

July 2023

---

## WORKING PAPER SERIES

2023-ACF-02

### Board Gender Diversity Reform and Corporate Carbon Emissions

**Raul Barroso**

IESEG School of Management, Univ. Lille, CNRS, UMR 9221 - LEM - Lille Économie Management, F-59000 Lille, France, [r.barrosocasado@ieseg.fr](mailto:r.barrosocasado@ieseg.fr)

**Tinghua Duan**

IESEG School of Management, Univ. Lille, CNRS, UMR 9221 - LEM - Lille Économie Management, F-59000 Lille, France, [t.duan@ieseg.fr](mailto:t.duan@ieseg.fr)

**Siyue Guo**

IESEG School of Management, France, [siyue.guo1@ieseg.fr](mailto:siyue.guo1@ieseg.fr)

**Oskar Kowalewski**

IESEG School of Management, Univ. Lille, CNRS, UMR 9221 - LEM - Lille Économie Management, F-59000 Lille, France, [o.kowalewski@ieseg.fr](mailto:o.kowalewski@ieseg.fr)

IESEG School of Management Lille Catholic University 3, rue de la Digue F-59000 Lille Tel: 33(0)3 20 54 58 92  
[www.ieseg.fr](http://www.ieseg.fr)

Staff Working Papers describe research in progress by the author(s) and are published to elicit comments and to further debate. Any views expressed are solely those of the author(s) and so cannot be taken to represent those of IESEG School of Management or its partner institutions.

All rights reserved. Any reproduction, publication and reprint in the form of a different publication, whether printed or produced electronically, in whole or in part, is permitted only with the explicit written authorization of the author(s).

For all questions related to author rights and copyrights, please contact directly the author(s).

## Board Gender Diversity Reform and Corporate Carbon Emissions

Raul Barroso<sup>a,b,c,\*</sup>, Tinghua Duan<sup>a,b,c</sup>, Siyue Guo<sup>d</sup>, Oskar Kowalewski<sup>a,b,c</sup>,

<sup>a</sup>*IESEG School of Management, UMR 9221 - LEM - Lille Économie Management, Lille, France*

<sup>b</sup>*Univ. Lille, UMR 9221 - LEM - Lille Économie Management, Lille, France*

<sup>c</sup>*CNRS, UMR 9221 - LEM - Lille Économie Management, Lille, France*

<sup>d</sup>*IESEG School of Management, France*

### Abstract

We examine the impact of international gender diversity reforms in the board of directors on carbon emissions. Employing a difference-in-differences-in-differences analysis, we analyze the relationship between the increase in female representation on boards following these reforms and changes in firms' carbon emissions. Our results reveal a significant decline in carbon emissions with an increase in the proportion of female board members. The reduction in carbon emissions is observed to be more pronounced when gender reform is legally enforced. Additionally, our findings indicate that a combination of climate regulations and higher female representation on boards leads to a decline in both, direct and indirect carbon emissions. These findings underscore the importance of legal enforcement in promoting board gender diversity, which, in turn, plays a critical role in addressing climate change.

*Keywords:* gender diversity reforms, climate change, law, enforcement

*JEL Code:* G34, J16, Q54, K42

---

\* Corresponding author: IESEG School of Management, Socle de la Grande Arche, 1 Parvis de La Défense - F-92044 Paris La Défense cedex, France, Tel. +33 (0)1 559 110 10, Emails: [r.barrosocasado@ieseg.fr](mailto:r.barrosocasado@ieseg.fr) (Raul Barroso), [t.duan@ieseg.fr](mailto:t.duan@ieseg.fr) (Tinghua Duan), [siyue.guo1@ieseg.fr](mailto:siyue.guo1@ieseg.fr) (Siyue Guo), [o.kowalewski@ieseg.fr](mailto:o.kowalewski@ieseg.fr) (Oskar Kowalewski)

## 1. Introduction

On December 2015, 195 countries signed the Paris Agreement with the aim to hold “the increase in the global average temperature to below 2°C above pre-industrial levels.”<sup>2</sup> This legally binding international treaty for tackling climate change is a landmark in limiting global warming. Despite the efforts of all stakeholders (governments, corporations, investors, and consumers), eight years after the signing of the treaty, carbon dioxide (CO<sub>2</sub>) emission was faster than agreed upon (IEA, 2021). Therefore, the search for effective methods to mitigate global warming continues. Reducing greenhouse gas (GHG) emissions remains the primary method for reducing global temperatures.

We build on this urgency, as well as on previous research linking the positive role played by female directors with corporate social responsibility (CSR) (e.g., Ding et al., 2022), to understand, using international data, whether there is a direct link between the increasing number of female directors on a firm’s board and a reduction in GHG emissions. There is already a wide line of research demonstrating that women’s responses to climate change differ from those of men, which is attributable to socioeconomic and cultural contexts (Pearce, 2017). Simultaneously, research investigating the relationship between gender and responsibility for a direct measure of GHG levels is underdeveloped.

This study aims to fill this gap by studying the impact of board gender diversity on firms’ CO<sub>2</sub> emissions, which is the primary driver of global climate change. To achieve this, we exploited two important legislative trends. The first is the increasing level and importance of the disclosure of carbon emissions (Bolton et al., 2021, 2002). Second,

---

<sup>2</sup> <https://unfccc.int/process-and-meetings/the-paris-agreement#:~:text=Its%20overarching%20goal%20is%20to,above%20pre%2Dindustrial%20levels>

two decades of legislative reform have induced gender diversity in different countries (e.g., Ahern and Dittmar, 2012) at different rhythms.

The socialization theory shows that, according to psychological characteristics, women are more concerned with the welfare of stakeholders, and are, therefore, more likely to take action to prevent environmental dangers that can impact communities (Adams et al. 2011; Carlson, 1972; Gilligan, 1977), and to support policies that regulate and protect citizens, consumers, and the environment (Liu, 2018; Shapiro and Mahajan, 1986). Because the objective of carbon emission reduction is to combat climate change, female, rather than male, directors are expected to perform better in effecting it.

Huang et al. (2018) document that climate risk negatively influences companies' performance and financing choices. Ramadorai and Zeni (2021) argue that regulatory climate risk increased further after the 2015 Paris Agreement. The Agreement obliges countries to manage the impact of climate change, including the need to limit global emissions.

Existing evidence shows that women are more risk-averse than men (Bernasek and Shwiff, 2001; Hudgens and Fatkin, 1985) and are more perceptive about financial (Croson and Gneezy, 2009; Faccio et al., 2016), and environmental risks (Bord and O'Connor, 1997). Female risk aversion is relevant to our study because corporate carbon emissions reflect the regulatory risk of climate change in the transition period to a low-carbon economy (Bolton and Kacperczyk, 2021; Bolton and Kacperczyk, 2022; Duan, et al., 2023). Because the objective of carbon emission reduction is to combat climate change, female directors are expected to perform better in effecting it, as compared to their male counterparts.

To investigate the influence of a greater proportion of women on corporate boards, on carbon pollution, we employed a difference-in-differences-in-differences (DiDiD)

strategy, using worldwide board diversity reforms. The board diversity reforms, which stem from the broader advocacy of good governance practices, are exogenous to individual firms within a country, including their carbon pollution levels.

Using a sample of international publicly traded firms for the 2002-2019 period, we link their board structures with the data on carbon emissions. To strengthen the validity of the setting, we verify, through a dynamic test, that no trends in carbon emissions existed before the initiation of board reforms. This premise satisfies the conditions for using the DiDiD method by supporting the exogeneity of the reforms (Bertrand and Mullainathan, 2003; Fauver et al., 2022).

We start our analysis by examining whether increasing female representation on boards, as induced by the reforms, increases, or decreases firms' carbon emissions. We conduct a baseline analysis on 9,883 non-financial firms, established in 50 countries that adopted board reforms for the first time within our sample period. We find that an increase in female representation following the adoption of reforms is associated with a statistically significant decline in firms' carbon emissions.

We differentiate the effects of the approaches to reform – whether the changes promulgated by board reforms are mandatory (legislative approach) or advising (comply-or-explain). Our results indicate that carbon emissions reduction is greater when female representation on the board is mandated by law (legislative approach). We further examine the effects of the regulations by investigating the effects of the 2015 Paris Agreement. Our results show that increases in female representation, following board and climate reforms, result in a greater reduction in direct and indirect carbon emissions. Thus, the results indicate that a legislative approach is advisable to address the diversity of boards and climate change. Finally, we conduct additional validity tests at the firm level to strengthen our baseline findings.

This study contributes to existing literature in several ways. First, it provides new evidence on the impact of gender on corporate carbon emissions. While previous research has primarily focused on examining sex differences in household and corporate energy consumption, our study expands the scope by exploring the relationship between female representation on corporate boards and carbon emissions. For instance, Carlsson-Kanyama et al. (1999) and Rätty and Carlsson-Kanyama (2010) documented that, on average, CO<sub>2</sub> emissions from men's transportation patterns were significantly higher than those from women's. They attributed these differences to factors, such as longer travel distances and the choice of energy-intensive vehicles. In line with these studies, Atif et al. (2021) found that increased board gender diversity in US firms is positively correlated with a higher consumption of renewable energy. Furthermore, Ergas and York (2012) demonstrated that countries with higher political status for women tend to have lower per capita CO<sub>2</sub> emissions from fossil fuels at a national level. Building on these existing findings, our study complements the literature by showing that an increase in female representation on corporate boards, following board gender reforms, leads to reduced carbon emissions across companies worldwide. By extending the analysis to the corporate level and focusing on the effects of gender diversity in the boardroom, this study contributes to a more comprehensive understanding of the relationship between gender and carbon emissions.

Second, we add to the growing literature on the adoption of gender diversity reforms in the board room. The main argument supporting the inclusion of women as board members is that diversity is crucial for corporate value creation. Advocates argue that women bring unique perspectives, experiences, and work styles that differ from their male counterparts (Daily and Dalton, 2003; Huse et al., 2009). By diversifying board composition, companies can tap into a wider range of ideas, insights, and decision-

making approaches, which can improve corporate performance. However, the literature exploring the relationship between female board members and company performance has produced mixed results (Huse et al., 2009). Rhode and Packel (2014) survey the impact of gender diversity on firm performance and find no consistent positive or negative relationships with various financial measures.

However, Ding et al. (2022) find that reforms increase corporate CSR performance, especially legislation-based regulations. We complement these results by showing that adopting board reforms that increase the number of female board members reduces corporate carbon emissions, a measure with direct impact on global warming.

The rest of this paper proceeds as follows. Section 2 presents the literature review and outlines our hypotheses. Section 3 introduces the data and methodology. Section 4 presents and discusses the empirical results, and Section 5 concludes the paper.

## **2. Hypothesis development**

### *2.1 Boardroom Gender Diversity*

Norway was the first country to introduce a boardroom gender diversity reform in 2006, mandating publicly listed firms to have a minimum of 40% female directors on their corporate boards by 2008, or face dissolution (Sjåfjell and Reiersen, 2008). The Norwegian government reported successful compliance with the program, which resulted in a remarkable increase in women's representation on boards, rising from 7% in 2002 to over 40% by the end of 2008. This approach, which was initially considered radical, inspired other countries to implement their own versions of quota regulations after 2008. For example, Italy and Belgium introduced laws in 2011 that required a third of board members of publicly listed and state-owned companies to be women (Carletti, 2019; Du Plessis et al., 2014). On the other hand, countries like the UK

launched voluntary initiatives that aimed for 33% of board of listed companies to be filled by women (Choudhury, 2014). Despite these efforts, many developed countries, including some European Union (EU) members, such as Malta, Poland, and Romania, have not implemented any measures. Furthermore, in some instances, board reforms have not achieved the desired results (Suk, 2012).

In 2012, the EU proposed a directive requiring a minimum representation of 40% of the under-represented sex among non-executive directors of companies listed on stock exchanges. However, the proposed law did not secure sufficient support within the EU, and was thus put on hold. By the end of 2022, only six out of 27 EU member states had implemented strong measures to promote more balanced representation at the board level. France, Italy, and the Netherlands have a significantly higher representation of women on boards. Ten member states adopted softer measures, demonstrating some progress, but with notable variations. For instance, Sweden and Denmark reported quotas above 35%, whereas Greece and Slovenia reported quotas slightly below 20%. On the other hand, eleven member states did not implement any measures, and their gender balance at the board level is significantly lower. Malta, Hungary, Estonia, and Cyprus have the lowest representation of women on boards (Nuyens, 2023). Finally, the European Parliament formally adopted a new EU law on the gender balance on corporate boards. By 2026, companies will need to have 40% of the under-represented sex among non-executive directors, or 33% among all directors.

The broad disparity between the EU member states illustrates that these differences cannot be attributed solely to a country's economic development or legal systems. The heterogeneity of board reforms across countries provides time-series variation and, therefore, a valuable setting for investigating the impact of increased female representation on climate change.



### *2.1 Why Gender Differences Matter for Carbon Emission?*

Following the adoption of these reforms, we anticipate an increase in the proportion of female directors on boards, which may affect carbon emissions for two primary reasons. First, research suggests that women inherently possess more prosocial and altruistic traits than men (Andreoni and Vesterlund, 2001) and are generally more sensitive to ethical issues and law abiding (Adams and Gneezy, 2009; Adams and Funk, 2012). Adams and Funk (2012) indicate that women are more concerned about stakeholders' interests, suggesting that they are less likely to make decisions solely for personal financial gains. Instead, they are inclined to supervise enterprises by taking action to prevent environmental hazards that can affect communities.

Women also tend to exhibit greater caution towards regulations and other protective policies that safeguard citizens, consumers, and the environment (Shapiro and Mahajan, 1986). This higher regard for policies enables them to effectively monitor companies' compliance with carbon emission reduction policies, thereby contributing to the fight against climate change. Liao et al. (2015) find that firms with more gender-diverse boards are more likely to respond to the Carbon Disclosure Project (CDP) questionnaire and achieve higher CDP scores. The presence and independence of an environmental committee also positively impacts the likelihood of reporting Greenhouse Gas (GHG) emissions. Ben-Amar et al. (2017) found similar results using a larger sample of Canadian firms. However, their results show that the positive effect of board gender diversity on the likelihood of responding to the CDP questionnaire was conditional on female directors reaching a critical mass in the boardroom.

Adams and Ferreira (2009) provide evidence that board gender diversity affects board governance. They found that greater female representation improved board attendance

and monitoring. Women also exhibit heightened attention to ethical issues and hold higher moral standards than men (Gilligan, 1977). They demonstrate greater concern for social responsibility and preservation of the environment, motivating female directors to take action to support climate protection.

Because carbon emissions constitute a significant dimension in measuring corporate environmental performance, the literature suggests that the presence of women on boards is associated with improved corporate Environmental, Social, and Governance (ESG) performance. Liu (2018) finds that in firms with low board gender diversity, the inclusion of female directors and CEOs is linked to fewer environmental lawsuits. Do et al. (2023) show that more diverse boards respond more strongly to regional voluntary climate reporting initiatives in the U.S., which, in turn, translates into better environmental performance.

Second, women tend to exhibit less risk-taking behavior and greater risk aversion than men (Bernasek and Shwiff, 2001; Hudgens and Fatkin, 1985; Faccio et al., 2016), in addition to a sharper perception of environmental risks (Bord and O'Connor, 1997). As companies navigate the transition to a low-carbon economy, they face potential risks due to stringent government policies aimed at combating climate change. Krueger et al. (2020) highlighted that government regulations related to carbon emission reduction are considered risk factors in financial markets. Empirical studies, such as those by Delis et al. (2019), demonstrate that banks price climate-policy risks or exposure to fossil fuel companies. They find that the cost of credit for fossil fuel firms increased after 2015, and "green banks" charge slightly higher loan rates to these firms. Bolton and Kacperczyk (2021, 2022) show that carbon emissions represent a systematic risk factor in the stock market, and market prices represent carbon risk. Duan et al. (2023) and Seltzer et al. (2022) provide evidence that corporate bonds issued by firms with

high carbon risk are riskier than by those with a low carbon risk.

In summary, companies with higher carbon emissions are associated with greater capital market risk. Therefore, with increased female representation on boards, firms are expected to implement more stringent measures to oversee emission reduction activities and mitigate risks. Hence, we hypothesize that the adoption of boardroom gender diversity reforms is linked to reduced corporate carbon emissions.

**H1:** *The adoption of boardroom gender diversity reforms is associated with lower corporate carbon emissions.*

Countries typically adopt one of two approaches to enforce board gender diversity reforms: soft and hard law. The first approach introduces a governance code that follows a 'comply-or-explain' principle, allowing firms to explain if they do not comply with the gender diversity requirement. The second is a rule-based system that mandates compliance. Both the 'comply-or-explain' reforms (soft law) and legislative-based reforms (hard law) are globally prevalent, and their effects are widely debated.

However, the use of a legislative approach, specifically, mandated quotas, remains controversial. Critics argue that a limited pool of qualified candidates undermines the decision-making effectiveness of corporate boards, negatively impacting financial performance. This controversy raises important questions about the necessity of regulatory intervention and the most effective regulatory approach for fostering gender balance on boards (Bennouri et al., 2020).

In contrast, Fauver et al. (2022) and Ding et al. (2022) find that legislative regulations lead to a greater increase in female representation on boards than governance code regulations. They also observe that legislation-based reforms have a stronger impact on corporate social responsibility (CSR) performance and are more effective in enabling foreign institutions to influence boardroom gender diversity. These findings suggest

that legislation-based reforms possess greater enforcement power and stricter sanctions, leading to better implementation of boardroom gender diversity reforms. Based on these insights, we hypothesize that firms subject to legislation-based reforms would exhibit more reduction in corporate carbon emissions. This hypothesis stems from the notion that the stringent enforcement and oversight associated with legislation-based reforms are conducive to the effective implementation of boardroom gender diversity reforms.

**H2:** *The impact of boardroom gender diversity reforms on the reduction of corporate carbon emission is stronger with the adoption of legislative-based (hard law) reforms.*

The existing literature increasingly recognizes the association between cultural dimensions, corporate strategic decision-making, and outcomes. Frijns et al. (2016) suggested that these cultural dimensions play a pivotal role in shaping board diversity, which subsequently influences firm performance. Similarly, Cai et al. (2016) report that disparities in corporate social performance across countries could be attributed to differences in national cultures. Consequently, we hypothesize that the impact of boardroom gender diversity reforms on firms may vary according to their cultural values.

We evaluate the significance of national culture by considering two dimensions of Hofstede's (2011) national culture construct: individualism and collectivism. Depending on the dominant culture, each country can be categorized as individualistic or collectivistic. In societies leaning towards individualism, emphasis is placed on personal independence, whereas collectivistic societies foster strong, cohesive in-groups (Hofstede, 2011). Women in individualistic societies are expected to prioritize their personal interests and well-being, whereas in collectivistic societies, women's

decisions align more closely with community interests.

Vu (2023) posits that individualistic societies are more proficient in implementing stringent climate mitigation policies than their collectivistic counterparts, arguing that such societies can tackle global warming more effectively by enhancing women's participation in legislation. Corroborating this, Nartova-Bochaver et al. (2022) found that, in individualistic countries, compared to their collectivistic counterparts, there is less denial of climate change, especially among women.

By contrast, Xiang et al. (2019) discovered that participants with stronger individualist orientations were less inclined to take climate-friendly actions than those with a collectivist mindset. Furthermore, they determined that individualistic or collectivist stances could mediate climate-change inaction through perceived intractability. Thus, we propose Hypothesis 3 as follows:

**H3:** *The impact of boardroom gender diversity reforms on the reduction of corporate carbon emission is stronger in firms in collectivist countries.*

As climate risk has emerged as a global concern for governments and societies alike, we anticipate that reforms towards greater gender diversity in the boardroom will significantly bolster efforts to reduce carbon emissions. In 2015, the Paris Agreement was adopted to limit the increase in global temperature to 1.5 degrees Celsius. To date, 195 out of 198 parties ratified this agreement. The governments party to the Paris Agreement are expected to enforce stringent climate regulations, thus exerting pressure on corporations to lower their carbon emissions. Seltzer et al. (2022) demonstrates that the Paris Agreement heightened the regulatory risk for firms with environmentally harmful practices or substantial carbon footprints. Consequently, we forecast that the impact of board gender diversity reforms on carbon emission reduction will be more marked in countries after the ratification of the Paris Agreement. Based on this, we

propose Hypothesis 4:

***H4:** The impact of boardroom gender diversity reforms on the reduction of corporate carbon emission is stronger after the signing of the Paris Agreement.*

### **3. Research Design**

#### *3.1 Data sources*

To conduct the data analysis, we first obtained firm-level carbon emissions data from the S&P Global Trucost database between 2002 and 2019.<sup>3</sup> Scope 1 emissions include those from fossil fuels used in production, and cover direct emissions from facilities owned or controlled by companies. Scope 2 emissions include those from the use of the heat, steam, and electricity purchased by companies. Scope 3 emissions are indirect emissions not produced by companies. We constructed direct CO<sub>2</sub> emissions by combining Scope 1 and Scope 2 emissions.

We then obtained the years of implementation of boardroom gender diversity reforms in different countries from Fauver et al. (2022) and Ding et al. (2022). Next, we obtained the characteristics of board directors from BoardEx, a widely used database that provides comprehensive board- and director-level information worldwide. Firms' fundamental data were obtained from Wordscope, which is the global financial industry's premier source of detailed financial statement information and profile data on public companies. Lastly, we obtained worldwide information on legal law and the ICRG.

---

<sup>3</sup> Trucost collects firm-level emissions data from various sources including company reports, environmental reports (CSR/ESG reports, the Carbon Disclosure Project, Environmental Protection Agency filings), and data from company websites. If a firm does not disclose emissions data, Trucost uses an input-output model to estimate the firm's carbon emissions.

### 3.2 Sample

To obtain the final sample, we merged the S&P Trucost database with the Worldscope database and BoardEx via the ISIN code and with the ICRG database via country name. After controlling for missing values, we removed firm-year observations using the following criteria: (1) stock price of less than one unit of local currency, (2) market capitalization of less than USD 10 million at the end of the fiscal year, (3) negative net sales and shareholder equity, and (4) countries with less than ten unique firms. Therefore, our final sample includes 64,374 firm-year observations covering 9,883 unique firms across 50 countries from 2002-2019.

Table 1 presents summary statistics. *Direct CO<sub>2</sub> emission* was measured as the natural log of Scope 1's and Scope 2's carbon emissions plus one. *Indirect CO<sub>2</sub> emission* is measured as the natural log of Scope 3's carbon emissions plus one. The average (median) *Direct CO<sub>2</sub> emissions* and *Indirect CO<sub>2</sub> emissions* for our sample were 11.3829 (11.3055) and 12.1299 (12.2267), respectively. All variables in our sample are winsorized at the top and bottom 1%.

Table 2 presents a breakdown of the sample and the average carbon emissions (i.e., direct and indirect emissions) across countries. In our final sample, the U.S. accounts for the largest number of observations (32.03%) with unique firms (3,102), while Pakistan has the smallest number of observations (0.05%) with unique firms (12). It is important to consider that our sample shows a high level of variance across countries and that our results are not driven by U.S. firms, as shown in our robustness tests. The highest average direct carbon emissions are from Russia (10887116), while the lowest are from the United Arab Emirates (171806.6).

[Tables 1 and 2 here]

### 3.3 Empirical strategy

To identify the causal effect, we applied the staggered DiDiD approach to examine the effect of the adoption of board gender diversity reforms on carbon emission reduction. The advantage of the staggered DiDiD approach is that it helps separate other factors that may affect corporate carbon emissions, and identify whether female directors affect corporate carbon emissions through boardroom gender diversity. More importantly, the staggered DiDiD approach could help avoid the coincidence between board gender reform and carbon emissions reduction compared to the single-event-based DiDiD approach.

To test our prediction, we apply the two-way fixed-effects model to conduct DiDiD estimates using model (1):

$$\begin{aligned} Emissions_{i,c,t} = & \beta_0 + \beta_1 Post_{c,t} * Female\ directors_{i,c,t} + \beta_2 Post_{c,t} + \\ & \beta_3 Female\ directors_{i,c,t} + Control_{i,c,t} + \lambda_i + \lambda_t + \varepsilon_{i,c,t} \end{aligned} \quad (1)$$

where the dependent variables are  $Emissions_{i,c,t}$ , which are proxied by *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> emission*. The independent variable is  $Post_{c,t}$ , which is a dummy variable that equals one for year  $t$  following the introduction of the boardroom gender diversity reform in country  $c$ , and zero otherwise (for year  $t$  before the introduction of the boardroom gender diversity reform and year  $t$  in country  $c$  without the introduction of such reform).  $Female\ directors_{i,c,t}$  represents the number of female directors in a firm. Ding et al. (2022) documented that more women were added to the board after the introduction of gender diversity reform.

The control variables include firm characteristics (*Market cap*, *Book-to-market*, *Leverage*, *ROA*, and *PPE*), governance characteristics (*Board size*, *Board independence*, *Non-Executive Directors (NED) ratio*, and *Average time in board*), and country-level characteristics (*Law and order*). We also include firm- and year-fixed



effects in all the specifications. Robust standard errors were clustered at the nation-by-year level.

## **4. Results and Discussion**

### *4.1 Baseline results*

We begin with the regression specification in equation (1). The results are summarized in Table 4. Across all specifications, we found a consistently negative and statistically significant coefficient for the interaction term between the dummy variable *Post* and *Female directors*, indicating that an increase in female representation on corporate boards following gender reform initiatives leads to a decrease in both, direct and indirect CO<sub>2</sub> emissions. These findings strongly support our first hypothesis, demonstrating that board gender reforms that lead to a greater presence of women on boards influence the behavior of companies, specifically resulting in a reduction in CO<sub>2</sub> emissions.

Our analysis reveals that the coefficient of the dummy variable *Post* lacks statistical significance in most of the model specifications. However, it is noteworthy that the variable *Female* consistently exhibits a positive and significant coefficient across all specifications. Given the effect of the reforms, this result suggests that the pre-reform number of female directors was not large enough to have a real influence on the decision-making process. Globally, these findings suggest that gender reform initiatives have achieved their intended consequences by altering the composition of corporate boards, thereby influencing the behavior of companies, including their emission levels. Consistent with previous studies, our findings align with those of existing literature, that larger companies, measured by assets size, with a higher proportion of fixed assets tend to have higher levels of direct and indirect CO<sub>2</sub> emission. However, contrary to

our initial expectations, we found a positive relationship between CO<sub>2</sub> pollution and companies with higher leverage and book-to-market values. Additionally, our analysis reveals that companies with larger boards and longer board tenures tend to exhibit higher levels of CO<sub>2</sub> emissions. Surprisingly, we do not observe any statistically significant difference between the share of independent board members and firms' CO<sub>2</sub> pollution. Therefore, the results demonstrate that a firm's emission level is not determined by other measures of good governance pondering board composition.

[Table 4 about here]

#### 4.2 Change in carbon emission around gender board reforms

One could be concerned that our results are driven by pre-existing trends in firms' carbon emission. If firms emit less CO<sub>2</sub> due to increased female participation induced by board gender reforms, rather than parallel trends, we should observe a decrease in carbon emissions only post-reform.

To provide evidence for this question, we perform an analysis in Table 5, by adopting dynamic effects with an event window that includes the period before and after the introduction of gender diversity reform. To examine pre-treatment trends in the carbon emissions of the treated and control firms, we performed an analysis in model (1) by replacing the *Post \* Female directors* by five interaction terms: *Before<sup>-2</sup> \* Female directors*, *Before<sup>-1</sup> \* Female directors*, *Current \* Female directors* (the year of reform implementation), *After<sup>+1</sup> \* Female directors*, *After<sup>+2</sup> \* Female directors*, to flag the year relative to the adoption year of the board gender diversity reform, interacted with proportion of female directors. *Before<sup>-t</sup>* is a dummy variable equal to one in year *t* before the implementation of the board's gender diversity reform, and zero, otherwise. *Current* is a dummy variable equal to one in the year of the implementation of the board's gender diversity reform, and zero, otherwise. *After<sup>+t</sup>* is a dummy variable equal to one in the

year after the implementation of the board's gender diversity reform, and zero, otherwise.  $After^{2+}$  is a dummy variable that equals one if a firm-year observation is at least two years after the implementation of the board's gender diversity reform, and zero, otherwise. This approach also provides evidence that the parallel-trend assumption of the DiDiD approach is fulfilled (Bertrand and Mullainathan, 2003; Chen et al., 2020; Fauver et al., 2022).

As shown in Table 5, the coefficients of the interaction between the dummy variables  $Before^{t-2}$  or  $Before^{t-1}$  and *Female directors* are not statistically significant in all specifications. We conclude that we did not observe any effect of female directors on firms' direct or indirect CO<sub>2</sub> emissions prior to board reforms in their countries.

In contrast, we observe that the coefficient for the interaction term representing the current year of reform implementation and increase in female directors is statistically significant only in one of the specifications, and only at the 10% significance level. Furthermore, the coefficient of the interaction term, including the one and two years following the reforms, was negative, and mostly statistically significant. In fact, the coefficient of the interaction term, including two years after the reform, is significant at the 1% level for all the specifications. Consequently, the results indicate that the number of female directors increased following the reforms, which, in turn, affected carbon emissions.

The coefficients of the pre-board reform years in these dynamic analyses indicate that pre-reform trends do not drive our results. In contrast, the post board reform interaction dummies are significantly negative, suggesting that CO<sub>2</sub> emissions decreased after the reforms, with an increase in the proportion of females on a firm's board. This lends empirical support to the parallel trend assumption and confirms the validity of the staggered DiDiD approach. These results also highlight that even if the effects of board

reforms on carbon emissions are not immediate, the positive effects of reducing such emissions are materialized after two years.

[Insert Table 5 about here]

#### *4.3 Role of reform approach on emissions*

Next, we investigate the heterogeneous roles of different reform approaches in board diversity. We perform this analysis by estimating equation (1) and introducing a dummy for the introduction of reform using legislation and the corporate governance code. We then interacted each of these dummies with a variable representing the share of female directors on the board.

Table 6 presents the results of this analysis. We find that the coefficients for both the interaction terms between either dummy, *Post\_legislation* or *Post\_code*, and the variable *Female directors*, are negative and statistically significant at the 1% level. Consequently, the results confirmed that the implementation of reforms led to an increase in the number of women on boards, resulting in lower CO<sub>2</sub> emissions.

However, the coefficients of the two interaction terms differ in size. In line with Hypothesis 2, the results suggest that passing legislation-based regulations has a stronger effect on CO<sub>2</sub> reduction than passing a governance code. The results complement the findings of Ding et al. (2022), who show that the effect of passing a legislation-based regulation on the increase in female representation is stronger than that of passing a governance code.

[Insert Table 6 here]

#### *4.4 National culture*

Next, we examine whether changes in carbon emissions following board gender reforms vary depending on the heterogeneous effects of the firm's national culture. We consider two conflicting cultures—collectivism and individualism—and divide the

sample into two groups. We then rerun the regression for each subsample following the baseline specification in Equation (1).

Columns (1) and (3) of Table 7 present the results for the subsample of firms located in collectivist countries, and Columns (2) and (4) present the results for the subsample of firms located in individualistic countries. As reported in Table 4, we find that board gender reforms materially and significantly decrease firms' CO<sub>2</sub> emissions. The coefficients of the interaction term *Post \* Female directors* in Columns (1) and (3) are larger than those in Columns (2) and (4). These results are consistent with the third hypothesis and show that board gender reforms have a stronger effect on reducing corporate carbon emissions in firms in collectivist countries.

[Insert Table 7 here]

#### *4.5 The effect of the Paris Climate Agreement*

This subsection investigates whether the 2015 Paris Agreement, a legally binding international treaty, affects the association between board gender reforms and carbon emissions. We use the date of agreement to divide the sample into two groups: prior- and post-agreement subsamples. We then rerun the regression for each subsample following the baseline specification in Equation (1).

In Columns (1) and (3) of Table 8, we present the results for the subsample before the implementation of the Paris Agreement, whereas in Columns (2) and (4), we analyze the subsample after the agreement. Consistent with our previous findings, we observe a negative and statistically significant coefficient for the interaction term *Post\*Female directors* in Columns (2) to (4).

These results indicate that the increased participation of women, following board reforms, led to a reduction in indirect carbon emissions after the implementation of the Paris Agreement. Notably, we find that the coefficient of the interaction term

*Post\*Female directors* in Column (2) is significantly larger (in absolute terms) than that in Column (4). This finding demonstrates that the impact of board reforms on corporate emissions has become more pronounced after the Paris Agreement.

Our findings align with the literature, specifically highlighting that corporations have effectively reduced carbon emissions in response to increased regulatory and investor pressure following the Paris Agreement, as noted by Bolton and Kacperczyk (2021). Additionally, our study provides further evidence that firms demonstrate a stronger commitment to limiting greenhouse gas (GHG) emissions from their own production and energy consumption while tending to overlook indirect emissions, as Deng et al. (2022) highlight.

However, our results indicate that the increased presence of female directors also plays a significant role in reducing firms' indirect carbon emissions, following the Paris Agreement. This finding supports our fourth hypothesis and reinforces the positive impact of regulations on firms' carbon emissions.

[Insert Table 8 here]

#### *4.6 Robustness check*

Finally, we conducted a robustness check of our primary results, given that US firms constitute over 30% of our sample, as demonstrated in Table 2. To verify whether the results were predominantly influenced by US firms, or by simultaneous changes not linked to board gender reforms, we reran our regression, excluding US firms from the analysis.

The results presented in Table 9 align closely with those outlined in Table 4. Consistent with our previous findings, our analysis reveals a statistically significant negative coefficient for the interaction between the post-reform period and female directors. This finding indicates the effectiveness of gender reforms in reducing firm CO<sub>2</sub> emissions.

Moreover, the coefficients of the remaining variables remained unaltered, both in terms of signs and statistical significance. Therefore, these results corroborate our hypothesis that the implementation of board gender reforms, leading to an increased representation of female board members, contributes to a reduction in firms' CO<sub>2</sub> emissions.

[Insert Table 9 here]

To address the potential concern that our findings may be affected by confounding events, we conducted a placebo (falsification) test using pseudo-board reform years. In this test, we randomly assigned each firm a pseudo-board reform year and repeated the baseline DiDiD analysis. This process was repeated 500 times and the results are shown in Figure 1. Graphs A and B display the distribution of the coefficient estimates when the dependent variable were direct and indirect CO<sub>2</sub> emissions, respectively. Both graphs show no evidence of changes in corporate carbon emissions following the pseudo board reform years, with the coefficient of the interaction term *Post\*Female* directors nearing zero in both cases. This outcome refutes the possibility that the reduction in carbon pollution following board reforms can be attributed to confounding effects. [Insert Figure 1 about here]

## 5. Conclusion

This study examines the effects of increased female representation following board reforms on firms' carbon pollution. Using a cross-country sample, we consistently found that increasing the representation of female directors, following board gender reforms, led to a reduction in both, direct and indirect carbon emissions.

Our analysis highlights the role of different reform approaches in shaping carbon emissions reduction. We found that legislation-based regulations had a stronger effect on carbon reduction than the implementation of governance codes. Moreover, our

results indicate that the effects of board reforms on carbon emission reduction evolved after the 2015 Paris Climate Agreement. Board reforms had a stronger effect on both, direct and indirect carbon emissions after the agreement, indicating the positive impact of increased regulatory pressure on companies' environmental practices. Before the agreement, board reforms primarily influenced the reduction in direct emissions.

Overall, our study contributes to the understanding of the relationship between board gender reforms and carbon emissions, emphasizing the importance of gender diversity on corporate boards in driving environmental sustainability. Our study is important from an investors' perspective as environmental risk increases. Also, from a policy perspective our paper underscores the significance of regulatory enforcement and global efforts towards reducing carbon emissions. From a broader societal perspective, companies play crucial roles in addressing climate change and achieving sustainable development by promoting gender diversity and implementing effective regulations.



## References

- Adams, R. B., & Ferreira, D. (2009). Women in the boardroom and their impact on governance and performance. *Journal of Financial Economics*, 94(2), 291-309.
- Adams, R. B., & Funk, P. (2012). Beyond the glass ceiling: Does gender matter?. *Management Science*, 58(2), 219-235.
- Adams, R. B., Licht, A. N., & Sagiv, L. (2011). Shareholders and stakeholders: How do directors decide? *Strategic Management Journal*, 32(12), 1331-1355.
- Ahern, K. R., & Dittmar, A. K. (2012). The changing of the boards: The impact on firm valuation of mandated female board representation. *The Quarterly Journal of Economics*, 127(1), 137-197.
- Andreoni, J., & Vesterlund, L. (2001). Which is the fair sex? Gender differences in altruism. *The Quarterly Journal of Economics*, 116(1), 293-312.
- Atif, M., Hossain, M., Alam, M. S., & Goergen, M. (2021). Does board gender diversity affect renewable energy consumption? *Journal of Corporate Finance*, 66, 101665.
- Ben-Amar, W., Chang, M., & McIlkenny, P. (2017). Board gender diversity and corporate response to sustainability initiatives: Evidence from the carbon disclosure project. *Journal of Business Ethics*, 142(2), 369-383.
- Bennouri, M., De Amicis, C., & Falconieri, S. (2020). Welcome on board: A note on gender quotas regulation in Europe. *Economics Letters*, 190, 109055.
- Bertrand, M., & Mullainathan, S. (2003). Enjoying the quiet life? Corporate governance and managerial preferences. *Journal of Political Economy*, 111(5), 1043-1075.
- Bernasek, A., & Shwiff, S. (2001). Gender, risk, and retirement. *Journal of Economic Issues*, 35(2), 345-356.
- Bolton, P., & Kacperczyk, M. (2021a). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2), 517-549.
- Bolton, P., & Kacperczyk, M. T. (2021b). Firm commitments. *Columbia Business School Research Paper*.
- Bolton, P., & Kacperczyk, M. T. (2022). Global Pricing of Carbon-Transition Risk. *Journal of Finance*, forthcoming.
- Bord, R. J., & O'Connor, R. E. (1997). The gender gap in environmental attitudes: The case of perceived vulnerability to risk. *Social Science Quarterly*, 78(4), 830-840.
- Cai, Y., Pan, C. H., & Statman, M. (2016). Why do countries matter so much in corporate social performance? *Journal of Corporate Finance*, 41, 591-609.
- Carletti, C. (2019). Gender diversity management and corporate governance: international hard and soft laws within the Italian perspective. *Italian Law Journal*, 5, 251.

Carlson, R. (1972). Understanding women: Implications for personality theory and research. *Journal of Social Issues*, 28(2), 17-32.

Carlsson-Kanyama, A., Juliá, I. R., & Röhr, U. (2010). Unequal representation of women and men in energy company boards and management groups: Are there implications for mitigation?. *Energy Policy*, 38(8), 4737-4740.

Carlsson-Kanyama, A., Lindén, A. L., & Thelanders, A. (1999). Insights and applications gender differences in environmental impacts from patterns of transportation-a case study from Sweden. *Society & Natural Resources*, 12(4), 355-369.

Chen, R. R., Guedhami, O., Yang, Y., & Zaynutdinova, G. R. (2020). Corporate governance and cash holdings: Evidence from worldwide board reforms. *Journal of Corporate Finance*, 65, 101771.

Choudhury, B. (2014). New rationales for women on boards. *Oxford Journal of Legal Studies*, 34(3), 511-542.

Croson, R., & Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, 47(2), 448-74.

Daily, C. M., & Dalton, D. R. (2003). Women in the boardroom: A business imperative. *Journal of Business Strategy*, 24(5).

Delis, M. D., De Greiff, K., & Ongena, S. (2019). Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans. *Climate Policy Risk and the Pricing of Bank loans. EBRD Working Paper*, 231.

Deng, S., Duan, T., Li, F. W., & Pu, X. (2022). Customer Concentration and Corporate Carbon Emissions. *Available at SSRN 4180681*.

Ding, R., Duan, T., Hou, W., Liu, X., & Xu, Z. (2022). Do women drive corporate social responsibility? Evidence from gender diversity reforms around the world. *International Review of Law and Economics*, 72, 106097.

Do, Q., Cao, N. D., Gounopoulos, D., & Newton, D. (2023). Environmental concern, regulations and board diversity. *Review of Corporate Finance*, 3(1-2), 99-148.

Du Plessis, J., O'Sullivan, J., & Rentschler, R. (2014). Multiple layers of gender diversity on corporate boards: To force or not to force. *Deakin Law Review*, 19, 1.

Duan, T., Li, F. W., & Wen, Q. (2023). Is carbon risk priced in the cross-section of corporate bond returns? *Journal of Financial and Quantitative Analysis*, forthcoming.

Ergas, C., & York, R. (2012). Women's status and carbon dioxide emissions: A quantitative cross-national analysis. *Social Science Research*, 41(4), 965-976.

Faccio, M., Marchica, M. T., & Mura, R. (2016). CEO gender, corporate risk-taking, and the efficiency of capital allocation. *Journal of Corporate Finance*, 39, 193-209.

Fauver, L., Hung, M., Taboada, A. G., & Wang, E. J. (2022). Boardroom gender diversity reforms and institutional monitoring: global evidence. *Review of Accounting*

*Studies*, 1-44.

Frijns, B., Dodd, O., & Cimerova, H. (2016). The impact of cultural diversity in corporate boards on firm performance. *Journal of Corporate Finance*, 41, 521-541.

Gilligan, C. (1977). In a different voice: Women's conceptions of self and of morality. *Harvard Educational Review*, 47(4), 481-517.

Hofstede, G. (2011). Dimensionalizing cultures: The Hofstede model in context. *Online Readings in Psychology and Culture*, 2(1), 2307-0919.

Huang, H. H., Kerstein, J., & Wang, C. (2018). The impact of climate risk on firm performance and financing choices: An international comparison. *Journal of International Business Studies*, 49, 633-656.

Hudgens, G. A., & Fatkin, L. T. (1985). Sex differences in risk taking: Repeated sessions on a computer-simulated task. *The Journal of Psychology*, 119(3), 197-206.

Huse, M., Nielsen, S. T., & Hagen, I. M. (2009). Women and employee-elected board members, and their contributions to board control tasks. *Journal of Business Ethics*, 89, 581-597.

IEA Report (2021). *Global Energy Related CO2 emissions, 1990-2020*. <https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-1990-2020>.

Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies*, 33(3), 1067-1111.

Liao, L., Luo, L., & Tang, Q. (2015). Gender diversity, board independence, environmental committee and greenhouse gas disclosure. *The British Accounting Review*, 47(4), 409-424.

Liu, C. (2018). Are women greener? Corporate gender diversity and environmental violations. *Journal of Corporate Finance*, 52, 118-142.

Nartova-Bochaver, S. K., Donat, M., Ucar, G. K., Korneev, A. A., Heidmets, M. E., Kamble, S., Khachatryan, N., Kryazh, I. V., Larionow, P., Rodríguez-González, D. Serobyan, A., Zhou, C., & Clayton, S. (2022). The role of environmental identity and individualism/collectivism in predicting climate change denial: Evidence from nine countries. *Journal of Environmental Psychology*, 84, 101899.

Nuyens, H. (2023), The European Women on Boards Directive what it means and why it matters, European Women on Boards, access on 15 June 2023 at <https://www.iod.com/resources/blog/inclusion-and-diversity/the-european-women-on-boards-directive-what-it-means-and-why-it-matters/>.

Pearse, R. (2017). Gender and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 8(2), e451.

Räty, R., & Carlsson-Kanyama, A. (2010). Energy consumption by gender in some European countries. *Energy policy*, 38(1), 646-649.

Ramadorai, T., & Zeni, F. (2021). Climate regulation and emissions abatement: Theory and evidence from firms' disclosures. *European Corporate Governance Institute–Finance Working Paper*, No. 730.

Rhode, D. L., & Packel, A. K. (2014). Diversity on corporate boards: How much difference does difference make. *Delaware Journal of Corporate Law*, 39(2), 377-425.

Seltzer, L. H., Starks, L., & Zhu, Q. (2022). Climate regulatory risk and corporate bonds. *National Bureau of Economic Research*, No. w29994.

Sjåfjell, B., & Reiersen, H. B. (2008). Report from Norway: Gender equality in the board room. *European Company Law*, (4).

Shapiro, R. Y., & Mahajan, H. (1986). Gender Differences in Policy Preferences: A Summary of Trends from the 1960s to the 1980s. *Public Opinion Quarterly*, 50(1), 42-61.

Suk, J. C. (2012). Gender parity and state legitimacy: From public office to corporate boards. *International Journal of Constitutional Law*, 10(2), 449-464.

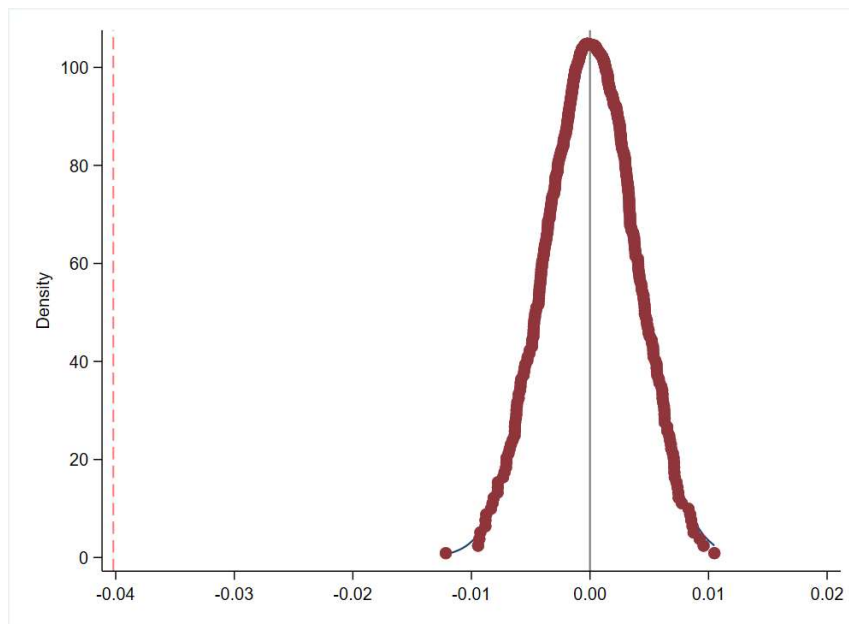
Vu, T. V. (2023). Individualism and climate change policies: International evidence. *Journal of Economics and Development*, 25(1), 22-36.

Xiang, P., Zhang, H., Geng, L., Zhou, K., & Wu, Y. (2019). Individualist–collectivist differences in climate change inaction: The role of perceived intractability. *Frontiers in Psychology*, 10, 187.

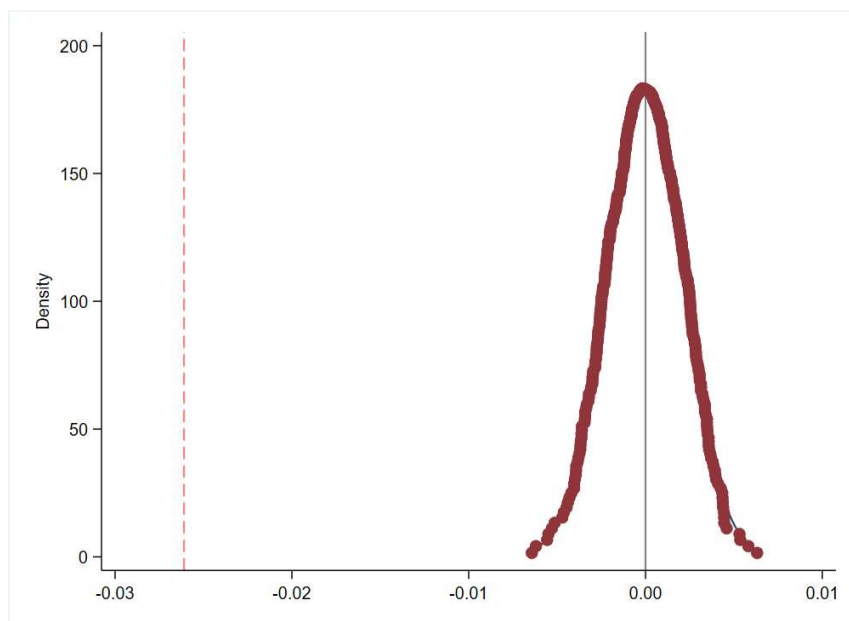
### Figure 1 Placebo tests

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

Graph A: Density of the coefficient estimates on *Post\*Female directors* when the dependent variable is *Direct CO<sub>2</sub> emissions*.



Graph B: Density of the coefficient estimates on *Post\*Female directors* when the dependent variable is *Indirect CO<sub>2</sub> emissions*.



**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.Dev.
Direct CO <sub>2</sub> emission	64,374	11.3829	9.6448	11.3055	13.0442	2.6312
Indirect CO <sub>2</sub> 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
Average time in board	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 CO2 emissions (4)	Indirect CO2 emissions (5)
Australia	3,148	4.89	470	854316.9	420345.6
Austria	343	0.53	43	1902030	1575131
Belgium	568	0.88	73	1365672	1242768
Brazil	781	1.21	128	2177813	2031059
Canada	2,800	4.35	427	1442974	711211.9
Chile	231	0.36	32	2766431	639826.3
China	1,919	2.98	427	1630502	1120645
Colombia	96	0.15	16	2569888	1469592
Denmark	451	0.7	53	1849738	811088.3
Egypt	67	0.1	17	297738.5	168881.9
Finland	532	0.83	68	1422545	1427146
France	2,377	3.69	285	2613928	2235585
Germany	2,069	3.21	273	3149049	2936900
Greece	241	0.37	35	3677563	721973.6
Hong Kong	1,825	2.83	338	1743965	721207.7
India	2,846	4.42	513	2629827	926886.3
Indonesia	388	0.6	101	1211957	559996.4
Ireland	546	0.85	59	969354.8	1353847
Israel	405	0.63	84	351030.3	314147.8
Italy	975	1.51	145	3098132	1571328
Japan	3,148	4.89	555	2627462	2795410
South Korea	466	0.72	87	3457758	3592923
Luxembourg	205	0.32	34	5078893	3154748
Malaysia	587	0.91	134	1690149	414857.1
Mexico	434	0.67	71	835870.1	1261000
Morocco	45	0.07	11	1073085	306203.6
Netherlands	849	1.32	101	647404.3	1916385
New Zealand	281	0.44	62	283984.8	334361.3
Nigeria	131	0.2	19	1468358	314851.2
Norway	547	0.85	86	1701598	1643668
Pakistan	29	0.05	12	1325589	202517.2
Peru	36	0.06	11	508971.2	150890.1
Philippines	299	0.46	63	1861547	708545.5
Poland	340	0.53	49	2798605	789070.1
Portugal	177	0.27	20	4091766	1286444
Qatar	65	0.1	21	408000.1	169297
Russia	287	0.45	43	10887116	4370560
Saudi Arabia	84	0.13	44	5308845	1765184
Singapore	622	0.97	102	979425.8	897888.9
South Africa	1,302	2.02	164	1295698	421890.3
Spain	865	1.34	98	3362244	1779217
Sweden	1,114	1.73	183	403676.8	947560.3
Switzerland	1,588	2.47	213	1074717	1281320
Taiwan	752	1.17	166	1601471	1157654
Thailand	402	0.62	106	3021872	1379451
Turkey	294	0.46	47	2531939	1129046
United Arab Emirates	132	0.21	35	171806.6	148535.1
United Kingdom	6,036	9.38	643	1187371	877438.1
United States	20,617	32.03	3,102	1799931	1322819
Vietnam	32	0.05	14	599756.3	545945.9

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

Nation	Reform	Female directors		Direct CO <sub>2</sub> emissions		Indirect CO <sub>2</sub> emissions	
		Pre (1)	Post (2)	Pre (3)	Post (4)	Pre (5)	Post (6)
Australia	YES	0.67	1.33	1106816	765671.5	518012.3	386057.5
Austria	YES	1.12	1.96	3599893	1542059	2370016	1406604
Belgium	YES	0.68	2.44	1495907	1330788	1698894	1120592
Brazil	NO	0.60		2177813		2031059	
Canada	NO	1.67		1442974		711211.9	
Chile	NO	0.55		2766431		639826.3	
China	NO	0.97		1630502		1120645	
Colombia	NO	0.96		2569888		1469592	
Denmark	YES	1.47	2.15	2615932	1658721	1000282	763921.1
Egypt	NO	0.87		297738.5		168881.9	
Finland	YES	1.82	2.30	2156501	1157870	2433256	1064329
France	YES	1.07	3.46	4324917	2027166	3658207	1747714
Germany	YES	1.51	2.41	5077751	2472996	4788466	2287885
Greece	YES	0.74	0.88	5420458	2354490	1038693	481544.1
Hong Kong	YES	0.99	1.15	2135682	1636113	712988.8	723470.6
India	YES	0.62	1.25	3164602	2435689	1187579	832247.7
Indonesia	NO	1.36		1211957		559996.4	
Ireland	YES	1.15	1.85	825324.8	1037293	1492049	1288657
Israel	NO	1.68		351030.3		314147.8	
Italy	YES	0.54	3.25	4914227	2215001	2204729	1263317
Japan	YES	0.19	0.43	3783833	2350662	4738256	2330351
South Korea	NO	0.21		3457758		3592923	
Luxembourg	YES	0.23	0.99	1.02E+07	4165663	6033024	2641952
Malaysia	YES	0.72	1.54	3234626	1558825	333957.8	421735.8
Mexico	NO	0.77		835870.1		1261000	
Morocco	NO	0.44		1073085		306203.6	
Netherlands	YES	0.60	1.53	917672.8	573657.8	2599064	1730106
New Zealand	NO	1.65		283984.8		334361.3	
Nigeria	NO	2.23		1468358		314851.2	
Norway	YES	2.78	3.00	5120205	1644409	5415601	1580569
Pakistan	NO	0.59		1325589		202517.2	
Peru	NO	0.44		508971.2		150890.1	
Philippines	NO	1.22		1861547		708545.5	
Poland	YES	1.25	1.86	646555.6	3196021	875702.8	773071.8
Portugal	NO	0.52	2.19	4795516	2488780	1366039	1105146
Qatar	NO	0.06		408000.1		169297	
Russia	NO	1.11		1.09E+07		4370560	
Saudi Arabia	NO	0.14		5308845		1765184	
Singapore	YES	0.66	1.11	1220267	900174.6	1365593	743986.4
South Africa	YES	1.87	2.38	4693535	1145834	972522.8	397604.2
Spain	YES	0.48	1.81	5131482	3077266	2675019	1634927
Sweden	YES	1.64	2.66	1134958	372893.2	2107733	898722.3
Switzerland	YES	0.68	1.13	1724986	672359.2	1926458	882137.3
Taiwan	NO	0.90		1601471		1157654	
Thailand	YES	1.26	1.78	4447596	2951144	1912782	1352993
Turkey	NO	1.17		2531939		1129046	
United Arab Emirates	NO	0.17		171806.6		148535.1	
United Kingdom	YES	0.63	1.51	1164519	1202750	858058.1	890479.8
United States	NO	1.53		1799931		1322819	
Vietnam	NO	1.47		599756.3		545945.9	



**Table 3 Correlation matrix**

This table present for 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 CO <sub>2</sub>	1.0000														
(2) Indirect CO <sub>2</sub>	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. time in board	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 the adoption of the gender diversity reform on firms' carbon emissions and the number of female directors over the period 2002-2019. The dependent variables are *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> emission*. *Direct CO<sub>2</sub> emission* was measured as the natural log of Scope 1's and Scope 2's carbon emissions plus one. *Indirect CO<sub>2</sub> emission* is measured as the natural log of Scope 3's carbon emissions plus one. The independent variables are *Post* and *Female directors*. *Post* is a dummy variable equal to one in years after a country adopts a board's 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 the 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 CO <sub>2</sub> emission		Indirect CO <sub>2</sub> emission	
	(1)	(2)	(3)	(4)
Post*Female directors	-0.0684*** (-7.624)	-0.0402*** (-4.558)	-0.0563*** (-8.538)	-0.0261*** (-4.714)
Post	0.0382 (1.256)	0.0469* (1.802)	0.0253 (0.988)	0.0355 (1.488)
Female directors	0.0379*** (5.161)	0.0114* (1.683)	0.0480*** (8.671)	0.0162*** (4.104)
Market cap		0.4504*** (31.557)		0.4993*** (42.836)
Book-to-market		0.5033*** (26.536)		0.4651*** (31.804)
Leverage		0.8099*** (15.686)		0.7543*** (18.823)
ROA		0.0989 (1.368)		0.1602** (2.354)
PPE		0.3446*** (5.523)		0.2551*** (5.217)
Board size		0.2343*** (9.057)		0.2550*** (13.014)
NED ratio		-0.0533 (-0.880)		0.0544 (1.453)
Avg. directors' tenure		0.0223*** (11.406)		0.0180*** (14.562)
Law and order		0.0758 (1.504)		0.0131 (0.505)
Constant	11.3889*** (796.960)	-0.0254 (-0.062)	12.1198*** (1019.660)	-0.0892 (-0.319)
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjust R <sup>2</sup>	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 the adoption of gender diversity reform on the carbon emissions of firms with more female directors over the periods 2002-2019. The dependent variables are *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> emission*. *Direct CO<sub>2</sub> emission* was measured as the natural log of Scope 1's and Scope 2's carbon emissions plus one. *Direct CO<sub>2</sub> emission* is measured as the natural log of Scope 3's carbon emissions plus one. The indicator variables are *Before<sup>-t</sup>*, *Current*, *After<sup>+1</sup>*, and *After<sup>2+</sup>*. *Before<sup>-t</sup>* is a dummy variable equal to one in year *t* before the implementation of the board's gender diversity reform and zero otherwise. *Current* is a dummy variable equal to one in the year of the implementation of the board's gender diversity reform and zero otherwise. *After<sup>+1</sup>* is a dummy variable equal to one in the year after the implementation of the board's gender diversity reform and zero otherwise. *After<sup>2+</sup>* is a dummy variable that equals one if a firm-year observation is at least two years after the implementation of the board's gender diversity reform and zero otherwise. 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 CO <sub>2</sub> emission		Indirect CO <sub>2</sub> emission	
	(1)	(2)	(3)	(4)
Before <sup>-2</sup> *Female directors	-0.0331 (-1.446)	-0.0332 (-1.626)	-0.0228 (-1.230)	-0.0235 (-1.477)
Before <sup>-1</sup> *Female directors	-0.0377 (-1.548)	-0.0273 (-1.203)	-0.0132 (-0.910)	-0.0009 (-0.086)
Current*Female directors	-0.0200 (-1.218)	-0.0116 (-0.726)	-0.0197* (-1.771)	-0.0064 (-0.674)
After <sup>+1</sup> *Female directors	-0.0157 (-1.143)	-0.0090 (-0.649)	-0.0248** (-2.245)	-0.0142* (-1.678)
After <sup>2+</sup> *Female directors	-0.0752*** (-8.122)	-0.0458*** (-4.877)	-0.0597*** (-9.397)	-0.0282*** (-5.162)
Post	0.0097 (0.312)	0.0277 (1.054)	0.0077 (0.300)	0.0267 (1.104)
Female directors	0.0423*** (5.384)	0.0154** (2.085)	0.0501*** (8.983)	0.0177*** (4.379)
Constant	11.3962*** (806.978)	0.0132 (0.033)	12.1244*** (1027.466)	-0.0712 (-0.254)
Controls	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjust R <sup>2</sup>	0.9510	0.9558	0.9681	0.9759
Observations	64,374	64,374	64,374	64,374

**Table 6 Analysis conditional on reform approaches**

This table presents the regression results for the effect of female directors on firms' carbon emissions following different reform approaches over the period 2002-2019. The dependent variables are *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> 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 CO <sub>2</sub> emission (1)	Indirect CO <sub>2</sub> emission (2)
Post_legislation*Female directors	-0.0384*** (-3.210)	-0.0331*** (-4.660)
Post_code*Female directors	-0.0267** (-2.332)	-0.0178*** (-3.151)
Post_legislation	0.1832*** (5.626)	0.1713*** (5.708)
Post_code	-0.0245 (-0.973)	-0.0258 (-1.233)
Female directors	0.0124* (1.933)	0.0185*** (4.853)
Constant	0.1890 (0.476)	0.1117 (0.396)
Controls	YES	YES
Firm FEs	YES	YES
Year FEs	YES	YES
Adjust R <sup>2</sup>	0.9559	0.9760
Observations	64,374	64,374

**Table 7 Subsample test by national culture: Collectivism and individualism**

This table presents the subsample tests between firms located in collectivistic and individualistic countries for the effect of female directors on firms' carbon emissions following board gender diversity reforms over the period 2002-2019. The dependent variables are *Direct CO2 emission* and *Indirect CO2 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 CO <sub>2</sub> emission		Indirect CO <sub>2</sub> emission	
	Collectivism (1)	Individualism (2)	Collectivism (3)	Individualism (4)
Post* Female directors	-0.0643*** (-4.344)	-0.0464** (-2.281)	-0.0302*** (-3.323)	-0.0224* (-1.977)
Post	0.1000** (2.213)	0.0088 (0.242)	0.0110 (0.307)	0.0435* (1.762)
Female directors	0.0196 (1.501)	0.0184* (1.919)	0.0178** (2.048)	0.0213*** (4.896)
Constant	1.5775*** (2.604)	-2.2096*** (-3.231)	0.2506 (0.635)	-1.0386* (-1.811)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjust R <sup>2</sup>	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 presents the tests of the before and after subsamples based on the Paris Agreement for the effect of female directors on firms' carbon emissions following board gender diversity reforms over the period 2002-2019. The dependent variables are *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> 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 CO <sub>2</sub> emission		Indirect CO <sub>2</sub> emission	
	Before (2)	After (1)	Before (4)	After (3)
Post*Female directors	-0.0316*** (-3.038)	-0.0394*** (-2.781)	-0.0091 (-1.426)	-0.0225*** (-3.908)
Post	0.0437* (1.713)	-0.2092*** (-2.670)	0.0214 (0.935)	0.0818** (2.365)
Female directors	0.0023 (0.273)	0.0200 (1.597)	-0.0016 (-0.337)	0.0222*** (4.542)
Constant	0.4292 (0.762)	4.2202*** (5.271)	0.3573 (0.777)	4.3914*** (8.560)
Controls	YES	YES	YES	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjust R <sup>2</sup>	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 US firms. The dependent variables are *Direct CO<sub>2</sub> emission* and *Indirect CO<sub>2</sub> 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. All variables are defined in Appendix A. 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.

	Direct CO <sub>2</sub> emission		Indirect CO <sub>2</sub> emission	
	(1)	(2)	(3)	(4)
Post*Female directors	-0.0592*** (-5.673)	-0.0428*** (-4.418)	-0.0406*** (-5.539)	-0.0225*** (-3.611)
Post	0.0660* (1.933)	0.0483 (1.604)	0.0299 (1.021)	0.0163 (0.610)
Female directors	0.0323*** (3.277)	0.0133 (1.507)	0.0344*** (5.092)	0.0103* (1.884)
Constant	11.4051*** (483.907)	0.2392 (0.533)	12.1224*** (646.541)	-0.1973 (-0.668)
Controls	NO	YES	NO	YES
Firm FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Adjust R <sup>2</sup>	0.9443	0.9489	0.9668	0.9746
Observations	43,757	43,757	43,757	43,757

## Appendix

**Table A1** Table: Definitions

Variables	Definition	Sources
Direct CO <sub>2</sub> emission	The natural log of scope 1's and scope 2's carbon emission plus one.	Trucost
Indirect CO <sub>2</sub> emission	The natural log of scope 3 carbon emission plus one.	Trucost
Post	A dummy variable that equals one in years after the adoption of a board gender diversity reform by a country (i.e., either the legislation-based 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 after 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 after a boardroom gender diversity governance code applied and zero otherwise.	Fauver et al. (2022) and Ding et al. (2022)
Female directors	The number of female directors.	BoardEx
Market cap	The nature log of market capitalization.	Worldscope
Book-to-market	The book value of total assets divided by the market value of total assets.	Worldscope
Leverage	The book value of total debt divided by the book value of total assets.	Worldscope
ROA	The net income divided by the book value of total assets.	Worldscope
PPE	The net property, plant and equipment divided by the total assets.	Worldscope
Board size	The nature log of the number of board directors.	BoardEx
NED ratio	The number of non-executive directors divided by the number of board directors.	BoardEx
Avg. directors' tenure	The average tenure of board directors on the board.	BoardEx
Law and order	The standardized value between 0 and 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