Climate board governance and carbon assurance – European evidence

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Abstract

Purpose – This paper aims to investigate the effect of climate board governance based on (1) carbon change committees, (2) critical mass of female board members and (3) carbon-related executive compensation, on the voluntary implementation and quality of carbon assurance.

Design/methodology/approach – Using stakeholder and critical mass theories, 978 firm-year observations for European Union firms for the 2017–2021 period are collected. Climate board governance and carbon assurance proxies come from the Carbon Disclosure Project.

Findings – Correlation and logit regression analyses show that climate board governance significantly improves carbon assurance (quality). The findings are robust to various robustness and endogeneity checks and are of great importance for researchers, regulators and business practice.

Originality/value – This analysis mainly contributes to previous studies by using a combined sustainable board governance score as a major driver of corporate carbon assurance practices for the first time.

Keywords Climate board governance, Board gender diversity, Climate board committees, Carbon-related incentives, Carbon assurance, Stakeholder theory

Paper type Research paper

1. Introduction

Since the last decade, stand-alone environmental reports in accordance with (inter)national frameworks, such as the Global Reporting Initiative Standards, have represented a "best practice" for public interest entities (PIEs) (Huang and Watson, 2015). In environmental reports, climate aspects are classified as core topics because of increased public awareness of climate change goals. As climate reports are still voluntary in many regimes from an international perspective and are connected with various reporting frameworks, stakeholders question their decision usefulness because of greenwashing policies and information overload (Huang and Watson, 2015). In reaction, firms provide voluntary external independent assurance of carbon reports and related carbon emissions (scopes 1, 2 and 3) by a third party (carbon assurance), such as professional accountants. The main goal of carbon assurance is to increase stakeholders' trust in carbon information and, thus, firm reputation (Cohen and Simnett, 2015).

In view of this increased stakeholder pressure, previous studies have stressed the lack of comparability in carbon assurance practices (Bradbury *et al.*, 2022). The voluntary adoption of

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carbon assurance can lead to either symbolic or substantive practices. The choice of the carbon assuror mainly differentiates between professional accountants and other external assurors. Moreover, firms may choose between a limited and reasonable level of assurance and between different assurance standards. To increase the motivation for carbon assurance and its quality in correspondence with stakeholders' demands, the board of directors should conduct an active monitoring and incentive system. Compared with classical board attributes, such as board independence or board size, sustainable board governance represents an attractive research topic. Three major categories of sustainable boards can be identified:

(1) board gender diversity (BGD);

(2) (institutionalized) sustainability board expertise; and

(3) sustainability-related executive compensation.

BGD refers to the recognition of female directors (either executive or nonexecutive) on the board of directors. In this study, we focus on critical mass theory (Kanter, 1977) and include a critical mass (at least 30%) of female directors on the board as our first variable. Moreover, we include climate board expertise as an institutionalized inclusion of climate goals [climate board committees (CC)]. Addressing the incentive function of corporate governance, climate-related executive compensation (CEC) is linked to the question of whether climate goals in variable executive compensation packages for executive directors are included. From a regulatory view, two of our included proxies (CCs and climate-related executive renumeration) are voluntary in most international settings, including Europe. Thus, the board of directors can decide whether to implement these. By contrast, many regimes have included mandatory gender quotas on the boards of directors in recent years. This also relates to the European Union (EU): a new directive on mandatory gender quotas for boards of directors of listed firms was implemented (Directive, 2022b). Countries may choose to refer to a gender quota of 40% for nonexecutive board members or a quota of 33% for the full board level (Directive, 2022b).

From a research perspective, many researchers have noticed increased research activity on the influence of the three factors of sustainable board governance on corporate sustainability assurance in recent years (e.g. Garcia-Sanchez *et al.*, 2023; Bradbury *et al.*, 2022). Sustainability board committees, BGD and sustainability-related executive compensation tend to have a positive effect on sustainability assurance (e.g. Garcia-Sanchez *et al.*, 2022; Dalla Via and Perego, 2020). However, the effect of climate board governance on carbon assurance has been analyzed in rare events, leading to a major research gap. Simic *et al.* (2023) found a positive effect of sustainability-related executive compensation on carbon assurance. Using climate change board committees, employee incentives based on carbon emissions reductions and carbon assurance, a positive relationship was stressed (Datt *et al.*, 2018). However, climate change board committees do not affect the choice of audit firms as carbon assurance provider (Datt *et al.*, 2020). Moreover, carbon-related employee incentives lead to the increased selection of nonaudit firms as carbon assurors. Thus, empirical results on the effect of climate board governance on carbon assurance are few. In view of the increased relevance of carbon assurance from a European perspective, we focus on three climate board proxies (based on a score and separately) and their effect on carbon assurance (implementation decision and quality). As we do not identify any prior studies on the link between climate board governance and carbon assurance (quality), we mainly contribute to the literature (e.g. Simic *et al.*, 2023; Datt *et al.*, 2018; Datt *et al.*, 2020) as follows. First, regarding methodology, no study has included multiple carbon board variables or analyzed the combined effects of carbon assurance. We assume a complementary relationship between these variables, leading to major synergies in corporate governance,

which should be included in empirical research. Second, we contribute to prior research and recognize carbon assurance quality, based on the choice of assurance provider (audit firms vs other providers), the level of assurance (reasonable vs limited) and the inclusion of assurance standards [International Standard on Assurance Engagements (ISAE) 3000 vs others]. Recognizing carbon assurance quality instead of the existence of carbon assurance as a dummy variable increases the validity of the research. Third, we conduct a cross-country study for the European capital market because of increased sustainability regulations, which we will highlight in the following section. Fourth, we contribute to theoretical development, stressing the association between stakeholder and critical mass theories.

In view of these research gaps, we address the need for evidence-based regulations for the EU standard-setting process and guide researchers, business practice and standard setters. Based on stakeholder and critical mass theories, we assume a positive effect of climate board governance (critical mass of female directors, CCs and CEC) on carbon assurance (quality). Our study includes a sample of 978 firm-year observations of EU listed firms for the time frame between 2017 and 2021. Logistic regressions follow our assumptions and show a significant positive influence of climate board governance on carbon assurance. Climate boards increase voluntary carbon assurance, choice of audit firms as assurance providers, reasonable assurance levels and reliance on high-quality assurance standards (ISAE 3000). Robustness and endogeneity checks are consistent with our basic results.

We start with the regulatory and theoretical framework, a literature review and the hypotheses (Section 2). The sample selection process, the variables and the econometric models are then described (Section 3). After presenting the empirical results (Section 4), the findings, conclusion, selected limitations, recommendations and implications are discussed (Section 5).

2. European Union regulatory environment

While the EU context is linked to the growing attraction in previous studies on the effect of sustainable corporate governance on sustainability outputs, a focus on climate board governance and climate assurance seems to be justified in view of the following major regulations. In reaction to the financial crisis of 2008–2009, the EU Commission finalized a massive reform of business reporting of specific PIEs through the Directive 2014/95/EU (Directive, 2014). Large PIEs (total assets > 20 Mio. €; revenues > 40 Mio. €) with more than 500 employees on average must prepare a nonfinancial declaration. Business year 2017 represents the first year of the mandatory nonfinancial declaration. The nonfinancial reporting directive (NFRD) does not include a specific framework, but refers to five miminum topics (environmental, employee and social concrns, human rights and protection from corruption, and bribery). The EU Commission explicitly recommends including carbon information in nonfinancial declarations. While the management report is classified as the main disclosure document, the NFRD includes a member state option to allow other disclosure variations, such as the webpage of the firm or the publication of a separate (full) sustainability report. Many EU member states have exercised this disclosure option because of management flexibility. The duties of the external auditor refer only to a formal check of the reports. Only a few regimes, such as Italy, implement stronger sustainability assurance regulations regarding the content (Korca and Costa, 2021). Thus, the credibility of nonfinancial reporting according to the NFRD is questionable (Cupertino *et al.*, 2021). Firms may choose between external auditors and other external assurance providers on the one hand and may also choose between a limited and reasonable assurance on the other hand (Velte and Stawinoga, 2017a). In recent years, an increased amount of empirical research on the NFRD has been conducted. Based on a literature review, Velte (2022) found a clear tendency toward a low decision usefulness of the NFD both a cross-country perspective and

in relation to specific EU member states as well as heterogeneous market reactions. Thus, the EU Commission's goal of realizing an adequate quality of sustainability reporting in EU member states has not been achieved.

The EU Green Deal Project incorporates three major corporate regulations that are important to our setting. First, the EU Taxonomy Regulative classifies sustainable business activities. These activities must significantly contribute to the realization of at least one of six environmental goals, do not significantly harm other environmental goals and refer to basic social protection. Climate change mitigation and climate change adaption are two of the environmental goals of the EU Taxonomy. Based on these aspects, listed and nonlisted firms with a specific minimum size must report on three major environmentally related key performance indicators:

(1) the ratio of environmental revenues;

(2) the ratio of environmental capital expenditures; and

(3) the ratio of environmental operation expenditures in the sustainability report.

Second, the EU Corporate Sustainability Reporting Directive (CSRD) 2022 (Directive, 2022a) includes a mandatory sustainability report for (non) listed firms with a specific quorum of size. The European Financial Reporting Advisory Group has prepared the first set of European Sustainability Reporting Standards (ESRS) in accordance with the goals of the EU Taxonomy Regulative. Climate information is included in ESRS E1 as a main part of the new sustainability report. Moreover, the following sustainable board governance information must be explained in the sustainability report:

- responsibility of the board of directors regarding sustainability aspects, expertise and skills to conduct this role, and access to this expertise and skills;
- corporate policies regarding sustainability; and
- sustainability-related compensation of the board of directors.

Third, the EU finalized a Corporate Sustainability Due Diligence Directive (CSDDD) (Directive, 2024). As a major element, the CSDDD stresses environmentally- and socially-related board duties in the value chain. The Directive incorporates several international guidelines and practices on environmental and social factors (e.g. human rights) that should be recognized by the boards (Directive, 2024). The CSDDD forces firms to integrate value chain issues into the risk and compliance management systems and the sustainability report. As a major step toward a climate-neutral economy, the CSDDD includes the mandatory implementation of climate transition plans in accordance with the goals of the Paris Climate Agreement (Directive, 2024). This plan intends to show the business model and strategy with which the company contributes to achieving the 1.5°C target by 2050.

As the EU Green Deal project and related carbon-related regulations (e.g. CSRD and CSDDD) are connected with the increased climate protection strategies of firms, the EU is a useful setting for this study. We assume that carbon board governance and carbon assurance can lead to successful carbon neutrality strategies, stressing the major role of carbon-related monitoring issues.

3. Theoretical framework, literature review and hypotheses

3.1 Stakeholder and critical mass theory, literature review and hypotheses development

3.1.1 Theoretical framework. Empirical research on climate boards and carbon outputs is linked with various theoretical frameworks (e.g. Velte and Stawinoga, 2017; Bouten

and Hoozée, 2024). Among others, stakeholder, critical mass, agency and institutional theories represent the most important theories in this context (Del Gesso and Lodhi, 2023). Agency theory focusses on the monitoring and incentive function of climate boards, assuming that CCs, female directors and climate-related compensation as climate-related composition and incentives will be positively related with carbon assurance (quality) (Jensen and Meckling, 1976). In this context, both climate boards and carbon assurance represent major monitoring tools, which should discipline top managers and reduce opportunistic behavior. In contrast to this, institutional theory explains why organizations in the same field are becoming homogeneous over time by adopting similar climate board and assurance practices and illustrating how particular ones may be gradually adopted (DiMaggio and Powell, 1983). In this vein, mimetic, coercive and normative isomorphism as a major element of institutional theory illustrates how processes among organizations supported by different drivers become similar over time (DiMaggio and Powell, 1983). While climate boards and climate assurance are voluntary, they represent "best practice" standards and are highly recommended by regulators and stakeholders. As stakeholder theory (Freeman, 1984) is the most important theory, we focused on it in our study. Climate boards and assurance are directly related to stakeholder preferences. There is a higher probability that firms realize successful corporate climate transformation processes in line with stakeholder needs if boards of directors have implemented climate committees, a critical mass of female directors and carbon-related compensation. This should lead to higher carbon assurance (quality), based on the choice of accounting firms as assurance providers, reasonable assurance level as increased scope and reliance on global assurance standards, and, thus, to an increased firm reputation. As stakeholder demand a critical mass of female directors, we see a major connectivity between stakeholder and critical mass theories in our study.

3.1.2 Critical mass of female directors. Stakeholder theory explains the responsibility that firms' strategies, processes and targets are in accordance with various stakeholder interests (Freeman, 1984; Freeman *et al.*, 2010). The effect of business strategies on environmental factors (e.g. climate aspects) is demanded by stakeholders (e.g. customers or suppliers). Stakeholders require a decision useful climate report to make the final decision on whether they invest in the firm (capital providers), buy the products or services (customers) or have contracts with the firm (suppliers) (Freeman, 1984). As climate reporting relates to management discretion and subjectivity, decoupling, information overload and lack of transparency may be major opportunistic outcomes (*Free et al.*, 2024).

These challenges may be lower if top managers are highly motivated to include carbon assurance voluntarily (Mardawi *et al.*, 2023) and to realize adequate carbon assurance quality (Free *et al.*, 2024). As the implementation of voluntary carbon assurance may also be related to greenwashing strategies (Free *et al.*, 2024), the quality of carbon assurance should be recognized. This relates to the choice of a high-quality assuror and a high level of assurance. Regarding carbon assurance providers, Big Four audits dominate these services from an international perspective (Somoza, 2023). The board of directors should realize a major monitoring function and push top management to engage proper carbon assurance providers (Freeman *et al.*, 2010). Sustainability efforts within the boards' composition and compensation will increase carbon assurance practices (Freeman *et al.*, 2010). Sustainable boards with female directors, climate expertise and climate-related executive remuneration address stakeholder demands about climate change and climate adaption to a greater extent (Velte, 2023). Sustainable boards consider climate reporting as a major stakeholder tool to inform how the firm connects climate issues and business strategies, operational processes and management systems (Sellami *et al.*, 2019). Thus, consistent with stakeholder theory, we assume that sustainable boards promote carbon assurance because of their sustainability

skills, resources and incentives (Al-Shaer and Zaman, 2018). Sustainable assurance may also be useful for successful corporate climate transformation, such as firms' emissions reduction initiatives (Issa and Hanaysha, 2023). Board mechanisms such as monitoring mechanisms and climate-based incentives will motivate executive directors to increase climate initiatives with a future positive effect on carbon assurance (Buertey, 2021). Although traditional board variables, such as board interlocks or size, may also be helpful, the probability of substantive inclusion of stakeholder demands within the board of directors may be more pronounced if climate board factors are recognized (Garcia-Sanchez *et al.*, 2022). Consequently, we included three sustainable board variables (BGD, CCs and CEC) in our study. In the following section, we explain the individual effect of the three board characteristics on carbon assurance.

Stakeholder theory assumes that female directors recognize stakeholder interests in climate goals in their decision-making (Freeman, 1984). BGD is the most prominent sustainable corporate governance variable, and female directors should motivate top management to realize a sound climate reporting system and carbon assurance practices (Dalla Via and Perego, 2020). Specifically, female directors increase board dynamics by addressing different stakeholders' attitudes and skills regarding climate change (Garcia-Sanchez, 2020). Stakeholder theory supposes that the representation of female directors *per se* (at least one) can greatly contribute to stakeholder demands and thus to increased climate awareness of boards of directors (Freeman, 1984). However, BGD can be used either for symbolic reasons or as a substantive sustainable management element. If BGD solely represents a tool for self-impression management, it will not be related to increased carbon assurance practices. The probability of substantive use of female directors as a mechanism to promote climate actions will be higher if they form a critical mass. Critical mass theory (Kanter, 1977) infers that stakeholders will demand a critical mass of female directors on boards. Thus, we highlight the connection between stakeholder theory and critical mass theory. A critical mass will promote the inclusion of substantive climate management and a reliable carbon report. Consequently, we also address critical mass theory (Kanter, 1977) and include a minimum quorum of at least 30% of female directors on the board. We consider an interdisciplinarity and complementary relationship between stakeholder and critical mass theories in our study. Stakeholder theory assumes a successful recognition of stakeholder needs on boards through female directors, whereas critical mass theory supposes that an adequate number of female directors has a significant effect on carbon assurance. As many firms fear high resources of carbon assurance, the information demands of stakeholders may only be realized by the recognition of a critical mass of BGD.

Previous archival research on this topic supports our theoretical assumptions. As we did not identify any study on the link between BGD on carbon assurance, we refer to previous research on overall sustainability assurance. Some researchers have found a positive effect of BGD on sustainability assurance (Garcia-Sanchez, 2020; Garcia-Sanchez *et al.*, 2022; Miras-Rodriguez and Di Pietra, 2018; Mardawi *et al.*, 2023).

Based on stakeholder theory, critical mass theory and empirical studies, we assume that a critical mass of female board members and carbon assurance (quality) are positively linked:

H1a. A critical mass of female board members is positively associated with carbon assurance (quality).

3.1.3 Climate board expertise through climate board committees. Regarding female directors, sustainable board expertise through climate committees is also linked to higher motivation for executives to improve climate issues (Datt *et al.*, 2018, 2020). The voluntary formation of CCs with experts shows a greater implementation of stakeholder demands,

which may increase carbon assurance and stakeholder satisfaction (Freeman, 1984; Freeman *et al.*, 2010). CCs may belong to the executive or nonexecutive level. Thus, climate change topics highlight sustainable strategic or monitoring responsibilities (Datt *et al.*, 2018). As climate board expertise is important to strengthen the sensibility of carbon assurance, the intrinsic motivation of the board to prevent decoupling and information overload can only be achieved with the inclusion of climate issues (Garcia-Sanchez *et al.*, 2023). Without climate-based skills, resources and values, the board of directors may neglect climate change goals with a significant reduction in the quality of climate reports. This creates low sensitivity to carbon assurance (quality). Consistent with stakeholder theory, CCs with respective experts will increase stakeholder demands and carbon assurance.

A positive connection between sustainability board committees and corporate sustainability assurance has also been shown in previous research. There is evidence of a positive relationship between sustainability committees and sustainability assurance (Garcia-Sanchez *et al.*, 2023, 2022; Garcia-Sanchez, 2020; Ruhnke and Gabriel, 2013; Mardawi *et al.*, 2023). Datt *et al.* (2018, 2020) analyzed the effect of climate change board committees on carbon assurance, whereas Datt *et al.* (2018) found that this kind of board committee had a positive effect on the implementation of carbon assurance, but it did not significantly relate to the selection of an audit firm as an assuror.

In congruence with stakeholder theory and previous studies on sustainability assurance, we assume that the implementation of CCs is linked with carbon assurance (quality):

H1b. CCs are positively associated with carbon assurance (quality).

3.1.4 Climate-related executive compensation. BGD and CCs are major board composition variables. However, climate board governance should also recognize stakeholder demands in compensation contracts for executives (Winschel and Stawinoga, 2019). Boards should achieve incentive alignment between executives and stakeholders regarding climate efforts (Winschel and Stawinoga, 2019). This leads to the inclusion of climate goals in variable renumeration. Traditional compensation systems are only connected with financial figures and related proxies. Stakeholder theory highlights that stakeholders demand the recognition of climate goals in executive compensation systems (Winschel and Stawinoga, 2019). The inclusion of climate incentives is consistent with stakeholder demands and promotes climate change policies (Freeman, 1984; Freeman *et al.*, 2010). This will increase extrinsic directors' incentives to include carbon assurance, as stakeholder needs are better included.

Consistent with our study, previous research has analyzed the effect of sustainability-related executive compensation on sustainability (Winschel and Stawinoga, 2019), assuming a positive effect of incentive-based executive compensation on corporate sustainability outputs. We know little about the effect of sustainability-related executive compensation on sustainability assurance compared with BGD and sustainability board committees. Dalla Via and Perego (2020) found a positive effect on the quality of sustainability assurance. Datt *et al.* (2018) also found a positive relationship between employee incentives based on carbon emission reduction and carbon assurance. However, it relates to a lower probability of engaging audit firms as carbon assurors.

In summary, according to stakeholder theory and empirical results, we assume that CEC is positively associated with carbon assurance:

H1c. CEC is positively associated with carbon assurance (quality).

Based on our explanations, we state the following hypothesis:

H1. Climate board governance (CCs, the critical mass of female board members and CEC), and carbon assurance (quality) are positively related.

Table 1 summarizes previous studies on the association between sustainable (climate) board governance and sustainability (carbon) assurance.

Figure 1 illustrates the research framework with independent and dependent variables.

4. Methodology

4.1 Data set description

This study used listed firms headquartered in an EU member state and included in the Carbon Disclosure Project (CDP) for the years 2017–2021. Carbon data were extracted from the annual voluntary CDP questionnaire. In detail, we merged the relevant annual sheets and turned the qualitative answers in the CDP questionnaires into quantitative scores. Data from the CDP are regularly used in carbon research, including studies on carbon assurance, because the CDP uses a standardized questionnaire that respondents cannot modify. Firms must leave questions blank that they choose not to answer, and stakeholders can interpret this lack of response as either an inability to answer the question or a lack of transparency (Simic *et al.*, 2023). Thus, CDP is frequently adopted as the primary source of carbon data in studies, including studies on carbon assurance, thus, allowing for consistency with the literature (Datt *et al.*, 2018; Simic *et al.*, 2023).

We chose the EU capital market because of the unique regulatory initiatives on carbon reporting and performance since the financial crisis of 2008–2009. We started with business year 2017 because it was the first year of compulsory recognition of the NFRD. The NFRD includes a mandatory nonfinancial declaration on environmental and social topics for some PIEs and this Directive has a consequence for our research topic. A focus on the EU capital market is useful due to the increased climate-based regulations of the EU Green Deal project (Taxonomy Regulative, CSRD and CSDDD). We also included the UK (UK) as a former EU member state. Consistent with the CDP, primary data for noncarbon aspects were collected from the Refinitiv database. Financial services firms were excluded because of their specific capital structure and regulatory requirements. Missing (non)financial datapoints lead to a decrease in firm-year observations. All continuous variables were winsorized at the bottom 1% and top 99% levels to remove the potential effect of outliers.

4.2 Carbon assurance (quality) as the dependent variables

The dependent variables were collected from the CDP. ASSU is a dummy variable that equals 1 if the company undertakes the external assurance of Scope 1 carbon emissions and 0 otherwise. Scope 1 emissions are directly related to the business operations of the firm and are the most easily calculated (Hoffman and Busch, 2008). Scope 2 emissions are produced by the consumption of electricity and other energy resources, such as gas from grids. Scope 3 emissions are indirect emissions generated during business but from sources not owned or controlled by the company (Hoffman and Busch, 2008). This study considered only Scope 1 emissions in the main body, which represent the most important Greenhouse Gas Emission (GHG) emissions because they are produced directly by firms and firms are more easily held accountable for them (Datt *et al.*, 2020). Regarding carbon assurance quality, we choose three different proxies. First, ASSUQ1 is a dummy variable that equals 1 if a firm has carbon emissions assured by an accounting firm and 0 otherwise. This is a common measure in the accounting and management literature (e.g. Datt *et al.*, 2020). Second, ASSUQ2 is a dummy variable that equals 1 if a firm has carbon emissions assured with a reasonable level and O otherwise (e.g. a limited assurance level). Previous research has also included this proxy

Table 1. Prior research on sustainable (carbon) board governance and sustainability (carbon) assurance

Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
Carbon assurance						
2023	Simic *et al.*	*International Journal of Auditing*	• UK (CDP) • 2010–2018 • 1,326 Firm-year observations • Probit; Heckman two stage	Sustainability-related executive compensation (Refinitiv) Moderator: mandatory carbon reporting mandate, noncarbon intensive industry, gender diversity	Carbon assurance (scope 1 emissions; scope 1 and/or scope 2 emissions; dummy; CDP)	+ Moderator: more pronounced
2020	Datt *et al.*	*International Journal of Auditing*	• International (CDP) • 3,635 Firm-year observations • 2010–2014 • Logit	Climate change board committee Employee incentives based on carbon emission reduction (CDP)	Carbon assurance (audit firms versus nonaudit firms; CDP)	+/− (committee) − (incentives and audit firms)
2018	Datt *et al.*	*Journal of International Accounting Research*	• International (CDP) • 5,184 Firm-year observations • 2010–2014 • Logit	Climate change board committee Employee incentives based on carbon emission reduction (CDP)	Carbon assurance (scope 1 emissions; dummy; CDP)	+

(*continued*)

Table 1. Continued

Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
Sustainability assurance						
2023	Garcia-Sanchez *et al.*	*Journal of Management and Governance*	• International • 2011–2017 • 44,282 Firm-year observations • Logit	Sustainability board committee (dummy) Moderator: integrated reporting (dummy)	Sustainability assurance (dummy; audit firm as assuror; full reporting assurance; reasonable assurance; ISAE 3000)	+ (dummy); +/− (other dimensions) Mod.: +/−
2023	Mardawi *et al.*	*Meditari Accountancy Research*	• International (Europe) • 895-Year observations • 2016–2018 • Logit	Sustainability board committees (dummy) Board gender diversity	Sustainability assurance (dummy)	+ +
2022	Aladwey *et al.*	*Corporate Governance*	• UK • 2016–2019 • 225 Firms • Logit	Board gender diversity (ratio) Female executive directors (ratio)	Sustainability assurance (dummy) Sustainability assuror (audit firm or not)	+ + +/− +
2022	Bradbury *et al.*	*Journal of Contemporary Accounting and Economics*	• Australia • 2004–2016 • 403 Firm-year observations • Logit; 2SLS/IV	Sustainability board committee (dummy; effectiveness as composition (independence and CSR expertise), authority (average board tenure and average committee tenure), resources (gender, positions in	Sustainability assurance (dummy) Sustainability assuror (big four audit firm; joint provision of financial and sustainability audit)	+/− (dummy) + (effectiveness) + (dummy; effectiveness) Moderator: + (dummy); more pronounced (effectiveness)

(*continued*)

Table 1. Continued

Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
				other organizations and higher education qualifications, membership overlaps) and diligence (meeting frequency, meeting attendance and shares by committee members) Moderator: environmentally sensitive industries		
2022	Garcia-Sanchez *et al.*	*Corporate Social Responsibility and Environmental Management*	• International • 1,588 Firms • 2009–2017 • Logit	Board gender diversity Sustainability board committee (also as interaction)	Sustainability assurance (dummy)	+ + Mod.: strengthened
2021	Buertey	*Corporate Social Responsibility and Environmental Management*	• South Africa • 2015–2018 • 97 Firms • Logit	Board gender diversity (ratio; critical mass of at least two; independent female directors) Moderator: ownership concentration	Sustainability assurance (dummy)	+ Mod.: change to insignificant results

(*continued*)

Table 1. Continued

Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
2020	Dalla Via and Perego	*Auditing*	• International • 2005–2013 • 1,248 Firm-year observations • Heckman two stage	Sustainability-related executive compensation (dummy)	Sustainability assurance quality (20 criteria based on ISAE 3000 and AA 1000AS)	+
2020	Garcia-Sanchez	*Corporate Social Responsibility and Environmental Management*	• International • 678 Firms • 2011–2017 • Tobit	Female CEO Board gender diversity Sustainability board committee	Sustainability assurance quality (self-created score)	+ + +/−
2019	Sellami	*Journal of Financial Reporting and Accounting*	• France • 2010–2012 • 807 Firm-year observations • logit	Sustainability board committee (dummy)	Sustainability assurance	+
2018	Al-Shaer and Zaman	*Business Strategy and the Environment*	• UK • 333 Firms • 2012 • Logit	Sustainability board committee (dummy) Moderator: sustainability-sensitive industry	Sustainability assurance (dummy) Sustainability assuror: big four audit firm (dummy) sustainability assurance standard (AA 1000AS and ISAE 3000 are used)	−−+/− Mod.: +/−
2018	Liao *et al.*	*Journal of Business Ethics*	• China • 2,054 Firm-year observations • 2008–2012 • Logit	Board gender diversity	Sustainability assurance (dummy)	+

(*continued*)

Table 1. Continued

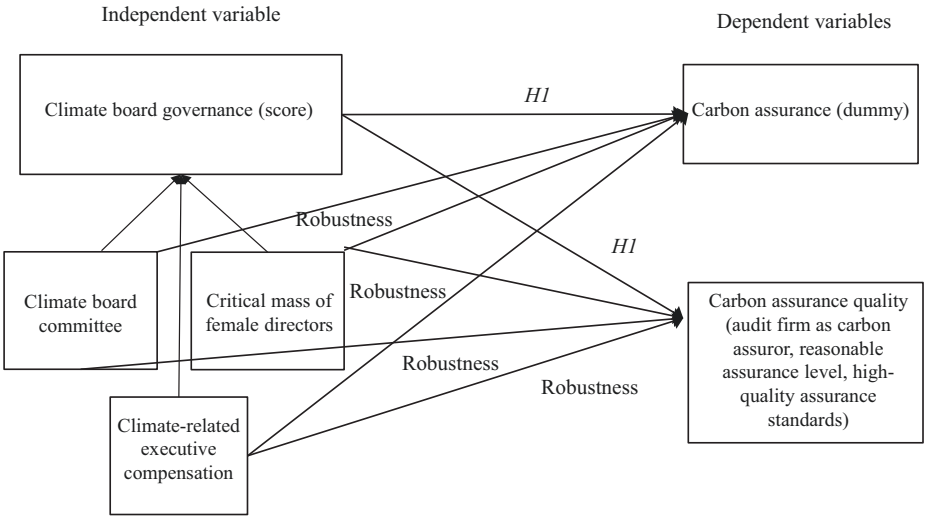
Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
2018	Miras-Rodriguez and Di Pietra	*Journal of Management and Governance*	• International • 176 Energy firms • 2012 • Logit	Board gender diversity	Sustainability assurance (dummy)	+/−
2017	Martinez-Ferrero and Garcia-Sanchez	*Journal of Management and Organization*	• International • 610 Firms • 2007–2014 • Logit	Sustainability board committee meetings	Sustainability assurance (dummy) Sustainability assuror: big four audit firm	+
2017	Rossi and Tarquinio	*Managerial Auditing Journal*	• Italy • 143 CSR reports • 2008–2012 • OLS	Sustainability board committee (dummy) Expert on the sustainability board committee (dummy) Sustainability officer (dummy)	Sustainability assurance quality (score)	+ + +/−
2015	Kend	*Sustainability, Accounting, Management and Policy Journal*	• Australia/UK • 220 Companies • 2010 • logit	Sustainability board committee (dummy)	Sustainability assurance (dummy) Sustainability assuror: audit firm	+/− +

(*continued*)

Table 1. Continued

Year of publication	Author(s)	Journal	• State • Sample • Years • Method	Independent variable(s)	Dependent variable (s)	Significant results
2015	Peters and Romi	*Auditing*	• USA • 963 CSR reports • 2002–2010 • Logit	Sustainability board committee (dummy) CSO (dummy)	Sustainability assurance (dummy) sustainability assuror: audit firm	+ + (stronger with more expertise) + (−) (consultant)
2013	Ruhnke and Gabriel	*Journal of Business Economics*	• International (Europe) • 2010 • 133 Firms • Logit	Sustainability board committee (dummy)	Sustainability assurance (dummy)	+

Notes: AA = Account ability; SLS = stage least squares
Source: Author's own work



Source: Author's own work

Figure 1. Research framework

based on overall sustainability assurance (e.g. Garcia-Sanchez *et al.*, 2023). Third, ASSUQ3 is a dummy variable that equals 1 if a firm has carbon emissions assured using ISAE 3000 as a high-quality assurance standard. Previous literature has also distinguished between these standards (e.g. Garcia-Sanchez *et al.*, 2023).

4.3 Climate board governance as the independent variable

We used the climate board governance score (CBS), based on the following dummy variables:

- the presence of a CC;
- the existence of a critical mass of female directors; and
- the existence of CEC packages as independent variable.

First, the CC is a dummy variable that equals 1 if the corporation implements a climate committee within the board of directors. As the implementation is voluntary from an EU perspective, the composition and tasks of this committee are heterogeneous. In view of the restricted validity of this dummy variable, we tried to hand-collect additional information on the CCs. We found a low transparency of the included firms due to climate committee members. A significant number of firms did not share the curriculum vitaes (CVs) of their committee members and update them regularly. Consequently, a detailed analysis of the composition variables would lead to a massive reduction of firm observations and, thus, a restricted validity of our models. Thus, we solely referred to the dummy variable, which is available in the CDP database. Second, critical mass of BGD is a dummy variable that equals 1 if at least 30% of the board members are women. Third, CEC is a dummy variable that equals 1 if the board of directors implements climate issues as part of the variable

renumeration of the executives. In accordance with our first variable, climate-related compensation systems are voluntary for EU firms. Thus, this proxy can be used heterogeneously. use of this proxy can be stressed. We relied on a dummy variable, based on the CDP. The three dummy variables were represented by a combined score (CBS), of 0–3. As robustness tests, we also used the single sustainable board proxies as robustness tests.

4.4 Control variables

In accordance with prior research (e.g. Datt *et al.*, 2018, 2020), our control variables recognized other climate attributes, firm characteristics and country-specific factors. In terms of climate controls, the first variable is carbon intensity (INT), which "relates to a firm's physical carbon performance and describes the extent to which its business activities are based on carbon usage for defined scope and fiscal year" (Hoffman and Busch, 2008). INT is calculated as the natural logarithm of the total Scope 1 GHG emissions divided by the total revenue. We assumed a positive effect on carbon assurance because of increased stakeholder pressure (Datt *et al.*, 2020). The second climate proxy is the number of carbon reduction initiatives (INI). INI is measured as the logarithm of one plus the number of initiatives a firm takes to reduce its carbon emissions. The logarithm transformation was used to reduce the skewness of this variable. As carbon reduction initiatives are linked to a greater sensibility toward climate transformation, we assumed a positive effect on carbon assurance (Datt *et al.*, 2020). The third variable is the firm's carbon transparency score (CT) is adopted. It is measured based on the CDP Carbon Disclosure Leadership Index methodology, which captures the extent and comprehensiveness of carbon disclosure in CDP company reports (Datt *et al.*, 2020). The final score was calculated as the total awarded score divided by the attainable score and ranged from 0% to 100%. We assumed that higher climate reporting scores would be associated with higher carbon assurance (Datt *et al.*, 2020).

Regarding other firm characteristics, board independence (IND) could increase effective monitoring and carbon assurance. Board size (BSIZE) and the meeting frequency of the board members (BMEET) were used, as we assumed a positive influence on carbon assurance (Simic *et al.*, 2023). CEO duality (DUAL) could cause opportunities for CEO power, reduce the effectiveness of the monitoring process and reduce the likelihood of carbon assurance (Simic *et al.*, 2023). We also included firms' natural logarithm of total assets as a measure of firm size (SIZE) and assumed a positive relationship with carbon assurance (Datt *et al.*, 2020). Consistent with the business case argument, as carbon assurance could be influenced by financial performance, we added firm performance measures to our model. Return on assets (ROA) was used as an accounting-based measure and Tobin's Q (TOBIN) as a market-based measure for financial performance (Datt *et al.*, 2020). The debt ratio (DEBT) was recognized as a proxy for idiosyncratic firm risk and was measured as total debt divided by total assets. Year fixed effects (YEAR) and industry fixed effects (INDU) were also included.

In terms of country governance variables, case (common) or code (civil) law could influence carbon awareness. Thus, we controlled for the legal system (CIV) using a dummy variable that equals 1 when the legal system is a civil law regime. Table 2 summarizes all variables.

4.5 Empirical methods

To analyze the effect of climate board governance on carbon assurance considering included controls, the base regression model für *ASSU* is expressed as follows:

Table 2. Variables of the study

Variables	Explanation and measurement
Dependent variables	
ASSU	A dummy dependent variable coded 1 if the firm undertakes external assurance of Scope 1 emissions and 0 otherwise
ASSUQ1	A dummy dependent variable coded 1 if a firm has Scope 1 carbon emissions assured by an audit firm and is 0 otherwise
ASSUQ2	A dummy dependent variable coded 1 if a firm has Scope 1 carbon emissions assured with a reasonable assurance level and is 0 otherwise
ASSUQ3	A dummy dependent variable coded 1 if a firm has Scope 1 carbon emissions assured with high-quality assurance standards (ISAE 3000) and is 0 otherwise
Independent variables	
CBS	Climate board governance score as the sum of (1) existence of a climate board committee (CC), (2) a critical mass of female directors on the board (BGD) and (3) the inclusion of climate-related executive compensation (CEC), 0 = otherwise
CC (robustness checks)	A dummy independent variable coded 1 if board committee or senior managers take direct responsibility for matters related *t* to climate change and is 0 otherwise
BGD (robustness checks)	A dummy independent variable coded 1 if a critical mass of at least three women or 30% on the board of directors exist, 0 = otherwise
CEC (robustness checks)	A dummy independent variable coded 1 if a firm's employees are provided incentives to reduce carbon emissions and is 0 otherwise
Control variables	
Climate variables:	Natural logarithm of total carbon emissions scope 1 divided by total revenue
INT	The logarithm of one plus the number of initiatives a firm takes to reduce its carbon emissions
INI	Carbon transparency score, which is publicly available from CDP, scored based on the carbon disclosure leadership index (CDLI) methodology
CT	
Other firm variables:	
IND	(Independent board members/total number of board members) × 100
BSIZE	Number of board members
BMEET	Number of board meetings
DUAL	Dummy variable for (1) CEO is (ex-)board chair (0) otherwise
SIZE	Natural log of total assets of the firm
ROA	Return on assets = {Net income before preferred dividends + ([interest expense on debt-interest capitalized] × [1− tax rate])}/average of last year's and current year's total assets × 100
DEBT	Total debt/total assets
TOBIN	(Market value of equity + liabilities)/(book values of equity + liabilities)
YEAR	Year fixed effects
INDU	Industry fixed effects
Country-related governance:	
CIV	Dummy variable for (1) Civil law and (0) Case law

Source: Author's own work

$$ASSU_{it+1} = \alpha_0 + \beta_1 CBS_{it} + \beta_2 INT_{it} + \beta_3 INI_{it} + \beta_4 CT_{it} + \beta_5 IND_{it} + \beta_6 BSIZE_{it} + \beta_7 BMEET_{it} + \beta_8 DUAL_{it} + \beta_9 SIZE_{it} + \beta_{10} ROA_{it} + \beta_{11} TOBIN_{it} + \beta_{12} DEBT_{it} + + \beta_{13} CIV_{it} + firm + year + \varepsilon_{it}$$

Consistent with the voluntary implementation of carbon assurance (ASSU), we also analyzed the effect of sustainable board governance on carbon assurance quality, based on our three quality dimensions (ASSUQ1, ASSUQ2 and ASSUQ3):

$$ASSUQ1_{it+1} = \alpha_0 + \beta_1 CBS_{it} + \beta_2 INT_{it} + \beta_3 INI_{it} + \beta_4 CT_{it} + \beta_5 IND_{it} + \beta_6 BSIZE_{it} + \beta_7 BMEET_{it} + \beta_8 DUAL_{it} + \beta_9 SIZE_{it} + \beta_{10} ROA_{it} + \beta_{11} TOBIN_{it} + \beta_{12} DEBT_{it} + \beta_{13} CIV_{it} + firm + year + \varepsilon_{it}$$

$$ASSUQ2_{it+1} = \alpha_0 + \beta_1 CBS_{it} + \beta_2 INT_{it} + \beta_3 INI_{it} + \beta_4 CT_{it} + \beta_5 IND_{it} + \beta_6 BSIZE_{it} + \beta_7 BMEET_{it} + \beta_8 DUAL_{it} + \beta_9 SIZE_{it} + \beta_{10} ROA_{it} + \beta_{11} TOBIN_{it} + \beta_{12} DEBT_{it} + \beta_{13} CIV_{it} + firm + year + \varepsilon_{it}$$

$$ASSUQ3_{it+1} = \alpha_0 + \beta_1 CBS_{it} + \beta_2 INT_{it} + \beta_3 INI_{it} + \beta_4 CT_{it} + \beta_5 IND_{it} + \beta_6 BSIZE_{it} + \beta_7 BMEET_{it} + \beta_8 DUAL_{it} + \beta_9 SIZE_{it} + \beta_{10} ROA_{it} + \beta_{11} TOBIN_{it} + \beta_{12} DEBT_{it} + \beta_{13} CIV_{it} + firm + year + \varepsilon_{it}$$

As binary variables were used as dependent variables, logistic regressions were recognized in accordance with previous studies (Datt *et al.*, 2018, 2020). We adopted a time lag of one business year between the independent, control and dependent variables. The risk of endogeneity decreases with this strategy. We addressed business practices in which the effects of the board of directors on carbon assurance were time lagged. As robustness tests, we divided CBS into three subitems CC, BGD and CEC.

5. Results

5.1 Descriptive statistics

Table 3 presents the descriptive statistics with the number of observations (*N*), means, standard deviations (SDs), minimums (min), medians and maximums (max). The dependent variable ASSU has an average of 0.54, with an SD of 0.31. Thus, 54% of the included firms conducted an external assurance of Scope 1 emissions during the time frame. A low number of firms engaged an audit firm as a carbon assuror (ASSUQ1) (mean: 0.39; SD: 0.25). A reasonable assurance level (ASSUQ2) was found in rare cases (mean: 0.23; SD: 0.21). High-quality assurance standards such as ISAE 3000 (ASSUQ3) are more common (mean: 0.37; SD: 0.26). Referring to our climate board score (CBS), we stress a mean of 1.2 and a SC of 0.6, indicating significant weaknesses in climate-related corporate governance. This also relates to the single elements of CC (mean: 0.53; SD: 0.30), BGD (mean: 0.42; SD: 0.28) and CEC (mean: 0.32; SD: 0.29). Collinearity diagnostics based on variance inflation factors (VIF) (mean VIF = 2.48; highest VIF = 2.93) are not connected with major multicollinearity concerns.

Table 3. Descriptive statistics

Variables	Mean	SD	Min	Median	Max	VIF
ASSU	0.54	0.31	0	0.	1	1.54
ASSUQ1	0.39	0.21	0	0.	1	0.42
ASSUQ2	0.23	0.21	0	0.	1	1.21
ASSUQ3	0.37	0.26	0	0	1	2.65
CBS	1.20	0.60	0	1	3	1.54
CC	0.53	0.30	0	0	1	2.22
BGD	0.42	0.28	0	0	1	2.84
CEC	0.32	0.29	0	0	1	2.63
INT	8.76	2.12	0	8.00	10.32	1.21
INI	0.56	0.27	0	0.7	1	1.65
CT	0.61	0.28	0	0.65	0.92	1.89
IND	51.23	19.32	0	47.00	100	2.89
SIZE	13.21	1.76	8.32	12.31	17.76	2.93
BSIZE	10.21	3.98	2	11	21	2.14
BMEET	6.11	3.41	1	7	27	1.54
DUAL	0.26	0.24	0	0	1	1.98
ROA	6.32	10.77	−6.06	6.21	42.87	2.13
DEBT	0.56	0.25	0.23	0.49	0.89	2.43
TOBIN	3.54	2.58	0.46	3.42	32.05	2.56
CIV	0.33	0.25	0	1	1	2.87

Notes: This table reports descriptive statistics for variables of the study. Table 2 summarizes all variables used in the analysis
Source: Author's own work

5.2 Correlation analysis

Table 4 presents the pairwise Pearson correlations of our variables. In accordance with our theoretical assumptions, CBS is positively and significantly associated with carbon assurance (quality) (ASSU, ASSUQ1, ASSUQ2 and ASSUQ3). The climate board score is also positively and significantly associated with the control variables, except IND, BMEET, ROA and DEBT. This infers an initial indication that climate board governance increases carbon assurance.

5.3 Main regression analyses, robustness and endogeneity checks

Table 5 summarizes the results of the multivariate regressions. Consistent with *H1* (*1a–1c*), CBS increases ASSU (ASSUQ1, ASSUQ2 and ASSUQ3). This result is in accordance with our theoretical foundation and previous studies (e.g. Simic *et al.*, 2023; Datt *et al.*, 2018; Datt *et al.*, 2020). Previous studies stressed that female directors (Garcia-Sanchez, 2020; Garcia-Sanchez *et al.*, 2022; Miras-Rodriguez and Di Pietra, 2018), sustainability committees (Garcia-Sanchez *et al.*, 2023, 2022; Garcia-Sanchez, 2020; Ruhnke and Gabriel, 2013; Mardawi *et al.*, 2023) and sustainability-related compensation (Dalla Via and Perego, 2020) improve sustainability assurance in general. Moreover, this result in consistent with that of Datt *et al.* (2018), who revealed a positive effect of sustainability board committees and employee incentives based on carbon emission reduction on carbon assurance. As stakeholders demand the recognition of climate issues in the composition and compensation of the boards of directors, this will motivate executives to implement carbon assurance and realize high quality.

Table 4. Correlation analysis

Variables		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	ASSU	1																
2	ASSUQ1	0.89**	1															
3	ASSUQ2	0.76**	0.87**	1														
4	ASSUQ3	0.89**	0.69**	0.16	1													
5	CBS	0.34**	0.32**	0.41**	0.35**	1												
6	INT	0.23**	0.21**	0.24**	0.29**	0.23**	1											
7	INI	0.12**	0.13**	0.14**	0.17**	0.14**	0.21**	1										
8	CT	0.12*	0.14*	0.13*	0.13*	0.24**	0.29**	0.20**	1									
9	IND	0.01	0.04	0.04	0.12	0.24	0.14*	0.05	0.04	1								
10	SIZE	0.12	0.18	0.08*	0.02	0.11*	0.21	0.24*	0.05*	0.13*	1							
11	BSIZE	0.23**	0.24**	0.22**	0.25**	0.12*	0.21	0.13*	0.11	0.23*	0.13	1						
12	BMEET	0.22*	0.12*	0.10*	0.19*	0.04	0.14	0.04*	0.11	0.03*	0.15	0.11*	1					
13	DUAL	0.24**	0.21**	0.25**	0.26**	0.11**	0.12	0.24	0.11	0.21	0.14	0.05	0.12	1				
14	ROA	0.05	0.11*	0.24*	0.15	0.12	0.22	0.11*	0.14*	0.05*	0.11	0.05*	0.04	0.04*	1			
15	DEBT	−0.12*	−0.14*	−0.15*	−0.19*	−0.13	−0.14	−0.04	−0.15	−0.23*	−0.12*	−0.15*	−0.11	0.12	0.12*	1		
16	TOBIN	0.23**	0.21**	0.19**	0.28**	0.12	0.21*	0.02*	0.11*	0.21*	0.11	0.19	0.21*	0.11	0.19	0.02	1	
17	CIV	0.12**	0.19*	0.12*	0.11*	0.21	0.21*	0.18	0.15*	0.02	0.03	0.03	0.11	0.18	0.21	0.12	0.12	1

Notes: *Significance at the 10% level; **significance at the 5% level; ***significance at the 1% level
Source: Author's own work

Table 5. Main regression analyses

Variables	Model 1 (ASSU)	Model 2 (ASSUQ1)	Model 3 (ASSUQ2)	Model 4 (ASSUQ3)
CBS	2.242**	2.278**	2.132**	2.145**
INT	1.431**	1.245**	1.243**	1.343**
INI	0.656*	0.565*	0.567*	0.614*
CT	2.882**	2.767**	2.817**	2.797**
IND	0.155	0.184	0.142	0.142
BSIZE	0.165**	0.153**	0.143**	0.165**
BMEET	0.132**	0.143**	0.132**	0.142**
DUAL	−0.014	−0.013	−0.014	−0.015
SIZE	0.143**	0.145**	0.154**	0.141**
ROA	0.133**	0.131**	0.130**	0.135**
DEBT	−0.142*	−0.134*	−0.131*	−0.138*
TOBIN	0.077	0.081	0.088	0.079
CIV	0.114**	0.134**	0.121**	0.131**
YEAR	YES	YES	YES	YES
INDU	YES	YES	YES	YES
N	978	978	978	978
CONSTANT	0.178*	0.189*	0.171*	0.176*
Pseudo R^2	0.212	0.214	0.201	0.210

Notes: *Significance at the 10% level; **significance at the 5% level; ***significance at the 1% level
Source: Author's own work

In the main regression, we recognized the combined CBS. As shown in Table 6 as robustness tests, the independent variable was modified, as follows. We analyzed the individual effect of a critical mass of female directors (BGD), CC and CEC on carbon assurance. The results correspond with the basic regressions and indicate that climate board governance, based on the three individual items (BGD, CC and CEC), is positively and significantly associated with carbon assurance (quality) (ASSU, ASSUQ1, ASSUQ2 and ASSUQ3).

Table 6. Robustness checks

Variables	Model 5 (ASSU)	Model 6 (ASSUQ1)	Model 7 (ASSUQ2)	Model 8 (ASSUQ3)
CC	2.121**	2.242**	2.078**	2.112**
BGD	1.982**	2.122**	2.131**	2.232**
CEC	2.143**	2.090**	2.019**	2.122*
CONTROLS	YES	YES	YES	YES
YEAR	YES	YES	YES	YES
INDU	YES	YES	YES	YES
N	978	978	978	978
CONSTANT	0.137*	0.132*	0.134*	0.139*
Pseudo R^2	0.192	0.191	0.196	0.202

Notes: *Significance at the 10% level; **significance at the 5% level; ***significance at the 1% level
Source: Author's own work

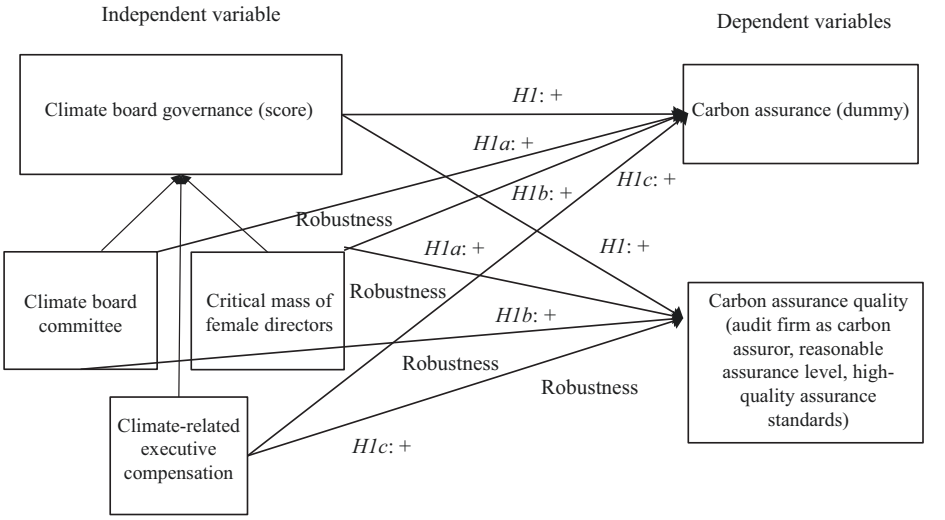
Previous studies have shown that studies on the effect of climate board governance on carbon assurance are confronted with endogeneity problems (Wintoki *et al.*, 2012). In our main regressions, we used logit models and included a time lag of one year to reduce endogeneity risks. However, two major problems can occur. First, carbon assurance (quality) could be higher due to firm-specific factors other than climate board attributes (self-selection bias) or a dynamic relationship between climate board governance and carbon assurance (reversed causality) could be more realistic. To address related endogeneity challenges, previous researchers have used advanced regression models (e.g. Wintoki *et al.*, 2012), such as two-stage least squares with instrumental variables. Consequently, we included the industry-year averages of our instrumental variable (CBS_mean) consistent with previous studies (Abreu *et al.*, 2023). These averages excluded the focal firm of analysis and were, therefore, regarded as exogeneous to carbon assurance. We also deleted industry-year combinations with fewer than 10 observations. The results presented in Table 7 correspond to our main regressions. The second stage coefficients for CBS were positively and statistically significantly related to carbon assurance (quality). The postestimation analysis confirmed the strength and relevance of our instrument. We also tried to include generalized method of moment (GMM) as another technique to address endogeneity concerns. The GMM dynamic panel estimators are appropriate for large observations and small-time frames, so that the central limit theorem can be invoked for the asymptotic normality of coefficients even if the residuals are nonnormal. Regarding our sample, the GMM estimators became unreliable because the number of instruments became large, and the instrumented variables were overfitted. Thus, they might not remove the endogenous components of the lagged dependent variable(s) as intended.

The major results of our regressions analyses are illustrated in Figure 2.

Table 7. Endogeneity checks, based on 2SLS and instrumental variable

Panel A: first stage of 2SLS				
Variables	CBS	CBS	CBS	CBS
CBS_mean	4.87**	4.87**	4.87**	4.87**
CONTROLS	YES	YES	YES	YES
N	978	978	978	978
CONSTANT	0.113**	0.113**	0.113**	0.113**
Pseudo R^2	0.142	0.142	0.142	0.142
Panel B: second stage of 2SLS				
Variables	Model 9 (ASSU)	Model 10 (ASSUQ1)	Model 11 (ASSUQ2)	Model 12 (ASSUQ3)
CBS	2.238**	2.212**	2.298**	2.210**
CONTROLS	YES	YES	YES	YES
YEAR	YES	YES	YES	YES
INDU	YES	YES	YES	YES
N	978	978	978	978
CONSTANT	0.145*	0.135*	0.156*	0.154*
Pseudo R^2	0.212	0.209	0.221	0.202

Notes: *Significance at the 10% level; **significance at the 5% level; ***significance at the 1% level
Source: Author's own work



Source: Author's own work

Figure 2. Major results of the regression analyses

6. Discussion and conclusion

6.1 Summary

We analyzed the effect of climate board governance on carbon assurance in the EU capital market. Based on three climate board variables (critical mass of female directors, CCs and CEC) in previous studies (Simic *et al.*, 2023; Datt *et al.*, 2018; Datt *et al.*, 2020), we constructed a CBS. In accordance with stakeholder and critical mass theories, we assumed that climate board governance would increase carbon assurance (quality). Due to greenwashing and information overload risks in climate reporting, the implementation of stakeholder demands in the composition and compensation of boards should promote climate change efforts and, thus, higher carbon assurance practices. Based on a sample with 978 firm-year observations between 2017 and 2021 from listed firms headquartered in an EU member state and with a CDP participation, we found that climate board governance increases carbon assurance (quality). Robustness tests on the three subpillars of climate board governance and endogeneity checks support our results.

Our study contributes to the current controversial debates on climate board governance and climate reporting regulations, based on climate issues in the composition and compensation of boards of directors (e.g. Simic *et al.*, 2023; Datt *et al.*, 2018; Datt *et al.*, 2020). Few studies on climate boards and their effect on carbon assurance have been published, thus, far (Simic *et al.*, 2023; Datt *et al.*, 2018; Datt *et al.*, 2020), leading to major research gaps. Based on CDP data and a UK sample, Simic *et al.* (2023) found that sustainability-related executive compensation was positively associated with carbon assurance. These results are congruent with our study. Datt *et al.* (2018) observed a positive effect of climate change board committees and employee incentives based on carbon reduction on carbon assurance in an international sample. These results are consistent with our study. Conversely, Datt *et al.* (2020) revealed that climate change

board committees did not lead to an increased choice of audit firms as carbon assurors. Moreover, employee incentives based on carbon emission reduction led to the increased selection of nonaudit firms as carbon assurors. This contrasts with our research results. We addressed the major research questions as follows: First, regarding methodology, no study has addressed the combined effects of climate board governance on carbon assurance. Second, we conducted a cross-country study for the EU capital market because of the massive regulatory initiatives on climate change. Third, we included both the implementation and the quality of carbon assurance to increase the validity of our study. Fourth, we addressed theoretical development as we observed a close association between stakeholder and critical mass theories. Therefore, we contribute mainly to prior research on the influence of sustainable board governance on carbon assurance.

Although EU regulatory efforts on carbon reporting and BGD (Directive, 2022b) are important, other carbon board factors, such as the implementation of carbon board committees or carbon-related executive compensation systems, are still voluntary. The CSRD and CSDDD emphasize the urgent need to recognize climate board mechanisms other than gender and climate-related expertise and compensation systems (Directive, 2024; Directive, 2022a). The board of directors should guarantee a proper level of climate goals in executive compensation based on the Paris Climate Agreement. Based on our research results, climate board governance may increase carbon assurance. Improved stakeholder attraction and firm reputation may be consequences. If the monitoring role of the board of directors is inadequate, then corporate climate strategies are not consistent with stakeholder needs and are unable to contribute to successful sustainable transformation (Freeman, 1984; Freeman *et al.*, 2010). There is also the major interrelation between climate reporting and carbon assurance quality.

6.2 Limitations and research recommendations

First, validity is limited because we used CDP files to extract the climate board governance and carbon assurance proxies. Our formation of carbon assurance variables is linked to restricted validity because it depends on voluntary corporate reporting and dummy variables. We were not able to measure whether the proxies were biased through self-impression management or represent substantive climate management. Management discretion may have a significant effect on the answers to the respective CDP questions. We also relied on the presence of climate-based compensation and CCs and did not analyze the heterogeneity of compensation contracts and the individual CVs of committee members. We propose automated analyses of corporate governance and climate reports in future research. This strategy will increase the quality of climate board factors, climate reporting scores and carbon assurance information. In this context, there are options to include more detailed climate committee variables, such as independence, diligence, size and expertise. Future researchers are also invited to include climate and audit committees. As audit committees monitor climate reports and the included climate management systems, related expertise must be recognized in these committees. Overlaps between climate and audit committees seem to be justified in the future. Moreover, as we focused on assurance on Scope 1 carbon emissions, Scopes 2 and 3 emissions are also relevant for stakeholders and should be examined in future research designs.

Second, our study is limited to the EU capital market. Thus, it is not directly transferable to other countries with different degrees of climate change goals, such as the US-American capital market. Consequently, future research designs should compare European and other regimes and include the regulatory effects of recent climate regulations (e.g. the CSRD and CSDDD).

Third, as we focused on climate board governance, other environmental corporate governance mechanisms should also be analyzed. We emphasized the significant effect of

climate-sensitive institutional investors on carbon assurance in the EU capital market (Kordsachia *et al.*, 2022). Recent studies have analyzed the signatures of the UN Principles for Responsible Investments (PRI) and the effect of these institutional investors on corporate environmental and carbon reporting (e.g. Kordsachia *et al.*, 2022). However, we did not identify any empirical studies on the influence of PRI investors on carbon assurance. Empirical research can be also conducted on the association between climate board governance, sustainable institutional investors and country-related governance proxies. As EU member states are heterogenous, there may be useful research possibilities in examining the macroeconomic and cultural differences between EU countries, enforcement issues, or shareholder rights.

6.3 Theoretical implications

Although this study is based on the interplay between stakeholder and critical mass theories, we included only a critical mass in the BGD variable. However, the critical mass of climate-related goals in comparison with other (non) financial goals in executive compensation packages may also be relevant to analyze. From the EU perspective, mandatory compensation reporting started in the business year 2021. Future researchers should conduct content analyses of compensation reports and integrate the ratio of climate goals into executive compensation. Critical mass theory assumes that the incentive function to promote climate assurance will be higher if a critical mass of at least 30% of climate goals is used. This also relates to the degree of climate experts on CCs.

6.4 Managerial implications

Although the practical use of carbon assurance is high, we stress the major complexity of assurance practices, leading to a lack of comparability within the EU. Without high-quality carbon assurance, the risks of greenwashing and information overload in climate reporting are dominant. Firms should be responsible for implementing an integrated climate management system with a direct link to climate neutrality and science-based targets in accordance with the Paris Climate Agreement. Otherwise, carbon reporting may be used for greenwashing purposes and for self-impression management. The strong association between climate reporting and carbon management systems is consistent with the new requirements of the CSDDD for mandatory climate transition plans. Climate neutrality remains an ambitious topic in the EU Green Deal project, leading to a massive reorganization of business strategies, models and processes. In other situations, a successful climate transformation of firms is questionable. Proper climate change strategies require a massive recognition of climate expertise in top, middle and lower management. The formation of CCs or chief climate officers can only be the first step. In the long run, climate skills must also be recognized in the accounting and finance departments of corporations. The implementation of a sound climate management system stresses the need to include interdisciplinary teams and to rely on external climate consulting providers. The last aspect is extremely relevant for small- and medium-sized entities that will not have sufficient resources to build up their internal climate knowledge without external support.

6.5 Implications for regulators and policymakers

Although the EU Commission has implemented several regulations on corporate sustainability, their real effects are still questionable. One major criticism is that the range of firms that must follow the CSRD and CSDDD differs. Even if the inclusion of a climate management system in line with the CSDDD is the basis for adequate climate reporting and climate assurance practices (CSRD), many smaller firms will have to present a CSRD report without including the CSDDD requirements. Thus, the major risks of greenwashing and information overload also exist in the future. The EU regulator should match the two Directives with a uniform user group. In

accordance with the EU Green Deal Project and related regulations (CSRD, CSDDD), other standard setters have also implemented stricter carbon reporting requirements. This relates to the International Sustainability Standards Board and its "climate first approach" and to the US Securities and Exchange Commission introducing mandatory carbon reporting for listed firms. Climate board governance can be classified as a major element of carbon reporting. We address the need for an international comparison of climate reporting for listed firms and related climate governance as "best practices." There may be competition and information overload among European listed firms that follow the CSRD and global standards. Thus, the readability and comparability of sustainability reporting may be questionable.

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