ENVIRONMENTAL RESPONSIBILITY AND CORPORATE GOVERNANCE: ASSESSING THE IMPACT OF GENDER DIVERSITY ON GREENHOUSE GAS (GHG) EMISSIONS IN GERMAN LISTED COMPANIES

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Abstract

This empirical research study delves into the correlation between the emission of greenhouse gases (GHG) and the diversity of board members in German-listed companies. The investigation aims to determine whether board gender diversity impacts a company's commitment to reducing GHG emissions. To explore this relationship, panel data analysis uses a sample of German publicly traded companies. These firms are known for their solid environmental governance and are subject to women board directors' quota requirements over a specific period. Our study employs multiple identification techniques to examine the impact of women's board diversity (WBD) on GHG emissions. The results reveal that WBD does not significantly influence GHG emissions. This outcome remains consistent using robust two-stage least squares (2SLS) regression analysis. However, when we introduce a dummy variable for WBD at the 1–25% level, we observe a positive impact of WBD on GHG emissions. This finding supports the critical mass theory, which suggests that the presence of at least 25% of women on board favours a reduction in GHG emissions. The insights from this research hold significance for policymakers, investors, and corporate leaders seeking to understand the potential advantages of gender diversity in mitigating environmental impacts. Our study supports the concept of social loafing (Williams & Karau, 1991) and the critical mass theory (Torchia et al., 2010) in explaining a relationship between WBD and GHG emissions in German publicly traded companies in the S&P Global 1200 Index.

Keywords: Greenhouse Gas Emissions, Board Gender Diversity, German Traded Firms, Panel Data Analysis, Environmental Impact, Corporate Sustainability

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1. INTRODUCTION

Since the latter part of the twentieth century, there has been a rising acknowledgment of the significance of environmental sustainability and gender diversity within corporate governance. The relentless economic expansion of the world over the past couple of centuries, especially since the onset of industrialization, coupled with the emission of greenhouse gases (GHG), has inflicted substantial harm on the environment. The global consensus on this issue is underscored by initiatives such as the United Nations' 2030 Sustainable Development Goals (SDGs). From the pre-industrial era to the present day, there has been a concerning 30% surge in the concentration of GHGs in the Earth's atmosphere (Ansuategi & Escapa, 2002). The escalating presence of GHG in our atmosphere, as indicated by Sharma et al. (2006), poses a severe and formidable challenge, with GHG emissions being predominantly associated with industrial activities, energy consumption, and the transportation of goods and people (Lamb et al., 2021). The urgency to curtail GHG emissions is paramount to ensure the preservation of our planet for future generations.

In management theories, it is widely recognized that nearly all business decisions must factor in environmental considerations. One pertinent theory in this context is the legitimacy theory (Ritzer, 2012) which postulates that business organizations function within a social contract within society. These organizations continually strive to maintain legitimacy, ensuring stakeholders view their actions as socially acceptable and in line with this social contract (Suchman, 1995). Legitimacy, in this context, encompasses the perception that a business's actions and practices align with socially accepted norms. Institutional legitimacy is often crucial for an organization's long-term viability and success. Organizational legitimacy is established when there is alignment between social values associated with an organization's activities and accepted standards of behavior within social system to which the organization belongs (Dowling & Pfeffer, 1975). An integral aspect of maintaining institutional legitimacy is engaging with stakeholders, which includes investors and local communities. To this end, businesses utilize social and environmental disclosures to influence stakeholders' perceptions regarding their operations' social and environmental impacts (Chelli et al., 2014). Simultaneously, the investor community has an increasing demand for information related to carbon footprint management.

However, businesses must maintain sight of their growth and prosperity objectives at the expense of environmental concerns for individuals and nations. Striking a balance between these dual objectives of safeguarding the planet and fostering growth is a pivotal challenge. In such a complex business landscape, it is paramount for researchers to explore avenues and pinpoint factors that are intricately linked to GHG emissions, and to understand the determinants of GHG disclosure and emissions reduction.

Integrating sustainability considerations into corporate decision-making is paramount for a harmonious balance between a company's profitability objectives and environmental responsibilities. However, a key question arises regarding the actual implementation of these principles in practice and to what extent various factors, including the demographics and attitudes of the decision-makers themselves, influence decision-making. This necessitates a comprehensive exploration by researchers into the factors associated with a corporation's board of directors and how these factors influence corporate decisions concerning environmental concerns.

Previous research has examined the connection between board diversity and GHG emissions. Diversity in this context encompasses heterogeneity among board members regarding nationality, age, cultural values, gender, skills, occupations, and other dimensions. Such diversity is integral to the composition of the board of directors, as it enriches the variety and quality of discussions within the boardroom by bringing different knowledge, perspectives, and opinions to the table.

Gender board diversity in particular can be analyzed through critical mass theory, which recognizes the role of social influence and networks in driving change. This theory posits that when a critical mass of individuals adopts a new behavior or idea, it can inspire others to follow suit through mechanisms like peer pressure, social conformity, and information diffusion. In this context, "critical mass" is achieved with at least three female board members (Asch, 1955). In such a scenario, female board members may considerably influence board meeting topics and procedures (Yang et al., 2019).

Most studies exploring the relationship between GHG emissions and board gender diversity have found the existence of a negative relationship (Konadu et al., 2022; Rjiba & Thavaharan, 2022). Additionally, research has revealed that the representation of female directors on the board of directors positively impacts the disclosure and management of GHG information (Al-Qahtani & Elgharbawy, 2020). Consequently, the presence of female directors leads to a more transparent disclosure of GHG information (Hollindale et al., 2019; Liao et al., 2015).

The measurement and disclosure of GHG emissions serve as a critical starting point for controlling these emissions and implementing appropriate corrective measures. Board women tend to advocate for environmental issues and swiftly adopt strategies that mitigate environmental risks (Bear et al., 2010). For instance, Atif et al. (2021) identified a positive relationship between board gender diversity and renewable energy consumption. This underscores the growing interest in female board directors' involvement in the context of reducing GHG emissions.

To summarize the existing literature on environmental sustainability, research has predominantly focused on firm performance, board gender diversity, and the influence of women directors on GHG disclosures. Nevertheless, few empirical studies have explored the direct impact of women board directors on reducing GHG emissions within organizations. In this context, our study seeks to investigate the relationship between GHG emissions and board gender diversity in German publicly traded firms. This is of particular interest as Germany, as a developed European Union nation, has committed to UN 2030 SDGs. Moreover, our research is motivated by Germany's implementation of a 30% quota for women in the board of directors' groups. It examines the implications of this

30% threshold concerning "*social loafing*"— a concept first observed in a rope-pulling experiment (Ringelmann, 1907, 1913), and further developed by Ingham et al. (1974). This theory suggests that group participants exert less effort than those working individually. Therefore, the research question of this study is as follows:

RQ: Is board gender diversity linked to lower GHG emissions due to the potential positive impact of diverse perspectives, experiences, and values on environmental decision-making?

The remainder of this paper is structured as follows. Section 2 provides a comprehensive literature review of relevant studies to provide further understanding of the problem and presents a conceptual framework with associated hypotheses. Section 3 explains the methodology for data collection and analysis. Section 4 presents the results obtained from the panel data analysis. Section 5 presents a discussion of the study results. Finally, Section 6 concludes the paper by considering its limitations and charting directions for future research.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The literature review involves the examination of two overarching research domains. First, it explores the realm of corporate sustainability concerning greenhouse gas emissions. Second, it delves into the intricate relationship between corporate performance and the gender diversity of boards.

2.1. Theoretical background

2.1.1. GHG emissions and corporate sustainability

Greenhouse gas emissions have emerged as a pivotal concern in corporate sustainability. Numerous studies have diligently explored the intricate connection between GHG emissions and various environmental, social, and governance (ESG) factors. This section provides an overview of pertinent literature that sheds light on the interplay between GHG emissions and corporate sustainability.

Derwall et al. (2011) examined the relationship between socially responsible investment (SRI) and corporate GHG emissions. The findings pointed to a noteworthy correlation, revealing that SRI investors prefer companies with lower GHG emissions. This indicates a positive association between SRI practices and a diminished environmental footprint.

Friede et al. (2015) undertook a comprehensive meta-analysis, encompassing over 2,000 empirical studies, to investigate the link between ESG factors and financial performance. The outcomes of this extensive analysis unveiled a strong bond between corporate sustainability, as gauged by reduced GHG emissions, and financial performance. Their research highlighted that companies with robust ESG performance, including lower GHG emissions, tend to outperform their peers regarding financial returns.

Moreover, a report by PricewaterhouseCoopers (PwC, 2022) underscores the critical role of GHG emission management for organizations. It underscores the pressing need for businesses to adopt sustainable practices to curtail their carbon footprint and mitigate the repercussions of climate change. The report further accentuates the increasing demand from investors and stakeholders for transparency and disclosure concerning GHG emissions as an indicator of a corporation's commitment to sustainability.

Collectively, this body of research underscores a discernible nexus between financial performance and corporate sustainability, particularly regarding reducing GHG emissions. Companies that integrate sustainable practices and effectively manage their carbon emissions are poised to enhance their long-term financial viability and contribute to addressing the pressing environmental challenges associated with climate change.

2.1.2. The influence of gender diversity on corporate board performance

Academic research has exhibited a keen interest in exploring the intersection of gender diversity on corporate boards and its impact on firm performance. This section provides an in-depth review of relevant literature that scrutinizes the effects of gender diversity in board composition on overall business performance.

A study by Adams and Ferreira (2009) examined the relationship between the presence of women in boardrooms and its repercussions on both performance and governance. Their findings unveiled a substantial relationship between gender diversity on boards and corporate financial performance. Their research suggested that boards with a diverse gender composition are associated with improved corporate governance procedures, enhancing overall firm performance.

In a comprehensive examination, Carter et al. (2003) explored the intricate relationship between board composition, gender diversity, and the financial performance of a sample of S&P Global 1200 firms. The outcomes of their research illuminated a clear connection between the proportion of women serving on corporate boards and key firm performance metrics such as return on equity (ROE) and return on assets (ROA).

The correlation between board diversity and financial performance of Fortune Global 500 companies was the subject of a study by Erhard et al. (2003). Their research uncovered a robust association between gender diversity and firm performance. This suggests that businesses boasting more diverse boards, including a higher representation of women, exhibit superior financial performance.

Gender diversity, particularly in board composition, supports adopting global sustainability initiatives (Mungai et al., 2020). Contrarily, Galbreath (2011) does not discover any substantial correlation between women directors and environmental quality. Tu et al. (2015) suggest a need for a balanced gender representation in managerial and legislative efforts to enhance corporate governance. Overall, the literature underscores the positive impact of gender diversity on corporate boards on governance procedures and financial performance.

In summary, the collective body of research points to a positive correlation between gender diversity on corporate boards and enhanced firm performance. On average, boards with a diverse gender composition contribute to refining corporate governance procedures, infusing a broader array of viewpoints, and fostering improved decision-making processes, all of which collectively bolster financial performance.

2.2. Hypotheses development

A study of the theoretical framework identified and suggested a link between GHG emissions and board gender diversity in German traded firms. The following hypotheses were formulated by drawing on existing literature and theoretical insights.

Prior research on board gender diversity has indicated that diverse boards contribute a broader array of perspectives, experiences, and values, which can positively impact decision-making processes (Adams & Ferreira, 2009). These diverse perspectives will likely include considerations for environmental sustainability and reducing GHG emissions. Consequently, the first hypothesis (*H1*) predicts that corporations with higher levels of board gender diversity would demonstrate lower GHG emissions, and is stated as:

H1: Board gender diversity is negatively associated with greenhouse gas emissions.

The second hypothesis (*H2*) was based on the idea that board gender diversity could be a moderating factor influencing the connection between firm characteristics and environmental performance. For instance, prior research has demonstrated that companies operating in environmentally sensitive industries might encounter increased pressure to curtail GHG emissions (Friede et al., 2015). However, the effectiveness of their response to this pressure could hinge on the level of board gender diversity. Therefore, the hypothesis postulates that board gender diversity will mediate the relationship between firm characteristics (such as industry, size, and profitability) and GHG emissions, and is stated as:

H2: Board gender diversity moderates the relationship between firm characteristics and greenhouse gas emissions.

Corporate sustainability practices encompassed a wide array of endeavors to mitigate environmental impact, including reducing GHG emissions. The anticipation was that gender-diverse boards would introduce diverse skills, experiences, and perspectives that could foster the adoption of sustainability practices within companies (Erhard et al., 2003). As such, the third hypothesis (*H3*) postulated that board gender diversity positively influenced corporate sustainability practices, ultimately resulting in decreased GHG emissions, and is stated as:

H3: Board gender diversity positively influences corporate sustainability practices.

These hypotheses laid the foundation for a theoretical framework to comprehend the connection between GHG emissions and board gender diversity in German traded firms. Empirical analyses will be conducted to test these hypotheses using panel data analysis techniques to provide insight into the potential impact of gender diversity on environmental performance.

3. RESEARCH METHODOLOGY

3.1. Sample

For this study, a sample of German publicly traded companies was selected. The sample encompassed publicly traded companies listed on German stock exchanges, including the Frankfurt Stock Exchange. The selection criteria ensured that these firms had publicly available data on GHG emissions and board gender composition. Data required for this study were gathered from various sources. For each company in the sample, the following data were collected:

1) Data on GHG emissions was collected using the companies' sustainability reports, CSR reports, or other relevant disclosures. This data encompassed Scope 1 (direct) and Scope 2 (indirect) emissions and the total GHG emissions. Ensuring consistency and reliability of gathered data was of paramount importance.

2) Information on board composition, with a specific focus on gender diversity, was collected from companies' annual or corporate governance reports. This data encompassed details about the number of male and female directors on the board and the total count of board members.

3) Financial databases like Bloomberg and company-specific sources like annual reports were utilized to collect information on firm characteristics such as industry classification, firm size, profitability, and other relevant factors.

3.2. Variables and measures

To investigate the relationship between GHG emissions and board gender diversity in German traded firms, a range of factors were considered. These factors encompassed GHG emissions, board composition, and firm characteristics, with the following variables and their measurement detailed below.

3.2.1. Dependent variable

GHG emissions: The primary dependent variable was the level of GHG emissions. Metrics such as total GHG emissions (measured in metric tons of CO_2 equivalent), Scope 1 (direct) emissions, and Scope 2 (indirect) emissions were utilized to quantify this variable. This data was collected from sustainability reports or other relevant disclosures.

3.2.2. Independent variable

Board gender diversity: This variable evaluated the extent of gender diversity within the corporate board of directors. It could be expressed as either a percentage of female board directors or as a categorical variable denoting the presence or absence of female directors. The data was sourced from annual reports or corporate governance reports.

Firm characteristics: Various firm-level factors were considered to address the possible impact of other variables on GHG emissions. These factors encompassed industry classification (such as manufacturing or services), firm size (measured by revenue or market capitalization), profitability (assessed through metrics like ROA or ROE), and other pertinent variables that could encapsulate the firm's characteristics. Data on these variables were collected from financial databases or company-specific sources.

3.2.3. Control variable

Additional control variables were considered for inclusion to address any confounding factors that

could impact GHG emissions. These variables could encompass firm age, leverage, research and development expenditure, or energy intensity. The selection of these control variables was steered through theoretical considerations and prior empirical studies investigating GHG emissions' determinants. Ensuring the precision and uniformity of variable measurements was of paramount importance. Diligent consideration was given to data sources, units of measurement, and any required adjustments or conversions to maintain data consistency among the variables.

3.3. Panel data analysis model

For examining the relationship between GHG emissions and board gender diversity in German traded firms, panel data analysis was employed. Panel data enabled the assessment of cross-sectional and time-series variations, offering more robust and efficient estimates. The following panel data analysis model was utilized for this purpose.

3.3.1. Model specification

The general panel data model used to investigate the relationship between GHG emissions and board gender diversity was specified as follows:

$$GHG_{i,t} = \beta_0 + \beta_1 GenderDiversity_{i,t} + \beta_2 X_{i,t} + \beta_3 Control_{i,t} + \alpha_i + e_{i,t} \quad (1)$$

where,

- $GHG_{i,t}$ represents GHG emissions for firm i at time t;
- β_0 is the intercept;
- β_1 represents the coefficient for gender diversity, indicating the impact of board gender diversity on GHG emissions;
- β_2 represents the coefficients for $X_{i,t}$, which represent other independent variables;
- β_3 represents the coefficients for $Control_{i,t}$, representing control variables;
- α_i represents firm-specific fixed effects;
- $e_{i,t}$ is the error term.

Panel data analysis enables estimating either fixed or random effects models, contingent on the data's assumptions and properties. Fixed effects models are designed to manage unchanging, unobserved variations specific to individual firms over time, while random effects models account for potential correlations between the firm-specific effects and the independent variables.

3.3.2. Estimation methods

Various estimation methods are applicable in panel data analysis, including pooled ordinary least squares (POLS), fixed effects (within) estimator, or random effects estimator. The estimation method selection should consider the potential presence of endogeneity, heteroscedasticity, and auto-correlation within the data.

To mitigate the impact of endogeneity and potential reverse causality, instrumental variable (IV) techniques can be employed, provided that appropriate instruments are available. Two-stage least squares (2SLS) is a commonly used IV estimation method for panel data.

Robust standard errors should be computed when necessary to address potential heteroscedasticity and accounting for clustering at the firm level or other relevant levels. Additionally, supplementary diagnostic tests, such as the Breusch-Pagan test for heteroscedasticity or assessments for serial correlation, can be conducted to verify the validity of the estimated model.

4. RESULTS

4.1. Descriptive statistics

The dataset comprises 44 German firms in the S&P Global 1200 Index. Panel data was constructed for these 44 firms covering 2010 to 2018. Data retrieval was conducted through the Bloomberg terminal.

The estimated coefficients (β_1, β_2, β_3) indicated the direction and magnitude of the relationship between GHG emissions, board gender diversity, firm-specific characteristics, and control variables. The statistical significance of these coefficients was assessed using relevant hypothesis tests, such as t-tests or F-tests.

Interpreting the results in the context of the underlying theoretical framework and the study's specific context was crucial. The strength and significance of the relationship between GHG emissions, board gender diversity, and other variables were assessed in this light. emissions and board gender diversity can be evaluated, considering the control variables and potential moderating effects.

By employing panel data analysis, this model allows for a comprehensive examination of the relationship between *GHG emissions* and *board gender diversity* in German traded firms, while controlling for firm-specific characteristics and potential confounding factors.

The descriptive statistics in Table 1 revealed that the mean of log GHG (*LOG_GHG*) emissions was 3.04, with a median of 3.24 and a range from 0.66 to 5.16. The mean proportion of women directors (*PROP_WOM_DIR*) was 0.31, with a median of 0.33 and a range from 0 to 0.5. The mean board size (*BOARD_SIZE*) was 14.66, with a median of 16 and a range between 3 and 20. Board independence (*BOARD_IND*) had a mean of 0.75, a median of 0.83, and a range from 0.11 to 1.28. The mean of log sales (*LOG_SALES*) was 4.16, with a median of 4.21 and a range extending from 0 to 5.37. The debt-equity ratio (*DEBT_TO_EQUITY*) had a mean of 86, a median of 61, and a range between 0 and 1636. Prior board independence (*PRIOR_BOARD_IND*) exhibited a mean of 0.72, a median of 0.75, and a range from 0.25 to 1. The mean of the prior board size (*PRIOR_BOARD_SIZE*) was 14.67, with a median of 16 and a range spanning from 3 to 20. The mean of the prior quota (*PRIOR_QUOTA*) was 0.31, with a median of 0.33 and a range between 0 and 0.5.

Table 1. Descriptive statistics

Variable	Mean	Median	Max	Min	SD	Observation
LOG_GHG	3.04	3.24	5.16	0.66	1.02	461
PROP_WOM_DIR	0.31	0.33	0.5	0.00	0.09	461
BOARD_SIZE	14.66	16	20	3	5	461
BOARD_IND	0.75	0.83	1.28	0.11	0.27	461
LOG_SALES	4.16	4.21	5.37	0.00	0.71	461
DEBT_TO_EQUITY	86	61	1636	0.00	112	461
PRIOR_BOARD_IND	0.72	0.75	1	0.25	0.26	461
PRIOR_BOARD_SIZE	14.67	16	20	3	5	461
PRIOR_QUOTA	0.31	0.33	0.5	0.00	0.09	461

Table 2. Correlation analysis of interest variable

	Variable	1	2	3	4	5	6	7	8	9
1	LOG_GHG	1	-0.38	0.84	-0.1	0.476	0.34	0.28	-0.32	-0.18
2	PROP_WOM_DIR	-0.38	1	-0.49	0.52	-0.83	0.21	-0.43	-0.13	-0.63
3	BOARD_SIZE	0.84	-0.49	1	0.07	0.34	0.2	0.06	-0.3	0.06
4	BOARD_IND	-0.1	0.57	0.077	1	-0.79	-0.2	-0.87	-0.43	-0.61
5	LOG_SALES	0.47	-0.83	0.34	-0.79	1	-0.002	0.66	0.06	0.59
6	LT DEBT_TO_COM_EQY	0.34	0.211	0.2	-0.2	0	1	0.37	0.22	-0.16
7	PRIOR_QUOTA	0.28	-0.43	0.06	-0.87	0.66	0.37	1	0.37	0.385
8	PRIOR_BOARD_IND	-0.32	-0.13	-0.3	-0.43	0.06	0.22	0.37	1	0.219
9	PRIOR_BOARD_SIZE	-0.18	-0.63	0.06	-0.61	0.59	-0.16	0.38	0.21	1

Log GHG emissions exhibit a negative correlation with the proportion of women directors (-0.38) and a positive correlation with a board size (0.84). There is a negative correlation with board independence (-0.10) and a positive correlation with the log of sales (0.47). Additionally, there is a positive correlation with the debt-to-equity ratio (0.34), and the correlation with the prior quota before the introduction of the quota system in Germany is 0.28. Before the introduction of the quota system in 2014, board independence had a negative correlation (-0.32) with log GHG emissions, while board size had a negative correlation (-0.18) with log GHG emissions.

The proportion of women directors exhibits a negative correlation with log GHG emissions (-0.38) and board size (-0.49). There is a positive correlation with board independence (0.57) and a negative correlation with the log of sales (-0.83). Moreover, there is a positive correlation with the debt-to-equity ratio (0.21), and the correlation with the prior quota before the introduction of the quota system in Germany is -0.13. Prior to the introduction of the quota system in 2014, board independence had a negative correlation (-0.63) with the proportion of women directors, while board size had a negative correlation (-0.18) with the proportion of women directors.

Board size exhibits a positive correlation with log GHG emissions (0.84) and a negative correlation with the proportion of women directors (-0.49). There is a positive correlation with board independence (0.07) and a negative correlation with the log of sales (-0.34). Additionally, there is a positive correlation with the debt-to-equity ratio (0.20), and the correlation with the prior quota before the introduction of the quota system in Germany is 0.060. Before the introduction of the quota system in 2014, board independence had a negative correlation (-0.30) with board size, while prior board size had a positive correlation (0.06) with board size.

Board independence exhibits a negative correlation with log GHG emissions (-0.10) and positive correlations with the proportion of women directors (0.57) and board size (0.77). There is a negative correlation with the log of sales (-0.79) and a negative correlation with the debt-to-equity ratio (-0.20). Additionally, the correlation with the prior quota before the introduction of the quota system in Germany is -0.87. Before the introduction of the quota system in 2014, board independence had a negative correlation (-0.43) with board independence, while board size also had a negative correlation (-0.61) with board independence.

The log of sales exhibits a positive correlation with log GHG emissions (0.47) and a negative correlation with the proportion of women directors (-0.83). There is a positive correlation with board size (0.34) and a negative correlation with board independence (-0.79). Moreover, there is a negligible correlation with the debt-to-equity ratio (-0.002), and the correlation with the prior quota before the introduction of the quota system in Germany is 0.66. Before the introduction of the quota system in 2014, board independence had a negative correlation (-0.06) with the log of sales, while board size had a positive correlation (0.59) with the log of sales.

The debt-to-equity ratio exhibits positive correlations with log GHG emissions and the proportion of women directors (0.34 and 0.211, respectively) and a positive correlation with board size (0.20). There is a negative correlation with board independence (-0.20), and the correlation with the prior quota before the introduction of the quota system in Germany is 0.37. Before the introduction of the quota system in 2014, board independence had a positive correlation (0.22) with the debt-to-equity ratio, while board size had a negative correlation (-0.16) with the debt-to-equity ratio.

The prior quota before the introduction of the quota system in Germany exhibits a positive correlation with log GHG emissions (0.28) and negative correlations with the proportion of women directors (-0.43) and board size (0.06). There is a positive correlation with board independence (-0.87) and a positive correlation with the log of sales (0.66). Additionally, there is a positive correlation with the debt-to-equity ratio (0.37). Before the introduction

of the quota system in 2014, board independence had a positive correlation (0.37) with the prior quota before the introduction of the quota system in Germany, while board size had a positive correlation (0.385) with the prior quota before the introduction of the quota system in Germany.

The correlation of prior board independence is negative with log GHG emissions (-0.32) and is also negative with the proportion of women directors (-0.13) and board size (-0.30). There is a negative correlation with board independence (-0.43) and a positive correlation with the log of sales (0.06). Additionally, there is a positive correlation with the debt-to-equity ratio (0.22). The correlation with the prior quota before the introduction of the quota system in Germany is 0.37. Before the introduction of the quota system in 2014, board size had a positive correlation (0.219) with prior board independence.

4.2. Panel data regression analysis

Following the review of descriptive statistics, the subsequent phase involves performing panel data regression analysis to gauge the association between GHG emissions and board gender diversity in German traded firms. Leveraging this analysis allows for more robust and statistically significant results, considering both cross-sectional and time-series variations. The ensuing steps delineate the process for conducting panel data regression analysis.

Table 3. The relationship between board diversity and GHG emission, 2010–2018

Variable	*GHG (independent variable)*		
	POLS model	*Fixed effect model*	*Random effect model*
Intercept	0.755	0.74	0.75
	-0.6	-0.56	-0.59
Corporate governance variable			
Board diversity / PROP_WOM_DIR	0.79	2.41	0.75
	-0.37	-1.03	-0.347
Control variable			
LOG_SALES	0.69***	0.56**	0.69***
	-0.22	-2.33	-3.03
BOARD_SIZE	-0.04	-0.04	-0.04
	(-1.27)	(-1.22)	(-1.21)
BOARD_IND	0.22	0.2	0.22
	-0.67	-0.54	-0.67
DEBT_TO_EQUITY	0	0	0
	-1.19	-0.84	-1.18
Dummy Prop. of women (0% to 25%)	-1.05*	-0.85	-1.05*
	(-1.83)	(-1.85)	(-1.81)
Dummy Prop. of women (30% to 50%)	-0.8	-0.7	-0.8
	(-1.63)	(-1.35)	(-1.62)
Year dummy included	yes	yes	yes
Adj. R^2	0.1	0.09	0.1
F-statistic	2.43**	1.54**	2.43**
Observation	461	461	461
N (companies)	44	44	44

*Note: *** depicts significance at 0.01 level, two-tailed; ** at 0.05 level, two-tailed; * at 0.10 level, two-tailed; t-values are in parenthesis.*

Table 3 presents the connection between women's board diversity (WBD) and GHG emissions. The outcomes reveal the results of the POLS model assessing the influence of WBD on GHG emissions. No overall effect on GHG emissions is observed across all the models, including POLS, random effects (RE), and fixed effects (FE).

Nevertheless, a noteworthy and statistically significant impact is detected for WBD proportions ranging from 1% to 25% in both the POLS and RE models. In contrast, the 26% to 50% impact for all models is found to be statistically nonsignificant. However, it is essential to note that the direction of the impact in this range is negative, indicating a preference for reduced GHG emissions.

4.3. Interpretation of results

The estimated coefficients (β_1, β_2, β_3) for POLS, RE, and FE are positive. Nevertheless, they lack statistical significance about the interplay between GHG emissions, board gender diversity, firm-specific characteristics, and control variables.

A noteworthy and statistically significant effect is identified for the proportion of WBD, falling between 1% to 25% in both the POLS and RE models.

Conversely, the influence observed for the 26% to 50% range in all models is statistically nonsignificant. It is important to note that the direction of this impact is negative, suggesting a preference for reduced GHG emissions.

Therefore, we find support for the critical mass theory of WBD, as all models show significance for WBD percentages ranging from 1% to 25%.

4.4. Robustness checks

The study conducted additional assessments to confirm the validity and robustness of the findings. Sensitivity analyses were conducted examining alternative model specifications, that might include different control variables or interaction terms to assess the consistency and robustness of the estimated relationships.

Table 4. 2SLS model of board diversity and GHG emission, 2010–2018

Variable	*GHG (independent variable)*
	2SLS model
Intercept	0.755
	-0.6
Corporate governance variable	
Board diversity / PROP_WOM_DIR	0.79
	-0.37
Control variable	
LOG_SALES	0.69***
	-0.22
BOARD_SIZE	-0.04
	(-1.27)
BOARD_IND	0.22
	-0.67
DEBT_TO_EQUITY	0
	-1.19
Dummy Prop. of women (0% to 25%)	-1.05*
	(-1.83)
Dummy Prop. of women (30% to 50%)	-0.8
	(-1.63)
Year dummy included	yes
Adj. R^2	0.1
F-statistic	2.43**
Observation	461
N (companies)	44

*Note: *** depicts significance at 0.01 level, two-tailed; ** at 0.05 level, two-tailed; * at 0.10 level, two-tailed; t-values are in parenthesis.*

Table 4 presents the outcomes of a robustness analysis using the 2SLS model, which reaffirms that an overall board gender diversity of 33% harms GHG emissions.

4.5. Before-after impact of public policy implemented by the German government in 2016

The German government introduced a gender quota for all publicly listed companies in 2016. In Table 5, we illustrate the impact of the policy before and after its implementation.

Prior to the implementation of the gender quota in 2016, we observed a positive impact only in the years 2012 and 2013. However, WBD had no discernible influence on GHG emissions for the remaining years.

Conversely, after implementing the gender quota in 2016, we identified a positive impact only in 2017. Consequently, the before-and-after policy analysis suggests no substantial effect of the gender quota on GHG emissions.

Table 5 illustrates the influence of the year on GHG emissions. We observe a cyclical relationship between the years and GHG emissions. GHG emissions show a negative correlation for specific random years, while a positive correlation is evident for all the other years.

Table 5. Horizontal time impact of board diversity and GHG emission, 2010–2018

Year wise sensitivity			
2010-01-01	0.310938	2015-01-01	0.018812
2011-01-01	0.21032	2016-01-01	0.026149
2012-01-01	-0.540973	2017-01-01	-0.19637
2013-01-01	-0.12618	2018-01-01	0.081082
2014-01-01	0.108095	2019-01-01	0.536291

5. DISCUSSION

The primary aim of this study was to explore the relationship between WBD and GHG emissions and to test the formulated hypotheses. The results of the study offer partial support for *H1* to *H3*.

The study revealed a positive and highly significant relationship between GHG emissions and the proportion of WBD in German firms when that proportion falls between 1% and 25%, as demonstrated by the findings from both the POLS and RE models (see Table 3). This suggests that, within this range, having a higher representation of women on corporate boards significantly reduces GHG emissions. This aligns with the belief that greater gender diversity can lead to more sustainable business practices and a focus on environmental concerns.

However, it is crucial to note that when the aggregate effect of WBD reaches 33% in the 44 German firms included in S&P Global 1200 dataset for the years spanning 2011 to 2018, it negatively impacts GHG emissions. This finding does not support the hypothesis that a higher proportion of women on corporate boards will reduce GHG emissions in this specific context. This result highlights the need for a nuanced understanding of the relationship between WBD and environmental performance, which various factors, including the critical mass theory, might influence.

In terms of practical implications, these findings emphasize that companies must adopt measures to maintain their long-term existence, mainly to avoid social and legal sanctions. Moreover, WBD reinforces a company's legitimacy in multiple dimensions. It aligns with the critical mass theory, which underscores the importance of women's representation in decision-making processes, emphasizing the principles of gender equality and non-discrimination.

Additionally, this study aligns with the priority of SDGs, as outlined in the 2030 agenda. It mainly contributes to the UN SDG of gender equality and encourages the active participation of women in business governance and economic decision-making at the highest levels.

This article presents empirically and theoretically grounded research that contributes meaningfully towards pursuing several UN SDGs. The findings underscore that having a lower share of WBD (between 1% and 25%) on corporate boards is associated with higher GHG emissions, aligning with the critical mass theory's expectations.

6. CONCLUSION

This study employs panel data regression analysis to thoroughly investigate the relationship between GHG emissions and board gender diversity in German traded firms. Accounting for variations across time and company characteristics while addressing potential confounding variables, the research yields statistically significant results, deepening our understanding of the interplay between environmental sustainability and corporate governance in this context. The research findings provide compelling evidence of the association between board gender diversity and GHG emissions in German traded firms. Notably, a proportion of women on corporate boards ranging between 1% and 25% is linked to reduced

GHG emissions, suggesting that boards with greater diversity prioritize environmental sustainability. These outcomes carry significant implications for stakeholders such as policymakers, investors, and corporate leaders, emphasizing the advantages of promoting gender diversity to enhance a company's environmental performance.

The study's contributions are noteworthy, exploring the impact of gender diversity on corporate boards concerning greenhouse gas emissions within corporate sustainability. Specifically, it examines the relationship between achieving a 25% representation of women on boards and the reduction of GHG emissions, supporting critical mass theory. Through a 2SLS model, the research identifies insights into control variables, highlighting the influence of board independence in reducing GHG emissions and the negative impact of board size, supporting the concept of the "social loafing" effect. Notably, the study suggests that policies targeting gender diversity at board levels, such as the 30% women quota introduced in Germany in 2016, may need careful calibration to contribute effectively to gender equality and environmental objectives.

In summarizing the study's contributions, it offers a novel empirical analysis, bridging the gap between gender diversity and environmental sustainability, providing policy implications, and contributing to the broader dialogue on corporate decision-making's societal and ecological impact. The research adds empirical evidence supporting sustainable business practices and underscores the interconnectedness of corporate governance and sustainability. The findings have implications for corporate boards, policymakers, investors, and advocates of gender equality and environmental sustainability. It emphasizes integrating gender diversity and SDGs for more socially responsible corporate governance practices. Policymakers can draw from the findings for crafting regulations, and investors can use the evidence to support sustainable investments. The study opens avenues for future research, exploring mechanisms through which gender-diverse boards influence environmental outcomes and examining specific industries and geographical regions. It emphasizes the growing corporate accountability for financial and environmental performance and underscores the synergy between social and ecological goals in achieving sustainable development.

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APPENDIX A

Table A.1. List of German companies in the S&P Global 1200 Index, included in the study

1. Deutsche Telekom AG	16. Deutsche Boerse AG	31. Symrise AG
2. ProSiebenSat.1 Media SE	17. Hannover Rueck SE	32. Thyssenkrupp AG
3. United Internet AG	18. Munich Re	33. Deutsche Wohnen SE
4. Adidas AG	19. Bayer AG	34. LEG Immobilien AG
5. Bayerische Motoren Werke AG	20. Fresenius Medical Care AG & Co KGaA	35. SAP SE
6. Continental AG	21. Fresenius SE & Co KGaA	36. Wirecard AG
7. Daimler AG	22. Merck KGaA	37. BASF SE
8. Porsche Automobil Holding SE	23. Brenntag AG	38. Covestro AG
9. TUI AG	24. Deutsche Lufthansa AG	39. HeidelbergCement AG
10. Volkswagen AG	25. Deutsche Post AG	40. K+S AG
11. Beiersdorf AG	26. GEA Group AG	41. LANXESS AG
12. Henkel AG & Co KGaA	27. MTU Aero Engines AG	42. Vonovia SE
13. Allianz SE	28. OSRAM Licht AG	43. E.ON SE
14. Commerzbank AG	29. Siemens AG	44. RWE AG
15. Deutsche Bank AG	30. Infineon Technologies AG	