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Board Gender Diversity Reform and Corporate Carbon Emissions[*]

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Abstract

We examine the impact of the increased presence of female board members on corporate carbon emissions. Using the staggered enactment of gender diversity reforms in different countries, we find that an increase in the number of female directors after the reforms leads to a reduction in corporate carbon emissions. This effect is particularly more pronounced when the reform is legislative, and occurs in collectivistic countries. Furthermore, the effect of enhanced female board representation on carbon emission reduction is greater following the Paris Agreement. This study offers valuable insights for policymakers who consider gender diversity reform as a strategy against climate change.

Keywords: Board gender diversity reforms, Carbon emission, Climate change, Law, Culture

JEL Code: G34, J16, Q54, K42

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1. Introduction

Climate change, primarily driven by carbon emissions, poses a major threat to global economic stability and social welfare. This pressing concern has attracted the attention of policymakers and the public, highlighting the urgency for the corporate sector to transition to a low-carbon economy (Hsiang et al., 2017; House, 2021). The literature acknowledges the engagement of various stakeholders in reducing carbon emissions, including institutional investors (Azar et al., 2021), banks (Kacperczyk and Peydró, 2022), corporate customers (Deng et al., 2023), and governments (Bartram, Hou, and Kim, 2022; Bai and Ru, 2024; Martinsson et al., 2024). However, the role of corporate governance, particularly from the perspective of female directors, remains under-researched.

With board gender diversity reforms worldwide, there has been a substantial increase in female representation on corporate boards (Fauver et al., 2022). This shift not only promotes board gender diversity, but also improves a corporation's environmental and social performance (Ding et al., 2022; Ginglinger and Raskopf, 2023). Given the critical issue of carbon emissions, female directors are positioned to prioritize reducing the corporate carbon footprint and aligning corporate strategies with climate change mitigation efforts. This study explores the extent to which the increased representation of female directors on boards, following board gender diversity reforms, reduces corporate carbon emissions.

Why are female directors particularly inclined to reduce corporate carbon emissions? This predisposition may stem from sex-specific differences in value orientation and risk preferences, which could align their attitudes toward corporate carbon emissions. Generally, women exhibit more prosocial and altruistic traits than men (Andreoni and Vesterlund, 2001), demonstrate greater sensitivity to ethical

concerns and regulations (Gilligan, 1977; Croson and Gneezy, 2009; Adams and Funk, 2012), and are more inclined to support policies that protect citizens, consumers, and the environment (Shapiro and Mahajan, 1986). Additionally, women tend to adopt a more conservative approach to risk-taking and exhibit greater risk aversion than men (Bernasek and Shwiff, 2001; Hudgens and Fatkin, 1985; Faccio et al., 2016). Considering the critical role of carbon pricing policies in addressing regulatory climate risks during the transition to a low-carbon economy (Bolton and Kacperczyk, 2021a; Bolton and Kacperczyk, 2023; Duan, Li, and Wen, 2023), the prosocial values, ethical orientation, and conservative risk preferences of female directors align naturally with efforts to mitigate corporate carbon emissions.

To identify the causal effect of increased female board representation on carbon emission reduction, we use a difference-in-differences-in-differences (DiDiD) estimation approach based on the staggered enactment of worldwide board gender diversity reforms. These reforms, which mandate incremental female representation quotas, are exogenous to the country's firms. We hypothesize that the increased presence of women on corporate boards, as prompted by the reforms, would lead to significant reductions in carbon emissions.

This analysis involves several comparative steps. Initially, we assess changes in carbon emissions among firms with varying numbers of female directors, focusing on those below the quotas mandated by the board's gender diversity reforms (the first difference). The second difference involves a comparison of the carbon emissions before and after the implementation of these reforms. Importantly, the reform affects "treated firms", those with fewer female directors than the prescribed quota. The third difference compares the changes in carbon emissions between treated and non-treated firms. Our DiDiD strategy estimates the differential changes in carbon emissions

following gender diversity reforms by comparing firms with more and fewer female directors.

To test our hypotheses, we obtain corporate carbon emissions data from S&P Trucost. The final sample includes 64,374 firm-year observations covering 9,883 unique firms in 50 countries from 2002–2019. Our measures include both direct and indirect carbon emissions. Direct carbon emissions include Scope 1 and Scope 2 emissions, which represent emissions from the use of fossil fuels and consumption of purchased energy, respectively. Indirect carbon emissions are emissions from supply chain activities.

Before conducting the main analysis, we first analyze the changes in female representation on boards before and after the reforms. The results confirm a significant increase in the number of female directors in firms headquartered in countries that enact a board gender diversity reform. We then validate the parallel trend assumption inherent in the DiDiD approach using a dynamic test. We find that in the absence of board gender diversity reforms, the carbon emissions (direct and indirect) of firms with a higher representation of female directors evolve similarly to those of control firms. These results support the exogeneity of reforms and validate the parallel trend assumption when using the DiDiD estimation approach (Bertrand and Mullainathan, 2003; Fauver et al., 2022).

The results of our DiDiD estimator show that firms that increase their number of female directors in response to gender diversity reforms experience a reduction in direct and indirect carbon emissions. To better understand the heterogeneous effects of the reforms, we classify them as binding (legislative reforms) and non-binding (governance code-based reforms). We rerun the baseline estimation using both types of reforms simultaneously. These results confirm that an increase in female board

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representation following these reforms is associated with a significant decrease in carbon emissions, particularly in the context of legislative reform. This result further demonstrates the more pronounced effectiveness of legislative actions in promoting gender diversity on boards and driving the reduction of carbon emissions.

Moreover, we investigate the mitigating impact of national culture, which significantly influences the effectiveness of corporate board reforms (Dak-Adzaklo and Wong, 2024), including shaping board composition (Frijns, Dodd, and Cimerova, 2016) and perceptions of corporate social responsibility (CSR) (Maignan, 2001). Our results show that an increase in female board representation after the reforms lead to a more substantial reduction in carbon emissions for firms headquartered in countries with collectivistic cultures. Additionally, we examine whether the effect of curbing carbon emissions is greater after the signing of the 2015 Paris Agreement. We find that increased female representation on boards after the reforms lead to a greater reduction in carbon emissions, following the Paris Agreement.

In the robustness tests, we exclude the U.S. firms to address any bias stemming from the U.S.-based firms. Furthermore, we conduct a placebo test using pseudo-board reform years to control for the impact of other potentially confounding events. Our results remain consistent despite the additional sensitivity tests, confirming the robustness of the main findings.

This study contributes to the literature in several ways. First, it adds to the growing literature on the impact of gender diversity reforms on various aspects of firm performance and governance. These aspects include the effects on firm value (Ahern and Dittmar, 2012; Matsa and Miller, 2013), the monitoring role of institutional investors (Fauver et al., 2022), and CSR performance (Ding et al., 2022; Ginglinger and Raskopf, 2023). Other studies highlight the influence of boardroom gender

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diversity on improving corporate governance (Adams and Ferreira, 2009), affecting acquisition strategies (Levi, Li, and Zhang, 2014), reducing environmental litigation (Liu, 2018), and fostering corporate innovation (Griffin, Li, and Xu, 2021). Our study responds to the call by Gillan, Koch, and Starks (2021) for research on governance effectiveness in addressing corporate sustainability, by focusing on climate change regulatory risks during the transition to a low-carbon economy.

Additionally, we contribute to the rapidly expanding field of climate finance by examining the roles of climate policies, firms, investors, and corporate customers in reducing carbon emissions to combat climate change. Bai and Ru (2024) and Martinsson et al. (2024) document the effects of carbon pricing policies on curbing carbon emissions. Bartram, Hou, and Kim (2022) find that after the implementation of the carbon ETS in California, firms with financial constraints shift emissions from plants in California to other states. Bolton and Kacperczyk (2021b) show that firms committed to carbon emissions reduction achieve more significant results. Azar et al. (2021) demonstrate the significant role that 'Big Three' institutional investors play in decreasing carbon emissions in high-emission firms. Kacperczyk and Peydró (2022) provide evidence of lenders' influence on firms reducing emissions. Deng et al. (2023) found that customer concentration is associated with lower carbon emissions from suppliers.

This study complements these findings by presenting evidence that the board of directors, specifically, from the perspective of board gender diversity as a corporate governance mechanism, is vital in mitigating climate change by reducing carbon emissions. Importantly, to the best of our knowledge, this study is the first to establish a direct relationship between board gender diversity and the reduction in carbon emissions on an international scale. Although previous research has highlighted the

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positive association between female participation and lower carbon emissions, this approach offers a novel perspective. Specifically, Carlsson-Kanyama et al. (1999) and Räty and Carlsson-Kanyama (2010) document higher transportation emissions caused by men than women could be attributed to their longer travel distances and preference for energy-intensive vehicles. Additionally, Ergas and York (2012) find that countries with a greater political representation of women tend to have lower per capita carbon emissions from fossil fuels. Our study extends these findings to the corporate level, demonstrating that increased female representation on boards can effectively reduce carbon emissions following the implementation of gender diversity reforms in different countries.

Our findings align with those of Atif et al. (2021), who document a positive effect of board gender diversity on the utilization of renewable energy in the U.S.; however, this study is different in several respects. Atif et al. (2021) focus on renewable energy consumption as a means of mitigating climate regulatory risks during the transition to a low-carbon economy. Contrarily, our study uses direct and indirect carbon emissions as broader indicators of climate regulatory risks, capturing additional channels such as green innovation (Cohen, Gurun, and Nguyen, 2021). Second, while Atif et al. (2021) focus on the U.S., our study provides extensive and comprehensive evidence from 50 countries, offering generalized implications. This wider scope offers valuable insights for policymakers considering board gender diversity reform strategies against climate change. Importantly, we demonstrate that the manner of implementation and the dominant culture of a country have heterogeneous effects. Our results align with the recent findings of Dak-Adzaklo and Wong (2024), who show that a country's informal norms moderate the impact and effectiveness of adopting corporate governance reforms. Finally, our method employs a staggered triple-difference

identification strategy to establish a causal effect, whereas Atif et al. (2021) use director turnover as a plausible exogenous shock.

The remainder of this paper is organized as follows: Section 2 presents the literature review and outlines the hypotheses, Section 3 introduces the research design, Section 4 presents and discusses the empirical results, and Section 5 concludes.

2. Hypothesis development

2.1 Boardroom Gender Diversity Reforms

In 2006, Norway set a precedent by enacting a boardroom gender diversity reform that required publicly listed firms to ensure that at least 40% of their board members were female by 2008, under the penalty of dissolution for non-compliance (Sjåfjell and Reiersen, 2008; Ahern and Dittmar, 2012). This policy successfully increased women's representation on Norwegian boards from 7% in 2002 to over 40% in 2008. Inspired by Norway's example, countries such as Italy and Belgium introduced similar laws in 2011, requiring a minimum of one-third female representation on the boards of publicly listed and state-owned companies (Carletti, 2019; Du Plessis, O'Sullivan, and Rentschler, 2014). Other countries, such as the UK, have adopted a flexible, voluntary approach to achieve comparable levels of representation without imposing legal requirements (Choudhury, 2014).

This global landscape shows a diverse range of approaches to gender diversity reform. Remarkably, some developed countries, including European Union (EU) members such as Malta, Poland, and Romania, have not implemented gender-related board reforms. Moreover, there have been instances in which the intended outcomes of such reforms did not fully materialize (Suk, 2012).

The evolution of EU legislation provides insights into the complexity of

progress towards board gender diversity. In 2012, the European Commission proposed a directive requiring a minimum of 40% representation of the underrepresented genders among Non-Executive Directors (NED) of listed companies, leading to the approval of the "Women on Boards" directive a decade later. This directive mandates that major EU-listed companies increase female leadership by June 2026, while exempting small and medium-sized enterprises with fewer than 250 employees. This legislative effort aimed to harmonize board diversity policies in EU member states. As of 2022, six of the 27 EU member states had enforced gender-balanced policies. Countries that have adopted legislative measures, such as France, Italy, and the Netherlands, have reported higher representation of women on boards. However, 10 states that opted for more moderate measures showed varied progress; for example, Sweden and Denmark exceeded 35%, while Greece and Slovenia remained below 20%. Eleven EU member states did not introduce any measures that contributed to major disparities in gender parity in the EU. This disparity resulted in an average of 30.6% female board members in the EU's largest companies, with France leading at 45.3% and Cyprus trailing at 8.5% (Nuyens, 2023).[3]

The EU's major variation in board gender reforms in member states illustrates that these differences extend beyond economic development and legal framework. This variety of reform approaches provides substantial time-series variability, offering a valuable setting for testing whether the increased number of female directors following the enactment of board gender diversity reforms leads to changes in corporate carbon emissions.

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[3] Press Releases of the European Parliament at https://www.europarl.europa.eu/news/en/press-room/20221118IPR55706/parliament-approves-landmark-rules-to-boost-gender-equality-on-corporate-boards

2.2 Why Gender Differences Matter for Carbon Emission

The influence of female directors on corporate carbon emissions may diverge considerably from that of their male counterparts because of distinct differences in values and risk preferences. First, regarding value orientation, women are often perceived as more prosocial and altruistic than men (Andreoni and Vesterlund, 2001), displaying an increased sensitivity to ethical concerns and regulations (Croson and Gneezy, 2009; Adams and Funk, 2012). Adams and Funk (2012) argue that women are more likely to prioritize stakeholder interests, suggesting a lower propensity for decisions solely motivated by personal financial gains.

Furthermore, women's increased responsiveness to policies that benefit citizens, consumers, and the environment (Shapiro and Mahajan, 1986) positions them as effective agents for ensuring firm compliance with carbon emission reduction initiatives. Liao, Luo, and Tang (2015) demonstrate that gender-diverse boards are more engaged in the Carbon Disclosure Project (CDP), typically achieving higher CDP scores. This trend is supported by Ben-Amar et al. (2017), who report an increase in responsiveness to the CDP questionnaire as female board representation reaches a critical mass.

Additionally, board gender diversity contributes to improved governance outcomes, including better board attendance and more rigorous monitoring of CEO performance (Adams and Ferreira, 2009). This aspect is particularly relevant when considering women's typically higher ethical sensitivity and moral standards (Gilligan, 1977), which is supported by recent findings relating female board presence to improved corporate Environmental, Social, and Governance performances. Liu (2018) observes that introducing female directors to companies with low board gender diversity is correlated with fewer environmental lawsuits. Similarly, Do et al. (2023)

report that boards with greater diversity exhibit stronger engagement in regional voluntary climate reporting initiatives, ultimately leading to improved environmental outcomes. Therefore, women's inherent prosocial and altruistic values suggest a predisposition towards managing firms with a focus on carbon emissions, emphasizing broader benefits for all stakeholders and community impact.

Second, women typically exhibit more conservative risk-taking behaviors and display greater risk aversion than men (Bernasek and Shwiff, 2001; Hudgens and Fatkin, 1985; Faccio, Marchica, and Mura, 2016), with a keen perception of environmental risks (Bord and O'Connor, 1997). As governments worldwide tighten climate regulations, including carbon pricing policies aiming at reducing corporate carbon emissions (Bartram, Hou, and Kim, 2022; Bai and Ru, 2024; Martinsson et al., 2024), these policies represent major risk factors in financial markets (Krueger, Sautner, and Starks, 2020). The extent of corporate carbon emissions indicates a firm's exposure to regulatory climate risk (also known as carbon risk). Bolton and Kacperczyk (2021a, 2023) document that investors price carbon risk based on stock prices. Duan, Li, and Wen (2023) and Seltzer, Starks, and Zhu (2022) show that corporate bonds issued by firms with higher carbon emissions bear higher carbon risks. Consequently, the inherently risk-averse nature of women suggests a management style that prioritizes the reduction of climate regulatory risks.

In summary, female directors' tendency towards more prosocial values and risk aversion suggests that they may prioritize carbon emissions management more than their male counterparts. Hence, an increase in female board representation following gender diversity reforms is expected to intensify firms' efforts to reduce carbon emissions. Thus, we propose Hypothesis 1 as follows:

H1: *Increased female board representation after the enactment of board gender*

diversity reforms is associated with reduced corporate carbon emissions.

2.3 Enforcement Approaches to Board Gender Diversity and Carbon Emissions

As with other corporate governance reforms, board gender diversity reforms can be classified into governance code-based and legislative reforms. Governance code-based reforms typically publish governance code guidelines, offering firms the flexibility to either adhere to the recommended practices or explain their reasons for non-compliance regarding gender diversity on boards (the comply-or-explain principle). Legislative reforms involve enactment of mandatory laws or regulations that require strict compliance without exception.

The effectiveness of these approaches in fostering corporate governance reforms, including gender diversity, is widely debated. On the one hand, in the context of global board independence reforms, Fauver et al. (2017) observe that governance code-based reforms have a greater impact on firm value than the legislative approach. On the other hand, Andres and Theissen (2008) critique the effectiveness of the comply-or-explain model, as initially implemented in Germany for executive remuneration disclosure, pointing out its limitations and the eventual transition to a legislative framework.

Similar to the transparency of executive remuneration reforms in Germany, Ding et al. (2022) investigate the impact of board gender diversity reforms and concluded that legislative reforms are more effective than governance code-based reforms in increasing female representation on boards. They further argue that an increase in female board representation facilitated by legislative measures positively influences firms' CSR performance, highlighting the benefits of stricter enforcement mechanisms. This observation is consistent with Bear, Rahman, and Post (2010), who

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find a positive relationship between board gender diversity and firms' CSR ratings. Moreover, Boulouta (2013) suggests that the greater "empathic caring" attribute of women directors contributes to the effectiveness of gender-diverse boards on CSR metrics, particularly in mitigating negative business practices.

In summary, existing evidence indicates that legislative reforms for promoting board gender diversity are more effective in achieving a significant increase in female board representation. This enhanced representation leads to a pronounced reduction in corporate carbon emissions. Therefore, we propose Hypothesis 2 as follows:

H2: *The effect of increased female board representation following legislative board gender diversity reforms on the reduction of corporate carbon emissions is more pronounced.*

2.4 National Cultural Factors Affecting Carbon Emissions.

The existing literature has increasingly recognized the role of cultural dimensions in shaping corporate strategies, including environmental stewardship decisions (Wang, Guo, and Tang, 2021). Frijns, Dodd, and Cimerova (2016) highlight the significant influence of cultural factors on board diversity and, subsequently, on a firm's performance. Similarly, Cai, Pan, and Statman (2016) attribute variations in corporate social performance across countries to differences in national culture.

Ioannou and Serafeim (2012) propose that national culture is a flexible, implicit institutional force, distinct from explicit mechanisms such as laws, that significantly align corporate responses to a carbon-neutral economy (Wang, Guo, and Tang, 2021). Panfilo and Krasodomska (2022) emphasize that cultural and normative dimensions affect the quality of a firm's carbon disclosures, with cultural factors gaining importance in less stringent regulatory environments.

Understanding these cultural dimensions is crucial for assessing the impact of boardroom gender-diversity reforms. The interplay between cultural and gender dynamics requires a careful approach that considers cultural variables when evaluating the effectiveness of reforms. Dak-Adzaklo and Wong (2024) demonstrate that a country's informal norms can significantly affect the success of governance reforms. Similarly, variations in the effectiveness of board gender diversity reforms, whether through governance codes or legislative measures, can be expected in cultural contexts and reform approaches (Andres and Teissen, 2008; Fauver et al., 2017; Ding et al., 2022). The choice between legislative and governance code-based reforms is likely to be influenced by prevailing national culture.

Consequently, we argue that a national cultural context is essential for developing a comprehensive understanding of these reforms, particularly concerning their role in reducing carbon emissions. Our study focuses on two major dimensions of Hofstede's (2011) national cultural framework: individualism and collectivism. This focus is based on the established impact of national cultural traits on environmental sustainability (Wang, Guo, and Tang, 2021; Huang et al., 2022).

According to Hofstede (2011), individualistic societies emphasize personal autonomy, whereas collectivistic societies prioritize strong and cohesive in-groups. In individualistic cultures, women are generally expected to focus on their own needs and well-being, whereas in collectivistic societies, women's decisions often align with communal interests. Vu (2023) suggests that individualistic societies are more effective in enforcing climate-change mitigation policies, partly because of the increased involvement of women in legislative processes. Nartova-Bochaver et al. (2022) observe a lower tendency for women in individualistic countries to deny climate change. Conversely, Xiang et al. (2019) find that individualist tendencies negatively affect

climate-friendly actions, suggesting that individualism and collectivism mediate perceptions of climate change.

Given these contrasting perspectives, we hypothesize that the effectiveness of gender diversity reforms in reducing corporate carbon emissions varies according to a firm's cultural context. Therefore, we propose Hypothesis 3 as follows:

H3: *Increased female board representation following gender board diversity reforms leads to a more substantial reduction in corporate carbon emissions in firms located in collectivist countries.*

2.5 Effect of the Paris Climate Agreement

The ambitious goal of the 2015 Paris Agreement to limit the global temperature rise to 1.5 °C above pre-industrial levels, represents a critical milestone in international climate policy. With 195 of the 198 signatory countries ratifying it, the agreement imposes responsibility for governments to implement strict climate regulations. This increases the regulatory risk for corporations operating in signatory nations and compels them to reduce their carbon emissions (Ramadorai and Zeni, 2021).

Seltzer, Starks, and Zhu (2022) find that the Paris Agreement intensifies the regulatory risk for firms with high environmental impacts or large carbon footprints. Delis, De Greiff, and Ongena (2019) document that, after the adoption of the Paris Agreement, banks began pricing the risk of stranded fossil fuel reserves, leading to an increase in the cost of credit for fossil fuel firms. Similarly, Ehlers, Packer, and De Greiff (2022) report a significant carbon premium in the syndicated loan market after the Paris Agreement is adopted. Interestingly, they find that a premium exists for direct carbon emissions (Scope 1), suggesting that banks are less concerned regarding firms' broader carbon footprint. Ginglinger and Moreau (2023) corroborate this finding by

noting that increased physical climate risks, since the ratification of the agreement, lead to decreased leverage for polluting firms. Consequently, the existing results indicate that awareness of the risks associated with carbon emissions and the prospects of regulatory interventions in limiting carbon emissions have significantly increased following the Paris Agreement (Bolton and Kacperczyk, 2021a).

Therefore, we predict that the impact of the increased number of female directors following board gender diversity reforms on carbon emissions reduction would be more pronounced in the period following the ratification of the Paris Agreement. Therefore, we propose Hypothesis 4 as follows:

H4: *The increase in female board representation subsequent to gender diversity reforms significantly enhances the reduction of corporate carbon emissions following the Paris Agreement ratification.*

3. Research Design

3.1 Data and Sample

To conduct the data analysis, we obtain firm-level carbon emissions data (in tons) from the S&P Global Trucost database from 2002–2019.[4] This dataset categorizes emissions into the following three categories: Scope 1 covers direct emissions from facilities owned or controlled by companies, primarily from fossil fuel usage in production and Scope 2 encompasses emissions from heat, steam, and electricity purchased by companies. Scope 3 refers to emissions generated by a firm's operations and production from sources not owned or controlled by the firm. We combine Scope

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[4] Trucost collects firm-level emissions data from various sources including company reports, environmental reports (CSR/ESG reports, Carbon Disclosure Project, Environmental Protection Agency filings), and company websites. If a firm does not disclose emissions data, Trucost uses an input-output model to estimate the firm's carbon emissions.

1 and Scope 2 data to measure direct carbon emissions and use Scope 3 data to measure indirect carbon emissions.

We follow Fauver et al. (2022) and Ding et al. (2022) for the data on the implementation of boardroom gender diversity reforms in various countries. We obtain director characteristics from BoardEx, a widely used database that provides comprehensive global board- and director-level information. Firm-level financial data is obtained from World Scope, a leading provider of detailed financial statement information for public companies. Additionally, we obtain information on legal characteristics worldwide from the International Country Risk Guide (ICRG).

To obtain the final sample, we merge the S&P TruCost, WorldScope, and BoardEx databases. The data is then aligned with the ICRG database using country names. After controlling for missing values, we exclude firm-year observations based on the following criteria: (1) stock prices below one unit of the local currency, (2) market capitalization under USD 10 million at the fiscal year-end, (3) negative net sales or shareholder equity, and (4) countries with fewer than 10 unique firms. Consequently, the final sample includes 64,374 firm-year observations of 9,883 unique firms in 50 countries from 2002–2019.

3.2 Descriptive Statistics

Table 1 presents the summary statistics. We measure *Direct carbon emissions* as the natural logarithm of the combined Scopes 1 and 2 emissions plus one, and *Indirect carbon emissions* as the natural logarithm of Scope 3 emissions plus one. The average (median) *Direct* and *Indirect carbon emissions* in the sample are 11.3829 (11.3055) and 12.1299 (12.2267), respectively. All variables are winsorized at the top and bottom 1%.

Table 2 presents the breakdown of the sample and average carbon emissions (direct and indirect) by country. The U.S. represents the largest percentage of the sample (32.03%) with 3,102 unique firms, whereas Pakistan contributes the least (0.05%) with 12 unique firms. Notably, there is considerable variance in countries, and the robustness test confirms that our results are not driven by the U.S. firms. Russia exhibits the highest average direct carbon emissions (10 887 116 tons), whereas the United Arab Emirates has the lowest (171 806.6 tons). Table 3 presents the correlations among the main variables.

[Insert Tables 1, 2, and 3 here]

3.3 Empirical Strategy

To identify the causal effect of board gender diversity reforms on carbon emissions reduction, we adopt the staggered DiDiD approach following He et al. (2022) and Potemkina (2022). This approach helps isolate other variables that potentially influence corporate carbon emissions and determines the specific impact of female directors on boardroom gender diversity. More importantly, the staggered DiDiD method helps differentiate the effects of board gender reform on carbon emissions reduction from other factors, which is a challenge often faced when using a single-event-based DiDiD approach.

This analysis involves several comparative steps. Initially, we assess changes in carbon emissions among firms with different numbers of female directors, focusing on those below the quota mandated by the board's gender diversity reforms (the first difference). The second difference involves a comparison of the carbon emissions before and after the implementation of these reforms. Importantly, the reform affects "treated firms" – those with fewer female directors than the prescribed quota. The third

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difference is the comparison of the changes in carbon emissions between treated and non-treated firms. Our DiDiD strategy estimates the differential changes in carbon emissions following gender diversity reforms by comparing firms with more and fewer female directors.

To test our hypothesis, we use a two-way fixed-effects model for DiDiD estimation, as specified in Model (1).

$$Emissions_{i,c,t} = \beta_0 + \beta_1 Post_{c,t} * Female\ directors_{i,c,t} + \beta_2 Post_{c,t} +$$

$$\beta_3 Female\ directors_{i,c,t} + Control_{i,c,t} + \lambda_i + \lambda_t + \varepsilon_{i,c,t} (1)$$

where the dependent variable $Emissions_{i,c,t}$ is proxied by *Direct carbon emission* and *Indirect carbon emission*. The independent variable $Post_{c,t}$ is a dummy variable set to one for the years following the introduction of the boardroom gender diversity reform in country *c* and zero otherwise (for years before the introduction of the boardroom gender diversity reform and years in countries that never introduce such reforms). $Female\ directors_{i,c,t}$ represents the number of female directors in a firm.

The control variables include firm characteristics such as *Market cap*, *Book-to-market*, *Leverage*, *ROA*, and *PPE*; governance characteristics such as *Board size*, *Board independence*, *Non-Executive Directors (NED) ratio*, and *Average time in board*; and country-level characteristics such as *Law and order*. Additionally, all specifications include firm and year fixed effects to control for unobservable heterogeneity. Robust standard errors are clustered at the country-by-year level. For brevity, we do not report a constant term in all tables.

4. Results and Discussion

4.1 Baseline Results

Table 4 presents the results of the analysis of Hypothesis 1. In all specifications,

the interaction term between the *Post* and *Female directors* has a significantly negative coefficient. This indicates that an increase in female representation on boards after the gender reform is associated with reductions in direct and indirect carbon emissions.[5] In terms of the economic magnitude, an increase of one female director on the corporate board after the board gender diversity reforms, on average, leads to a 4.02 and 2.61% reduction in direct and indirect carbon emissions, respectively. These findings strongly support our first hypothesis, affirming that board gender diversity reforms that lead to a greater presence of women on boards influence corporate behavior, resulting in a reduction in carbon emissions.

Although the coefficient of *Post* lacks statistical significance in most specifications, the coefficient of *Female directors* consistently exhibits a significantly positive coefficient. This pattern implies that the number of female directors before the reforms was insufficient to significantly influence decision-making processes. Globally, these findings suggest that gender reform initiatives effectively transform board composition, thereby influencing corporate emission behavior.

Consistent with previous studies, our findings show that larger companies tend to have higher levels of direct and indirect carbon emissions as measured by asset size and higher percentages of fixed assets. Contrary to initial expectations, we find a positive relationship between leverage, book-to-market value, and carbon emissions. Additionally, our analysis indicates that companies with larger boards and longer board tenures tend to exhibit higher carbon emission levels. Surprisingly, we find no statistically significant difference between the percentage of independent board members and firms' carbon emissions. This finding suggests that other governance

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[5] We verify that the enactment of board gender diversity reforms leads to the increased number of female directors. The result is reported in Table IA1 column (1).

measures related to board composition do not significantly affect a firm's emission levels.

[Table 4 about here]

4.2 Change in Carbon Emissions Post Board Gender Diversity Reforms

One concern is that our results are driven by preexisting trends in firms' carbon emissions. If the decrease in carbon emissions results from increased female participation induced by board gender reforms, instead of parallel trends, we should observe a decrease in carbon emissions only post-reform.

To investigate this, Table 5 presents an analysis using dynamic effects in an event window that includes the periods before and after gender diversity reform. To examine pretreatment trends in the carbon emissions of the treated and control firms, we replace *Post ∗ Female directors* in Model (1) with the following five interaction terms: *Before^{-2}∗ Female directors*, *Before^{-1}∗ Female directors*, *Current∗ Female directors* (the reform implementation year), *After^{+1}∗ Female directors*, and *After^{2+}∗Female directors*. These terms identify the year of reform adoption and interact with the percentage of female directors. *Before^{-1}, Before^{-2}, Current, After^{+1},* and *After^{2+}* dummies are defined according to specific timeframes relative to the reform implementation. This approach addresses concerns regarding pre-treatment emission trends and provides evidence supporting the parallel-trend assumption, which is vital for the DiDiD approach (Bertrand and Mullainathan, 2003; Chen et al., 2020; Fauver et al., 2022).

As shown in Table 5, the coefficients of the interaction between the *Before^{t-2}* or *Before^{t-1}* dummies and *Female directors* are not statistically significant in all the specifications. This suggests that, prior to board reforms, female directors do not

significantly affect firms' direct or indirect carbon emissions.

Nonetheless, the coefficient of the interaction term representing the current year of reform implementation and the increase in female directors is statistically significant in one specification at the 10% significance level. Furthermore, the coefficients for the interaction terms one- and two-years post-reform are negative and statistically significant. The interaction term for two-years post-reform is statistically significant at the 1% level in all specifications, indicating a notable increase in the number of female directors following the reforms, which subsequently affects carbon emissions.

The lack of significance of the coefficients for the pre-reform years in these dynamic analyses suggests that the results are not driven by pre-reform trends. By contrast, the significantly negative post-reform interaction terms indicate a reduction in carbon emissions following the reforms, coinciding with an increase in female board representation. This empirically supports the parallel-trend assumption and validates the staggered DiDiD approach. Additionally, these findings highlight that firms adapt more quickly to adjust their indirect emission activities post-reform. Although the impact on direct carbon emissions may not be immediate, the positive effects become evident after two years.

[Insert Table 5 here]

4.3 Enforcement Approaches to Board Gender Diversity Reforms and Carbon Emissions

To test Hypothesis 2, we examine the differential impact of legislative and governance code-based board diversity reforms. Model (1) introduces two dummy variables: *Post_legislation* and *Post_code*. *Post_legislation* is set to one for the years following the implementation of boardroom gender diversity legislation and zero

otherwise, whereas *Post_code* is set to one for the years following the adoption of a gender diversity governance code and zero otherwise. Next, we interact each of these dummies with a variable representing the number of female directors on the board.

The results present in Table 6 show that the coefficients of the interaction terms between both *Post_legislation* and *Post_code* and *Female directors* are negative and statistically significant at the 1% level. These results suggest that the implementation of the reforms lead to an increase in female board representation, which, subsequently, lead to lower carbon emissions. More importantly, consistent with Hypothesis 2, there is a notable difference in the magnitudes of the coefficients. Legislative reforms have a 40% (85%) stronger impact on direct (indirect) carbon emission reduction than governance code implementation, which is economically significant. Importantly, the coefficient of *Post_code* is not statistically significant, indicating that the type of approach may influence carbon emissions by increasing or decreasing the power or indispensability of women on boards. Our results suggest that reforms had an indirect effect on carbon emissions through the resulting increase in female directors.

These results complement the findings of Ding et al. (2022), who show that legislative reforms have a more pronounced effect on increasing female board representation than governance code-based reforms. We also verify that the effect of enacting legislative board gender diversity reforms on increasing female board representation is greater. The results are reported in Table IA1, column (2).

[Insert Table 6 here]

4.4 National Cultural Factors Affecting Carbon Emissions

To evaluate Hypothesis 3, we examine whether the effectiveness of board gender diversity reforms on carbon emissions varies according to a firm's national

culture, focusing on the dichotomy between collectivism and individualism. We split the sample into two groups based on these cultural characteristics and rerun the regression using baseline model (1) for each subsample.

Columns (1) and (3) of Table 7 present the results for firms in collectivist countries, whereas Columns (2) and (4) present the results for firms in individualistic countries. As reported in Table 4, the results show that board gender reforms materially and significantly decrease firms' carbon emissions in both cultures. Notably, the interaction term *Post * Female directors* exhibits larger coefficients in Columns (1) and (3) than in Columns (2) and (4). This finding indicates that the impact of increased female board representation on carbon emissions reduction after board gender diversity reforms is more pronounced in firms located in collectivist countries, consistent with the third hypothesis.

[Insert Table 7 here]

4.5 Effect of the Paris Climate Agreement

Next, we investigate the influence of the 2015 Paris Agreement, a legally binding international treaty, on the association between board gender reform and carbon emissions. We use the date of agreement to divide the sample into two groups: pre- and post-agreement. Additionally, we distinguish between direct and indirect carbon emissions. Columns (1) and (2) of Table 8 present the results for direct emissions, whereas Columns (3) and (4) focus on indirect emissions. We then run the regression for each subsample following the baseline specification in Model (1).

The findings for the pre-Agreement subsample are shown in Columns (1) and (3) of Table 8, whereas Columns (2) and (4) display those for the post-Agreement subsample. Consistent with previous findings, we observe a negative and statistically

significant coefficient for the interaction term *Post*Female directors* in Columns 2 and 4 post-Agreement.

These results suggest that following the Paris Agreement, the addition of female directors to boards after reforms significantly contribute to a reduction in carbon emissions, with a 24% increase in the impact on emissions reduction. Notably, the influence of female directors on indirect carbon emissions becomes statistically significant at the 1% level post-Agreement. This finding underscores the relevance of the regulatory risks in our analysis. Before the Paris Agreement, international and national legislation often lack comprehensiveness and explicit distinctions regarding methods for reducing direct and indirect emissions, leading firms to focus primarily on direct emissions. Overall, these findings show that the impact of board reforms on corporate emissions intensifies following the Paris Agreement.

Our results are consistent with the existing literature, indicating that corporations respond to increased post-Agreement regulations and investor insistence by effectively reducing their carbon emissions (Bolton and Kacperczyk, 2021b). Furthermore, this study corroborates firms' tendency to focus on reducing carbon emissions based on their production and energy consumption, while often overlooking indirect emissions, as noted by Deng et al. (2023).

However, our findings underscore that the increased presence of women on boards after the reforms is crucial in curbing firms' indirect carbon emissions in the post-Paris Agreement period. This supports the fourth hypothesis and emphasizes the positive influence of regulations on corporate carbon emission reduction.

[Insert Table 8 here]

4.6 Robustness Check

Finally, we conduct an additional analysis to assess the robustness of the results. Initially, we examine the impact of the U.S. firms, which constitute over 30% of our sample, on our main results, as shown in Table 2. Consequently, we exclude the U.S. firms from our dataset and run a regression analysis. Table 9 presents the results of the robustness test, which are consistent with earlier findings and show a statistically significant negative coefficient for the interaction between the post-reform period and female directors. This finding reaffirms the baseline results.

Notably, after excluding the U.S. firms, the coefficient of *Female directors* in Column (1) is insignificantly positive. This observation helps elucidate the significantly positive effect observed in the baseline test, suggesting that the initial results might be influenced by the sample from the U.S.. This is particularly relevant given that the U.S. accords less emphasis on implementing carbon pricing policies (i.e., carbon tax and ETS) for carbon emission reduction.

[Insert Table 9 here]

To mitigate concerns regarding the influence of external factors, we conduct a placebo (falsification) test using randomly assigned pseudo-board reform years for each firm. We repeat the baseline DiDiD analysis 500 times for these pseudo-board reform years, and present results in Figure 1. Graphs A and B represent the distributions of the coefficient estimates for direct and indirect carbon emissions, respectively. In both scenarios, the coefficient of the interaction term *Post*Female directors* approaches zero, indicating no significant changes in corporate carbon emissions following the pseudo-board reform years. This lack of change in the placebo test rejects the notion that the observed reduction in carbon emissions in firms with an increased number of

female directors following the reforms is caused by confounding events.

[Insert Figure 1 here]

5. Conclusion

This study examines the impact of increased female representation on corporate boards following gender diversity reforms on companies' carbon emissions. Our cross-country analysis consistently demonstrates that such reforms leading to an increase in the number of female directors, result in reduced corporate carbon emissions.

These findings are based on the differentiation of reform approaches. The effect of increasing board gender representation after board gender diversity reforms on curbing corporate carbon emissions is greater for legislative reforms than for governance-code-based reforms. Moreover, although collectivist national cultures amplify these effects, significant reductions in carbon emissions have predominantly been achieved in individualistic societies pre-reforms. Additionally, the impact of increased female board representation on carbon emissions reduction after the reforms is notably more pronounced in the post-2015 Paris Climate Agreement period, highlighting the influence of increased regulatory insistence on corporate environmental practices. Prior to the agreement, the reforms focused primarily on mitigating direct emissions.

Overall, this study contributes to a broader understanding of how gender diversity reforms on boards intersect with environmental sustainability. This underscores the importance of gender diversity on corporate boards for addressing environmental challenges. From an investor perspective, these findings are crucial for navigating escalating environmental risk. This study emphasizes the need for robust regulatory enforcement and cohesive global collaboration to reduce carbon emissions

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from a policy perspective. In a broader societal context, corporations' commitment to gender diversity and effective regulatory frameworks are essential for combating climate change and promoting sustainable development.

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Figure 1 Placebo tests

Figure 1 plots the density of the coefficient estimates for *Post*Female directors* based on the 500 bootstrap simulations of the baseline model in Table 4. For each reform event, we assign a randomly chosen pseudo-implemented country. We then estimate the baseline regressions in Columns 2 and 4 of Table 4 based on the pseudo-event years and save the coefficient estimates for *Post*Female directors*. We repeat this procedure 500 times. Graph A displays the distribution of the coefficient estimates when the dependent variable is *Direct carbon emission*. Graph B shows the distribution of the coefficient estimates when the dependent variable is *Indirect carbon emission*.

Graph A: Density of the coefficient estimates on *Post*Female directors* when the dependent variable is *Direct carbon emission*.
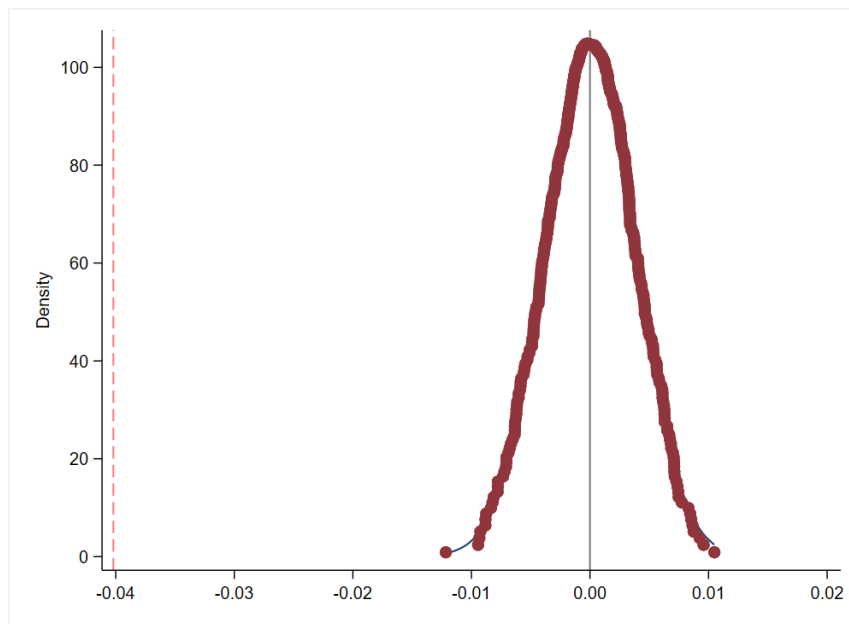
Graph B: Density of the coefficient estimates on *Post*Female directors* when the dependent variable is *Indirect carbon emission*.
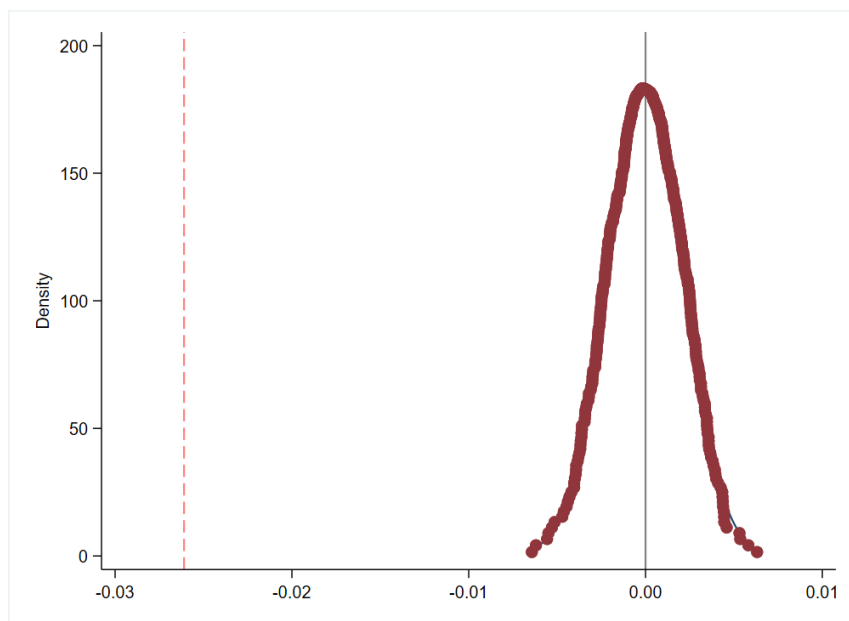
Table 1 Summary statistics
This table provides the summary statistics for the sample over the period 2002-2019. Variable definitions are provided in Appendix A.

variable	N	Mean	P25	P50	P75	Std.De.
Direct carbon emission	64,374	11.3829	9.6448	11.3055	13.0442	2.6312
Indirect carbon emission	64,374	12.1299	10.6164	12.2267	13.7115	2.2169
Post	64,374	0.3899	0.0000	0.0000	1.0000	0.4877
Post_legislation	64,374	0.1561	0.0000	0.0000	0.0000	0.3630
Post_code	64,374	0.3491	0.0000	0.0000	1.0000	0.4767
Female directors	64,374	1.4496	0.0000	1.0000	2.0000	1.3225
Market cap	64,374	21.7670	20.7094	21.7653	22.7943	1.5359
Book-to-market	64,374	0.6274	0.2832	0.4976	0.8178	0.5023
Leverage	64,374	0.2403	0.0906	0.2266	0.3583	0.1781
ROA	64,374	0.0418	0.0116	0.0403	0.0785	0.0888
PPE	64,374	0.2832	0.0543	0.1963	0.4492	0.2696
Board size	64,374	2.2383	2.0794	2.1972	2.4849	0.3285
NED ratio	64,374	0.7681	0.6667	0.8182	0.8889	0.1793
Avg. directors' tenure	64,374	6.7695	3.9889	6.1500	8.9308	3.8105
Law and order	64,374	4.8523	5.0000	5.0000	5.0000	0.8481

Table 2 Sample distribution by country

This table reports the sample distribution by country over the period 2002-2019.

Panel A: Overall sample distribution

Nation	# Firms (1)	Percentage (2)	# Unique firms (3)	Direct carbon emissions (4)	Indirect carbon emissions (5)
Australia	3,148	4.89	470	854,316.9	420,345.6
Austria	343	0.53	43	1,902,030	1,575,131
Belgium	568	0.88	73	1,365,672	1,242,768
Brazil	781	1.21	128	2,177,813	2,031,059
Canada	2,800	4.35	427	1,442,974	711,211.9
Chile	231	0.36	32	2,766,431	639,826.3
China	1,919	2.98	427	1,630,502	1,120,645
Colombia	96	0.15	16	2,569,888	1,469,592
Denmark	451	0.7	53	1,849,738	811,088.3
Egypt	67	0.1	17	297,738.5	168,881.9
Finland	532	0.83	68	1,422,545	1,427,146
France	2,377	3.69	285	2,613,928	2,235,585
Germany	2,069	3.21	273	3,149,049	2,936,900
Greece	241	0.37	35	3,677,563	721,973.6
Hong Kong	1,825	2.83	338	1,743,965	721,207.7
India	2,846	4.42	513	2,629,827	926,886.3
Indonesia	388	0.6	101	1,211,957	559,996.4
Ireland	546	0.85	59	969,354.8	1,353,847
Israel	405	0.63	84	351,030.3	314,147.8
Italy	975	1.51	145	3,098,132	1,571,328
Japan	3,148	4.89	555	2,627,462	2,795,410
South Korea	466	0.72	87	3,457,758	3,592,923
Luxembourg	205	0.32	34	5,078,893	3,154,748
Malaysia	587	0.91	134	1,690,149	414,857.1
Mexico	434	0.67	71	835,870.1	1,261,000
Morocco	45	0.07	11	1,073,085	306,203.6
Netherlands	849	1.32	101	647,404.3	1,916,385
New Zealand	281	0.44	62	283,984.8	334,361.3
Nigeria	131	0.2	19	1,468,358	314,851.2
Norway	547	0.85	86	1,701,598	1,643,668
Pakistan	29	0.05	12	1,325,589	202,517.2
Peru	36	0.06	11	508,971.2	150,890.1
Philippines	299	0.46	63	1,861,547	708,545.5
Poland	340	0.53	49	2,798,605	789,070.1
Portugal	177	0.27	20	4,091,766	1,286,444
Qatar	65	0.1	21	408,000.1	169,297
Russia	287	0.45	43	10,887,116	4,370,560
Saudi Arabia	84	0.13	44	5,308,845	1,765,184
Singapore	622	0.97	102	979,425.8	897,888.9
South Africa	1,302	2.02	164	1,295,698	421,890.3
Spain	865	1.34	98	3,362,244	1,779,217
Sweden	1,114	1.73	183	403,676.8	947,560.3
Switzerland	1,588	2.47	213	1,074,717	1,281,320
Taiwan	752	1.17	166	1,601,471	1,157,654
Thailand	402	0.62	106	3,021,872	1,379,451
Turkey	294	0.46	47	2,531,939	1,129,046
United Arab Emirates	132	0.21	35	171,806.6	148,535.1
United Kingdom	6,036	9.38	643	1,187,371	877,438.1
United States	20,617	32.03	3,102	1,799,931	1,322,819
Vietnam	32	0.05	14	599,756.3	545,945.9

Panel B: Pre- and post-reforms sample descriptive statistics

Nation	Reform	Female directors		Direct carbon emissions		Indirect carbon emissions	
		Pre	Post	Pre	Post	Pre	Post
		(1)	(2)	(3)	(4)	(5)	(6)
Australia	YES	0.67	1.33	1,106,816	765,671.5	518,012.3	386,057.5
Austria	YES	1.12	1.96	3,599,893	1,542,059	2,370,016	1,406,604
Belgium	YES	0.68	2.44	1,495,907	1,330,788	1,698,894	1,120,592
Brazil	NO	0.60		2,177,813		2,031,059	
Canada	NO	1.67		1,442,974		711,211.9	
Chile	NO	0.55		2,766,431		639,826.3	
China	NO	0.97		1,630,502		1,120,645	
Colombia	NO	0.96		2,569,888		1,469,592	
Denmark	YES	1.47	2.15	2,615,932	1,658,721	1,000,282	763,921.1
Egypt	NO	0.87		297,738.5		168,881.9	
Finland	YES	1.82	2.30	2,156,501	1,157,870	2,433,256	1,064,329
France	YES	1.07	3.46	4,324,917	2,027,166	3,658,207	1,747,714
Germany	YES	1.51	2.41	5,077,751	2,472,996	4,788,466	2,287,885
Greece	YES	0.74	0.88	5,420,458	2,354,490	1,038,693	481,544.1
Hong Kong	YES	0.99	1.15	2,135,682	1,636,113	712,988.8	723,470.6
India	YES	0.62	1.25	3,164,602	2,435,689	1,187,579	832,247.7
Indonesia	NO	1.36		1,211,957		559,996.4	
Ireland	YES	1.15	1.85	825,324.8	1,037,293	1,492,049	1,288,657
Israel	NO	1.68		351,030.3		314,147.8	
Italy	YES	0.54	3.25	4,914,227	2,215,001	2,204,729	1,263,317
Japan	YES	0.19	0.43	3,783,833	2,350,662	4,738,256	2,330,351
South Korea	NO	0.21		3,457,758		3,592,923	
Luxembourg	YES	0.23	0.99	10,204,759	4,165,663	6,033,024	2,641,952
Malaysia	YES	0.72	1.54	3,234,626	1,558,825	333,957.8	421,735.8
Mexico	NO	0.77		835,870.1		1,261,000	
Morocco	NO	0.44		1,073,085		306,203.6	
Netherlands	YES	0.60	1.53	917,672.8	573,657.8	2,599,064	1,730,106
New Zealand	NO	1.65		283,984.8		334,361.3	
Nigeria	NO	2.23		1,468,358		314,851.2	
Norway	YES	2.78	3.00	5,120,205	1,644,409	5,415,601	1580569
Pakistan	NO	0.59		1,325,589		202,517.2	
Peru	NO	0.44		508,971.2		150,890.1	
Philippines	NO	1.22		1,861,547		708,545.5	
Poland	YES	1.25	1.86	646,555.6	3,196,021	875,702.8	773,071.8
Portugal	NO	0.52	2.19	4,795,516	2,488,780	1,366,039	1,105,146
Qatar	NO	0.06		408,000.1		169,297	
Russia	NO	1.11		10,887,116		4,370,560	
Saudi Arabia	NO	0.14		5,308,845		1,765,184	
Singapore	YES	0.66	1.11	1,220,267	900,174.6	1,365,593	743,986.4
South Africa	YES	1.87	2.38	4,693,535	1,145,834	972,522.8	397,604.2
Spain	YES	0.48	1.81	5,131,482	3,077,266	2,675,019	1,634,927
Sweden	YES	1.64	2.66	1,134,958	372,893.2	2,107,733	898,722.3
Switzerland	YES	0.68	1.13	1,724,986	672,359.2	1,926,458	882,137.3
Taiwan	NO	0.90		1,601,471		1,157,654	
Thailand	YES	1.26	1.78	4,447,596	2,951,144	1,912,782	1,352,993
Turkey	NO	1.17		2,531,939		1,129,046	
United Arab Emirates	NO	0.17		171,806.6		148,535.1	
United Kingdom	YES	0.63	1.51	1,164,519	1,202,750	858,058.1	890,479.8
United States	NO	1.53		1,799,931		1,322,819	
Vietnam	NO	1.47		599,756.3		545,945.9	

Table 3 Correlation matrix

This table presents the correlation matrix for all variables. *indicates significance at the 10 % level.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Direct carbon emission	1.0000														
(2) Indirect carbon emission	0.8426*	1.0000													
(3) Post	-0.0695*	-0.0696*	1.0000												
(4) Post_legislation	-0.0735*	-0.0736*	0.5380*	1.0000											
(5) Post_code	-0.0597*	-0.0568*	0.9161*	0.3515*	1.0000										
(6) Female directors	0.0879*	0.1402*	0.1770*	0.2431*	0.1709*	1.0000									
(7) Market cap	0.5337*	0.6386*	-0.1284*	-0.1038*	-0.1063*	0.2365*	1.0000								
(8) Book-to-market	0.0726*	-0.0069*	0.1097*	0.0279*	0.1124*	-0.0288*	-0.2302*	1.0000							
(9) Leverage	0.2334*	0.1207*	-0.0293*	0.0049	-0.0310*	0.0263*	0.0547*	0.0726*	1.0000						
(10) ROA	0.1365*	0.1811*	0.0451*	0.0076*	0.0306*	0.0104*	0.2267*	-0.2468*	-0.1491*	1.0000					
(11) PPE	0.3929*	0.0961*	-0.0278*	-0.0373*	-0.0253*	-0.0664*	0.0095*	0.1142*	0.3306*	0.0206*	1.0000				
(12) Board size	0.3408*	0.4237*	-0.0330*	-0.0071*	-0.0246*	0.3853*	0.4879*	0.0506*	0.0685*	0.0096*	-0.0454*	1.0000			
(13) NED ratio	0.0135*	0.0043	-0.1988*	0.0392*	-0.2113*	0.2784*	0.1058*	-0.1047*	0.0740*	-0.0623*	0.0210*	0.0223*	1.0000		
(14) Avg. director's tenure	0.0261*	0.0524*	-0.1086*	-0.0540*	-0.1010*	-0.0148*	0.0436*	-0.0445*	-0.0493*	0.1275*	0.0035	0.0215*	0.0060	1.0000	
(15) Law and order	-0.0604*	-0.0201*	0.0568*	0.1044*	0.0693*	0.0323*	-0.0083*	-0.0604*	-0.0206*	-0.0438*	0.0154*	-0.1206*	0.0544*	0.0108*	1.0000

Table 4 Board gender diversity reform, female directors, and carbon emissions
This table reports the regression results of the impact of adopting board gender diversity reforms and the number of female directors on firms' carbon emissions over the period 2002-2019. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. *Direct carbon emission* is calculated as the natural logarithm of the Scope 1 and 2 carbon emissions plus one. *Indirect carbon emission* is calculated as the natural logarithm of Scope 3 carbon emissions plus one. The independent variables are *Post* and *Female directors*. *Post* is a dummy variable equal to one in the years following a country's adoption of board gender diversity reform (i.e., either legislation-based or governance code-based) and zero otherwise. *Female directors* refer to the number of female directors on corporate boards. The other variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Direct carbon emission		Indirect carbon emission	
	(1)	(2)	(3)	(4)
Post*Female directors	-0.0684***	-0.0402***	-0.0563***	-0.0261***
	(-7.624)	(-4.558)	(-8.538)	(-4.714)
Post	0.0382	0.0469*	0.0253	0.0355
	(1.256)	(1.802)	(0.988)	(1.488)
Female directors	0.0379***	0.0114*	0.0480***	0.0162***
	(5.161)	(1.683)	(8.671)	(4.104)
Market cap		0.4504***		0.4993***
		(31.557)		(42.836)
Book-to-market		0.5033***		0.4651***
		(26.536)		(31.804)
Leverage		0.8099***		0.7543***
		(15.686)		(18.823)
ROA		0.0989		0.1602**
		(1.368)		(2.354)
PPE		0.3446***		0.2551***
		(5.523)		(5.217)
Board size		0.2343***		0.2550***
		(9.057)		(13.014)
NED ratio		-0.0533		0.0544
		(-0.880)		(1.453)
Avg. directors' tenure		0.0223***		0.0180***
		(11.406)		(14.562)
Law and order		0.0758		0.0131
		(1.504)		(0.505)
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.9510	0.9558	0.9681	0.9759
Observations	64,374	64,374	64,374	64,374

Table 5 Dynamic effect analysis

This table reports the regression results for the dynamic effect of adopting the gender diversity reform and the number of female directors on firms' carbon emissions over the period 2002-2019. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. *Direct carbon emission* is calculated as the natural logarithms of the Scope 1 and Scope 2 carbon emissions plus one. *Indirect carbon emission* is calculated as the natural logarithm of Scope 3 carbon emissions plus one. *Before^{-1}, Before^{-2}, Current, After^{+1},* and *After^{+2}* dummies are defined corresponding to the specific timeframes relative to the reform implementation. The control variables are the same as those listed in Table 4. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Direct carbon emission (1)	Indirect carbon emission (2)
Before^{-2}*Female directors	-0.0332	-0.0235
	(-1.626)	(-1.477)
Before^{-1}*Female directors	-0.0273	-0.0009
	(-1.203)	(-0.086)
Current*Female directors	-0.0116	-0.0064
	(-0.726)	(-0.674)
After^{+1}*Female directors	-0.0090	-0.0142*
	(-0.649)	(-1.678)
After^{2+}*Female directors	-0.0458***	-0.0282***
	(-4.877)	(-5.162)
Post	0.0277	0.0267
	(1.054)	(1.104)
Female directors	0.0154**	0.0177***
	(-2.085)	(-4.379)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.9558	0.9759
Observations	64,374	64,374

Table 6 Analysis conditional on reform approaches

This table presents the regression results of the impact of adopting the board gender diversity reform and the number of female directors on firms' carbon emissions following different reform approaches over the period 2002-2019. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. The independent variables are *Post_legislation*, *Post_code,* and *Female directors*. The control variables are the same as those listed in Table 4. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Direct carbon emission	Indirect carbon emission
	(1)	(2)
Post_legislation*Female directors	-0.0384***	-0.0331***
	(-3.210)	(-4.660)
Post_code*Female directors	-0.0267**	-0.0178***
	(-2.332)	(-3.151)
Post_legislation	0.1832***	0.1713***
	(5.626)	(5.708)
Post_code	-0.0245	-0.0258
	(-0.973)	(-1.233)
Female directors	0.0124*	0.0185***
	(1.933)	(4.853)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.9559	0.9760
Observations	64,374	64,374

Table 7 Subsample test by national culture: Collectivism and individualism

This table presents subsample tests between firms located in collectivistic and individualistic countries regarding the impact of board gender diversity reform adoption and the number of female directors on firms' carbon emissions during the period 2002-2019. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. The independent variables are *Post* and *Female directors*. The control variables are the same as those listed in Table 4. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Direct carbon emission		Indirect carbon emission	
	Collectivism	Individualism	Collectivism	Individualism
	(1)	(2)	(3)	(4)
Post*Female directors	-0.0643***	-0.0464**	-0.0302***	-0.0224*
	(-4.344)	(-2.281)	(-3.323)	(-1.977)
Post	0.1000**	0.0088	0.0110	0.0435*
	(2.213)	(0.242)	(0.307)	(1.762)
Female directors	0.0196	0.0184*	0.0178**	0.0213***
	(1.501)	(1.919)	(2.048)	(4.896)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.9550	0.9633	0.9785	0.9777
Observations	19,537	26,653	19,537	26,653

Table 8 Subsample test by Paris Agreement: Before and after
This table reports the regression results of the impact of adopting board gender diversity reform and the number of female directors on firms' carbon emissions, segmented before and after the Paris Agreement between 2002-2019. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. The independent variables are *Post* and *Female directors*. The control variables are the same as those listed in Table 4. All variables are defined in Appendix A. All regressions include firm and year fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

	Direct carbon emission		Indirect carbon emission	
	Before	After	Before	After
	(1)	(2)	(3)	(4)
Post*Female directors	-0.0316***	-0.0394***	-0.0091	-0.0225***
	(-3.038)	(-2.781)	(-1.426)	(-3.908)
Post	0.0437*	-0.2092***	0.0214	0.0818**
	(1.713)	(-2.670)	(0.935)	(2.365)
Female directors	0.0023	0.0200	-0.0016	0.0222***
	(0.273)	(1.597)	(-0.337)	(4.542)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjusted R^2	0.9556	0.9764	0.9733	0.9886
Observations	30,395	33,979	30,395	33,979

Table 9 Robustness test: excluding U.S. firms

This table presents the results of the baseline specifications (see Table 4), excluding the U.S. firms. The dependent variables are *Direct carbon emission* and *Indirect carbon emission*. The independent variables are *Post* and *Female directors*. The control variables are the same as those listed in Table 4. All regressions include firm and year fixed effects. Appendix A defines all the variables. The numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	Direct carbon emission	Indirect carbon emission
	(1)	(2)
Post*Female directors	-0.0428***	-0.0225***
	(-4.418)	(-3.611)
Post	0.0483	0.0163
	(1.604)	(0.610)
Female directors	0.0133	0.0103*
	(1.507)	(1.884)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.9489	0.9746
Observations	43,757	43,757

Appendix A Table of Definitions

Variables	Definition	Sources
Direct carbon emission	Natural log of Scopes 1 and scope 2's carbon emission plus one.	Trucost
Indirect carbon emission	Natural log of Scope 3 carbon emission plus one.	Trucost
Post	A dummy variable that equals one for years following the adoption of a board gender diversity reform by a country (i.e., either the legislative or the governance code-based) and zero otherwise	Fauver et al. (2022) and Ding et al. (2022)
Post_legislation	A dummy variable that equals one for the years following boardroom gender diversity legislation applied and zero otherwise.	Fauver et al. (2022) and Ding et al. (2022)
Post_code	A dummy variable that equals one for the years following a boardroom gender diversity governance code is applied and zero otherwise.	Fauver et al. (2022) and Ding et al. (2022)
Female directors	Number of female directors.	BoardEx
Market cap	Natural log of market capitalization.	Worldscope
Book-to-market	book value of total assets divided by the market value of total assets.	Worldscope
Leverage	Book value of total debt divided by the book value of total assets.	Worldscope
ROA	Net income divided by the book value of total assets.	Worldscope
PPE	Net property, plant and equipment divided by the total assets.	Worldscope
Board size	Natural log of the number of board directors.	BoardEx
NED ratio	Number of non-executive directors divided by the number of board directors.	BoardEx
Avg. directors' tenure	Average tenure of board directors on the board.	BoardEx
Law and order	Standardized value between 0–6 capturing the strength and impartiality of the legal system, and the popular observance of the law. The higher value indicates the better law and order.	ICRG

Internet Appendix

Table IA1 Board gender diversity reform and female directors

This table reports the regression results of the impact of adopting gender diversity reform on the number of female directors over the period 2002-2019. The dependent variables is *Female directors*. The independent variables are *Post*, *Post_legislation* and *Post_code*. The control variables are the same as those listed in Table 4. All variables are defined in Appendix A. All regressions include firm- and year-fixed effects. Numbers in parentheses are *t*-statistics based on standard errors clustered at the country level by year. ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively.

Variables	Female directors (1)	Female directors (2)
Post	0.3231***	
	(4.344)	
Post_legislation		0.7466***
		(7.406)
Post_code		0.2422***
		(3.768)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjusted R^2	0.7644	0.7745
Observations	64,374	64,374