Panel B	(1) OLS	(2) OLS	(3) OLS	(4) Lagged-OLS	(5) IV	
					1st stage	2nd stage
boardsize			0.121**	0.133**	0.237***	0.0867***
			(0.0528)	(0.0537)	(0.0173)	(0.0170)
indep			0.138**	0.127**	0.0568**	0.153***
			(0.0554)	(0.0576)	(0.0280)	(0.0255)
roledual			0.00542	0.00305	0.00443	−0.000573
			(0.0140)	(0.0146)	(0.00757)	(0.00693)
shrhdg			0.190	0.255**	0.181***	0.0753
			(0.140)	(0.125)	(0.0584)	(0.0538)
Constant	0.295***	−2.042***	−2.253***	−2.496***	−1.207***	−2.303***
	(0.00894)	(0.122)	(0.140)	(0.128)	(0.200)	(0.185)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,778	6,778	6,778	6,777	6,777	6,777
R-squared	0.417	0.567	0.574	0.400	0.444	0.430

Note: Dependent variable is *EP*, measuring a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes. Main independent variable *bgd*, percentage of female directors on board, is in Panel A and *critical mass*, a dummy variable indicating 1 if at least three female directors are on board and zero otherwise, is in Panel B.
*Significance at 10%.
**Significance at 5%.
***Significance at 1%.

industry. For all analyses, we replace *bgd* with *critical mass* as it has been documented in literature that women can play effective role on the board if there are at least three women on the same board (Joecks et al., 2012).

To further explore the emission performance of a firm with a gender diverse board or a critical mass of female board representation in comparison to its industry peers, we also estimate a logistic regression below.

$$emission\_perf_{it} = \alpha + \beta_1 X_{it} + \sum \beta_n Controls_{it} + \sum Year\ effect + \sum Industry\ effect + \varepsilon_{it}, \quad (2)$$

where *emission_perf* takes a value of 1 if the firm's *EP* is above the industry-median *EP* and 0 otherwise and *X* represents either *bgd* or *critical mass*.

To address potential endogeneity, we estimate three additional models as in Usman et al. (2018). First, to allow for the effect of *bgd* to kick in, we re-estimate Equation 1 with *bgd*, and governance and firm controls lagging by 1 year (*lagged-OLS*). Second, we estimate two-stage least squares regression (*IV-2SLS*). In the first stage, *bgd* is regressed on two instruments (1-year-lagged *bgd* and industry-average *bgd*) and the controls. The instruments are likely to be correlated with the current year *bgd*, but not with the *EP*. Finally, we apply the propensity score matching approach (*PSM*) to mitigate heterogeneities between firms with and without BGD. Here, we compare the *EP* of the treated group (firms with at least one female director) to the control group (firms with no female director) chosen based on the probability that the firm has female directors on the board given firm characteristics, governance structure, year, and industry. Then, we re-estimate Equation 1 on the firms that are matched based on propensity score.

To reduce endogeneity even further, we employ a unique approach known as entropy balancing to more effectively minimize variations in observable variables across the treatment and the control groups. To address concerns with ordinary propensity score matching (PSM), researchers have lately turned to the entropy balancing approach, which ensures that covariate imbalance improves after matching (Gaver & Utke, 2019; Hainmueller, 2012; McMullin & Schonberger, 2020). Entropy balancing, as Hossain and Kryzanowski (2021) point out, boosts the power of tests by minimizing data loss or the generation of random matches. This novel matching method has been widely used in recent research (Bol et al., 2021; Chatjuthamard et al., 2021; Glendening et al., 2019; Hossain & Kryzanowski, 2021; Marcus, 2013; Mazumder & Saha, 2021; McMullin & Schonberger, 2020; Neuenkirch & Neumeier, 2016; Neuenkirch & Tillmann, 2016; Ongsakul et al., 2022). To begin, we select firms in the top quartile of our sample in terms of board gender diversity to create our treatment group. The remainder of the sample serves as the control group. Then, using entropy balancing, we ensure that the mean, variance, and skewness of observations in the two groups are comparable.

TABLE 3 Propensity score matching

Panel A: treatment effect of board gender diversity (*bgd*) on emission performance (EP)			
	Treated	**Controls**	**Difference**
Unmatched	0.34604	0.14285	0.2032***
			(0.01118)
ATT	0.34604	0.16227	0.18377***
			(0.03143)
Panel B: regression results (firms matched on propensity score)			
		bgd	**Critical mass**
bgd/critical mass		**0.514*****	**0.0826*****
		(0.0976)	**(0.0178)**
size		0.145***	0.143***
		(0.00776)	(0.00792)
roa		0.124*	0.127**
		(0.0647)	(0.0639)
ln_age		0.00466	0.00518
		(0.00569)	(0.00570)
mkt2book		0.000367	0.000416
		(0.000396)	(0.000418)
td_ta		−0.117**	−0.112**
		(0.0556)	(0.0563)
three			0.0826***
			(0.0178)
Constant		−2.261***	−2.190***
		(0.142)	(0.147)
Industry fixed effect		Yes	Yes
Year fixed effect		Yes	Yes
Observations		5,628	5,628
R-squared		0.431	0.425

Note: Panel A reports findings from propensity score matching. For Panel B, dependent variable is *EP*, measuring a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes. Main independent variable *Bgd*, percentage of female directors on board and *critical mass*, a dummy variable indicating 1 if at least three female directors are on board and zero otherwise.
*Significance at 10%.
**Significance at 5%.
***Significance at 1%.

4 | RESULTS

Table 1 shows that firms with gender diverse boards are different from firms without in terms of firm characteristics as well as *EP*. On average, female directors constitute 18% of the board on gender diverse boards. BGD is observed in 85% of the firm-year observations. *EP*, on average, is 0.35 in firms with BGD versus 0.14 in firms with no BGD. A pairwise correlation of 0.31 between *bgd* and *EP* is found. In general, we find a positive correlation between BGD and firm age, size, profitability, leverage, board independence, and large shareholding.

Models (1)–(3) in Table 2 show a positive relation between *bgd* (*or three*) and *EP* with or without firm and/or governance controls. This positive relationship is also observed in *lagged-OLS* (model [4]) as well as *IV-2SLS* estimation (model [5]). Further, Panel A of Table 3 reports that the *EP* of firms with BGD (treated group) is significantly higher than that of firms without (control group). Moreover, this is the case regardless of whether the control firms are chosen based on propensity score or not. In the former (latter) case, firms with BGD outperform the control group by 0.18 (0.20) points.

Our findings corroborate the suppositions of both the resource dependence and agency theories, according to which female directors strengthen board oversight and compel managers to implement corporate policies and strategies that benefit shareholders in the long run. Board gender diversity is seen as a strategic resource that improves board monitoring, as predicted by the resource dependence

hypothesis (Chatjuthamard et al., 2021; Hillman et al., 2000; Jamali et al., 2007). Female directors provide more diverse viewpoints, making board governance more effective and lowering agency conflicts, confirming the prediction of agency theory (Carter et al., 2003; Chatjuthamard et al., 2021).

Panel B of Table 3 shows results of the regression using the propensity-score matched sample. The coefficients *bgd* (0.514) and *three* (0.08) remain positive and significant. Regression results for the entropy-balanced sample are shown in Table 4. The coefficient of board gender diversity continues to be positive and significant, confirming once again the favorable influence of female board representation on emission performance. The coefficient value *bgd* in Models (2)–(5) in Tables 2 and Panel B in Table 3 suggest that a one-percentage-point increase in gender diversity on a firm's corporate board is correlated with approximately a 0.5 increase in the percentile rank score of its emission performance.

The positive and statistically significant coefficients *bgd* and *three* in Table 5 indicate that the presence of female director on the board increases the probability that the firm will achieve a good *EP* score. Row dy/dx highlights that there is a 0.04 probability that a firm will obtain a superior *EP* compared to its industry peers if it has at least three female directors on its board. These results bolster the expectation of the critical mass theory. Prior research indicates that the board

TABLE 4 Entropy balancing

	bgd	Critical mass
bgd/critical mass	**0.394*****	**0.0318****
	(0.0819)	**(0.0150)**
size	0.133***	0.136***
	(0.00910)	(0.00935)
roa	0.123*	0.128*
	(0.0663)	(0.0669)
ln_age	0.00972	0.00999
	(0.00633)	(0.00647)
mkt2book	−2.91e-05	−7.11e-05
	(0.000339)	(0.000347)
td_ta	−0.0796	−0.0771
	(0.0577)	(0.0589)
boardsize	0.201***	0.180***
	(0.0473)	(0.0512)
indep	0.139**	0.155**
	(0.0658)	(0.0684)
roledual	0.0122	0.0112
	(0.0169)	(0.0171)
shrhdg	0.0757	0.0679
	(0.152)	(0.161)
Constant	−2.441***	−2.380***
	(0.135)	(0.140)
Industry fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
Observations	6,764	6,778
R-squared	0.616	0.609

Note: Dependent variable is *EP*, measuring a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes. Main independent variable *Bgd*, percentage of female directors on board and *critical mass*, a dummy variable indicating 1 if at least three female directors are on board and zero otherwise.
*Significance at 10%.
**Significance at 5%.
***Significance at 1%.

TABLE 5 Logistic regression

	bgd_ind	Critical mass
bgd_ind/critical mass	**0.476*****	**0.258***
	(0.170)	**(0.141)**
size	0.853***	0.850***
	(0.0755)	(0.0748)
roa	0.454	0.397
	(0.555)	(0.548)
ln_age	0.0185	0.0201
	(0.0389)	(0.0384)
mkt2book	−0.00288	−0.00310
	(0.00293)	(0.00298)
td_ta	−0.550	−0.505
	(0.406)	(0.404)
boardsize	0.545	0.630
	(0.417)	(0.418)
indep	1.180**	1.284**
	(0.558)	(0.558)
roledual	0.114	0.112
	(0.116)	(0.115)
shrhdg	2.213**	2.259**
	(1.013)	(0.999)
Constant	−18.63***	−18.41***
	(1.417)	(1.433)
Year fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
Pseudo R^2	0.212	0.2105
dx/dy	0.0871***	0.0473*
	(0.031)	(0.0258)
Observations	6,766	6,766

Note: Dependent variable is an indicator variable that takes a value 1 if a firm's emission reduction performance is above industry median-performance, and zero otherwise. *bgd_ind* takes a value 1 if a board consists of one or more female directors, and 0 otherwise. *Critical mass* is a dummy variable indicating 1 if at least three female directors are on board and zero otherwise. See Table 1 for a detailed description of variables. Standard errors, reported in parenthesis, are clustered at firm level.
*Significance at 10%.
**Significance at 5%.
***Significance at 1%.

should comprise at least three female directors in order for them to have a substantial collective voice (Brahma et al., 2021; Joecks et al., 2012; Liu et al., 2014). Our results are consistent with those in previous studies that investigate the critical mass hypothesis with regard to female board members (Dobija et al., 2022; Nuber & Velte, 2021; Redor, 2018; Torchia et al., 2011; Wiley & Monllor-Tormos, 2018; Yarram & Adapa, 2021).

5 | CONCLUSION

Environmental concerns are of interest to many parties, from regulators, academics, and private organizations to the general public. Recently, abrupt climate changes have devastated many countries with severe floods and bushfires. The public believes that corporations are solely focused on enriching themselves and their shareholders and have not done enough to address the impact of their operations and resource consumption on the environment. This has increased pressure on corporations to adopt business strategies that are environmentally conscious. Decisions on business strategies are often made at the board level. An effective board generally supports sustainable development, including environmentally friendly policies. Board gender diversity, namely, female board representation, is an important board governance mechanism which has gained tremendous attention both academically and in practice. Globally, an increasing number of countries are mandating a minimum number of female board members be reached by companies. Existing literature also demonstrates that reaching the critical mass of female representation on the board improves its effectiveness. This paper explores the effect of female board representation on emission performance.

Our findings demonstrate that a higher proportion of female directors on the board results in a considerably stronger emission performance. Specifically, this study finds evidence that firms with a gender diverse board are better at committing to and effectively reducing environmental emission in their production and operational processes relative to their peers. A variety of robustness checks are performed to mitigate endogeneity, including propensity score matching, entropy balancing, and instrumental-variable analysis. All the robustness checks validate the results, suggesting that our findings are unlikely to be contaminated by endogeneity. Therefore, our conclusion probably reflects a causal effect, rather than mere association.

Our research contributes to several key areas of the literature, including board gender diversity, corporate governance, and sustainable development. Our findings have several significant practical implications. For example, it should be of interest to environmentally conscious shareholders and investors since we show that board composition, in particular board gender diversity, reduces environmental emission. Additionally, our results should benefit regulators and legislators, since we find that mandating a gender quota on corporate boards could affect the firm's emission performance. Female directors are not merely tokens. They exert a palpable influence on corporate policies and outcomes, which eventually lead to sustainable capital market development.

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ORCID

Khine Kyaw https://orcid.org/0000-0003-3971-8768
Sirimon Treepongkaruna https://orcid.org/0000-0002-3096-8499
Pornsit Jiraporn https://orcid.org/0000-0001-5480-7158

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APPENDIX

TABLE A1 Variable definitions

Variable	Definition
bgd	Board gender diversity—percentage of female directors on the board
roa	Return on assets—net income divided by total assets
size	Natural logarithm of total assets
ln_age	Firm age—natural logarithm of firm age
mkt2book	The market value of equity divided by the book value of equity
td_ta	Leverage- Total debt divided by total assets
boardsize	Number of directors on the board
indep	Percentage of independent directors on the board
roledual	CEO duality—whether the CEO also serves as chairman of the board
shrhdg	Percentage of shares owned by large shareholders