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Governance for a greener Europe: audit committee and carbon emission

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Abstract

Purpose – This study aims to examine the impact of Audit Committee (AC) characteristics on carbon disclosures and performance among companies listed in the STOXX Europe 600 index.

Design/methodology/approach – The sample consists of companies listed in the STOXX Europe 600 index over a 11-year period (2012–2022). The study uses panel data regression methods and uses the two-step system generalized method of moments to control for endogeneity.

Findings – The results indicate that AC size, independence and financial expertise positively influence carbon disclosure, highlighting the significance of these characteristics in promoting transparency and accountability in reporting carbon emissions. Additionally, these attributes are significantly associated with improved carbon performance, suggesting their potential role in advancing environmental sustainability.

Practical implications – The study provides practical insights for policymakers and regulatory bodies aiming to enhance carbon-related practices through improved corporate governance (CG) structures. By emphasizing the importance of specific AC characteristics, the findings suggest pathways for enhancing the quality of carbon disclosures and performance.

Originality/value – Despite extensive attention on CG in promoting sustainability, the specific influence of AC characteristics on carbon disclosures and performance remains underexplored. This study addresses this

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significant literature gap and, to the best of the authors' knowledge, is the first to link AC characteristics with both carbon disclosure and performance. It enriches the current body of knowledge in agency theory and provides critical insights for developing CG and regulatory policies that enhance the quality of carbon disclosures.

Keywords Corporate governance, Audit committee, Carbon disclosure, Carbon performance, Agency theory

Paper type Research paper

1. Introduction

Climate change is one of the greatest environmental challenges that the Earth faces in the 21st century. Recent statistics show that around 71% of total global green house gas emissions (GHG) emissions come from only 100 main companies, which creates growing pressure from all levels of stakeholders to take serious actions to minimise their GHG emissions (Crippa *et al.*, 2021). In this context, the United Nations' Sustainable Development Goal 13 (SDG 13) further stresses the critical roles of both public and private sectors in combating environmental pollution (Banerjee *et al.*, 2021).

Accordingly, it has been argued that corporate governance (CG) is pivotal in addressing climate-related challenges (Ahmed *et al.*, 2024; Abdelhaq and Dwekat, 2024; Abdelhaq *et al.*, 2024; Abu Alia *et al.*, 2024a; Oyewo, 2023; Haque and Ntim, 2018). Research suggests that firms with robust governance frameworks tend to provide detailed disclosures about their carbon footprint and implement comprehensive environmental policies, leading to better environmental performance (Haque and Ntim, 2018). From the perspective of agency theory, governance helps mitigate conflicts between shareholders and managers by ensuring that corporate actions align with the broader goals of environmental responsibility and sustainability (Goud, 2022; Jensen and Meckling, 1976). Consequently, the connection between CG and carbon performance is gaining traction (Liao *et al.*, 2015; Haque, 2017; Luo and Tang, 2021; Moussa *et al.*, 2020; Román *et al.*, 2021). However, despite the recognised importance of CG in enhancing environmental sustainability practices, there is limited knowledge regarding the influence of the Audit Committee (AC), as a governance mechanism, on firms' carbon disclosure and performance (Krishnamurti and Velayutham, 2018; Pozzoli *et al.*, 2022).

Buallay and Al-Ajmi (2020) state that ACs constitute a primary component of an effective CG framework. These committees are anticipated to enhance financial disclosure quality, improve auditors' efficiency, independence and objectivity, enhance the financial decision-making process and strengthen the risk-management function. Agency theory provides a framework to understand how these AC characteristics reduce information asymmetry, thereby aligning managerial actions with shareholder interests in environmental sustainability (Caers *et al.*, 2006). Furthermore, integrating internal controls, particularly focusing on ACs, plays a crucial role in mitigating the information asymmetry between companies and market participants. In a broad context, ACs are expected to provide enhanced oversight over both financial and non-financial information when assessing a firm's performance (Pozzoli *et al.*, 2022). Concerning nonfinancial issues, ACs play a supplementary role, encompassing a broader scope of responsibility that extends beyond financial reporting to include the supervision of sustainability matters (Appuhami and Tashakor, 2017). According to Al-Shaer and Zaman (2018), including assurance mechanisms, such as AC, in sustainability disclosure can enhance credibility and contribute to its improvement. Consequently, the AC serves as an executor and intermediary to ensure management policies on implementing CSR and is anticipated to significantly impact CSR

performance (Al-Shaer and Zaman, 2018; Trotman and Trotman, 2015). AC assists the directors in carrying out their duties. Prior research has shown that boards can influence CSR disclosure and performance (Al-Shaer and Zaman, 2016; Michelon and Parbonetti, 2012). Therefore, this study aims to examine the impact of AC attributes, namely the existence of financial expertise, meeting frequency, size and independence, on both carbon emission disclosure and performance in non-financial European firms that are publicly listed on the STOXX 600 index from 2012 to 2022.

By doing so, this study contributes to the literature in several ways. *Firstly*, this study provides a more specific examination of carbon disclosures and performance, in contrast to previous research that has generally explored the influence of AC characteristics on CSR or specific aspects of environmental disclosure, including (Pozzoli *et al.*, 2022), environmental, social and governance (ESG) disclosure environmental disclosure (Al-Shaer *et al.*, 2017), environmental performance (Paolone *et al.*, 2023), sustainability assurance (Dwekat *et al.*, 2022a). Despite the significant contributions made, to our knowledge, no known study has specifically examined the impact of AC attributes on carbon emissions disclosure and performance.

Secondly, it is noteworthy that previous scholarly investigations have predominantly focused on companies based in the UK, the US and Australia (Zaman *et al.*, 2021; Liao *et al.*, 2018; Al-Shaer and Zaman, 2018). However, the present study aims to broaden the geographical scope by including firms from 17 European countries that are part of the STOXX 600 index. The analysis presented in this study holds great importance, particularly in light of the EU's unique position, prominent involvement in environmental regulation and dedication to achieving a climate-neutral economy (Velte, 2023). By examining companies operating within the EU context, this research aims to offer valuable insights into how firms react to stringent environmental regulations. Consequently, this study will contribute to the enhancement of our understanding regarding carbon disclosure and performance within a region that holds significant importance in the global economy.

Thirdly, the study sample incudes small, medium and large entities. Thus, it advances agency theory by exploring its applicability and extending its boundaries to include the oversight of environmental disclosures, proposing a nuanced approach to understanding CG in the context of organisational complexity (Huse, 2007). *Finally*, our study shows the significance of the AC in enhancing the reliability and accuracy of non-financial disclosures, particularly regarding carbon emission reporting. The active engagement of the AC plays a critical role in ensuring the accuracy of information concerning the company's environmental performance. Thereby promoting trust and transparency.

This study is organised as follows: Section 2 provides a literature review, discussing the literature in the field of AC and carbon emissions from an empirical and theoretical perspective. Section 3 describes the methodology used in this study. Section 4 present the results of the analysis and include a detailed discussion. Section 5 provides the conclusion.

2. Literature review and development of hypotheses

2.1 Literature review

Climate change is still driven mainly by human-caused carbon emissions (Tanthanongsakkun *et al.*, 2023). Given the severity of climate change's adverse effects, a reactive strategy for controlling carbon emissions is no longer practical (Bose *et al.*, 2023; Albitar *et al.*, 2023). The international community has responded to the need to address the risks and opportunities associated with transitioning towards economic and structural models that produce fewer greenhouse gases through global initiatives such as the Kyoto Protocol and COP15 (Christoff, 2010). The Paris Climate Agreement was signed in 2015 to reduce global emissions and reach a net-zero emissions goal by the middle of the 21st century.

Given that the firm is the main polluter, it has been subjected to increasing pressure from stakeholders to be involved in environmental initiatives that proactively reduce its carbon footprint. This pressure is also driven by concerns regarding the reliability of carbon-related disclosures, particularly in cases where corporations are not legally required to disclose their carbon footprint (Kolk *et al.*, 2008; Stanny, 2018; Haque and Ntim, 2018; Haque and Deegan, 2010; Karim *et al.*, 2021). According to Velte *et al.* (2020), carbon performance and its disclosure could be linked with increased managerial discretions, information overload and risks of greenwashing. This brings us to the central point of the argument on the need for carbon disclosures to faithfully reflect a company's actual carbon performance. (Abweny *et al.*, 2024a; He *et al.*, 2022). There has been a suggestion that carbon disclosure not only serves as an indicator of a firm's carbon performance but also exerts an influence on it. According to Qian and Schaltegger (2017), a positive correlation exists between higher levels of carbon disclosure and improved carbon performance.

The analysis of carbon performance and disclosure in the broader CG framework highlights the substantial pressure management faces to disclose GHG emissions and mitigate carbon emissions over an extended period (Flammer, 2013; Qian and Schaltegger, 2017). The relationship between effective CG and transparent and credible disclosure is significant, as it increases carbon disclosure levels and accuracy in annual reports (Akben-Selcuk, 2019; Mallin *et al.*, 2013). In this regard, previous studies that attempted to understand the impact of CG mechanisms on environmental-related issues mainly focus on board composition (e.g. Haque, 2017; Nuber and Velte, 2021), ownership structure (e.g. Shan *et al.*, 2021; Wang *et al.*, 2019) or stakeholder pressures (e.g. Yunus *et al.*, 2020; Herold *et al.*, 2019). However, they overlook the potential impact of the AC as a crucial governance mechanism on carbon emissions disclosure and performance.

The AC can play a key role in improving the quality of carbon emission disclosures and the overall performance of environmental initiatives. By exercising rigorous oversight, the AC guarantees that disclosures are not only following environmental standards and regulations but also transparent and accurate (Pozzoli *et al.*, 2022). This oversight includes reviewing the methods used by management to measure and report carbon emissions, thus safeguarding against the risk of greenwashing, where companies may misrepresent their environmental impact (Dwekat *et al.*, 2022a, 2020; Meqbel *et al.*, 2024). Moreover, the AC can insist on integrating independent external audits to validate the reported data, adding additional credibility to the disclosures (Pozzoli *et al.*, 2022).

This reasoning is justified from the perspective of agency theory. According to Jensen and Meckling (1976), managers (agents) act on behalf of shareholders (principals). The principal, therefore, tends to use the AC as a monitoring mechanism to try to prevent or at least reduce the consequences of any misconduct of the agent and to implement incentive systems to reduce the conflict of interests. Moreover, following Healy and Palepu (2001), managers are more interested in maximising the firm's current value, while shareholders are focused on the long-term value of the firm. Indeed, agency theory suggests that the agency relationship between the principal and the agent comprises information asymmetries. It provides insight into the role of external auditing, which represents one of the effective monitoring tools to monitor managers' actions and to offer reasonable assurance on the quality reporting (Watts and Zimmerman, 1986; Bacha *et al.*, 2021), hence, external and internal auditing help to reduce information asymmetry that stems from the separation between principal and agent and protect the interests of the various stakeholders by presenting financial statements that are free of material misstatements, biases or fraud and, because of this, can adequately inform capital providers.

The effectiveness of the AC in these roles depends greatly on their characteristics (e.g. AC size, independence, expertise and meetings). Abbasi *et al.* (2024), suggest that effective ACs can ensure that disclosures not only comply with regulations but also genuinely reflect the company's carbon performance, thus playing a pivotal role in enhancing corporate accountability and stakeholder trust.

2.2 Hypotheses development

2.2.1 Audit committee size. The size of the AC is important in monitoring firms' sustainability reporting and carbon disclosure. Studies have recommended that the AC have at least three members to ensure various experiences and skills (Persons, 2009; Karamanou and Vafeas, 2005). In addition, a larger AC may lead to more control over corporate reporting and disclosure systems, resulting in less information asymmetry and agency problems (Chen and Jaggi, 2000). According to resource dependency theory, large ACs consist of individuals who possess the necessary authority as well as a diverse range of opinions, experiences and skills. This composition enables them to oversee effectively and address issues related to financial reporting while also enhancing their effectiveness in disclosing CSR matters (Bé dard *et al.*, 2004, Sultana *et al.*, 2015; Bedard and Gendron, 2010). According to the findings of Yekini and Jallow (2012), it can be concluded that companies that have a minimum of four members on their AC are more inclined to provide comprehensive and reliable CSR information in their annual reports. This suggests that having a larger AC can lead to more effective environmental "carbon-related" practices and reporting, which will reflect on carbon emission performance.

In contrast, it has been argued that increasing AC members could not be favourable. In this respect, a stream of previous research suggests that the number of members in the AC should not exceed five or six to avoid coordination and communication issues, decision-making delays and assigning responsibilities (Hoitash *et al.*, 2009; Appuhami and Tashakor, 2017; Li *et al.*, 2012).

Empirical evidence on the association between AC size, CSR disclosure and performance shows mixed findings. Omair Alotaibi and Hussainey (2016) show a positive correlation between the size of the AC and the extent of CSRD. However, they found no significant connection between the AC size and the quality of CSRD. Furthermore, Appuhami and Tashakor (2017) found a positive correlation between the size of the AC and the extent of CSRD. Buallay and Al-Ajmi (2020) have provided evidence to support the previous findings, revealing a significant positive connection between the size of the AC and the extent of CSRD among banks in the Gulf Cooperation Council. In a recent study of European companies, Dwekat *et al.* (2022a, 2022b) indicate a positive correlation between AC size and the company's inclination to seek sustainability assurance. On the other hand, other studies have found a negative (e.g. Adegboye *et al.*, 2020) association or no significant relationship. Based on the findings above, the present study posits the subsequent hypothesis:

H1a: Carbon emissions disclosure is likely to be positively affected by the larger size of the AC.

H1b: Carbon performance is likely to be positively affected by the larger size of the AC.

2.2.2 Audit committee independence. The AC's effectiveness in monitoring and supervising is closely tied to its level of independence from senior management (Bronson *et al.*, 2009; Lin *et al.*, 2008). This independence minimises information asymmetry and agency conflict (Fama and Jensen, 1983), as including independent members reduces the possibility of collusion among the management team and prevents the expropriation of shareholders' assets

(Fama, 1980). The AC is obligated to provide its assessment on significant matters, for instance, the effectiveness of the auditors' procedures, the accuracy of the data presented in the financial statements and the evaluation of the earnings' integrity, with independence being a critical characteristic in this context. Hence, the significance of perceiving independence cannot be overstated, given that stakeholders heavily depend on financial statements and other non-financial data for decision-making purposes (Chan and Li, 2008). Therefore, an independent AC is anticipated to significantly impact effective CG promotion and enhance auditing and financial reporting practices (Pozzoli *et al.*, 2022). According to Pucheta-Martínez and De Fuentes (2007), an AC exclusively formed from independent and external directors would lead to better transparency and accountability for the companies, which will ultimately increase the reliability of financial and non-financial information (Karamanou and Vafeas, 2005). The rationale is that independent ACs have no financial or personal association with the firm; thus, they tend to operate objectively and independently, separate from the top management (Bedard and Gendron, 2010; Persons, 2005; Musallam, 2018). This suggests that an independent AC can improve CSR disclosures and protect stakeholders from potentially misleading information (Appuhami and Tashakor, 2017; Mangena and Pike, 2005).

Prior research examining the correlation between AC independence and the extent of disclosures has yielded inconsistent empirical findings. Safari (2017) show a positive correlation between AC independence and earnings quality. Similarly, Zgarni *et al.* (2016) have documented that the independence of AC contributes to enhancing the accuracy of financial disclosures. Additionally, Raimo *et al.* (2021) indicate that the independence of AC is associated with higher-quality integrated reports. Studies on sustainability also show that the degree of CSRD and performance is positively impacted by AC independence. Dwekat *et al.* (2022a, 2022b) and Al-Shaer and Zaman (2018) found a positive correlation between the independence of the AC and the inclination to provide sustainability assurance.

Furthermore, Buallay and Al-Ajmi (2020) and Appuhami and Tashakor (2017) show that AC independence positively impacts ESG disclosure. Recently, Pozzoli *et al.* (2022) found that ESG performance score is influenced positively by the level of AC independence. However, when they tested the impact of AC independence on the ESG dimensions separately, they found that AC independence does not influence social and environmental performance. Alternatively, according to the results of Haniffa and Cooke (2005), there is a negative relationship between the independence of the AC and CSRD. In contrast, Li *et al.* (2012) found no evidence of a significant association between AC independence and non-financial disclosure. Likewise, Young and Marais (2012) find no significant association between AC independence and earnings disclosure.

Given the above, AC independence may increase the carbon emission disclosure level to safeguard stakeholders against managers' opportunistic behaviour by enhancing the oversight process's effectiveness, which will ultimately be reflected in better carbon emission management. In light of these findings, the research makes the following hypotheses:

H2a: Carbon emissions disclosure is likely to be positively affected by the independence of the AC.

H2b: Carbon performance is likely to be positively affected by the independence of the AC.

2.2.3 Audit committee financial expertise. The SOX (2002) recommended that some members of ACs must possess a sufficient understanding of finance and financial issues. In Europe, several laws, guidelines and recommendations have been implemented to achieve a goal similar to that of SOX. The European Parliament's Directive 2014 / 56/EU and the

corresponding laws in each member state require the AC to have at least one member with auditing and/or accounting expertise to enhance independence and technical competence. Additionally, EU Recommendation 2005 / 162/EC specifies that the AC members of listed companies must collectively have recent and relevant backgrounds and appropriate experience in accounting and finance for the company's activities.

Based on prior scholarly investigations, agency theory posits that the presence of AC members possessing financial expertise can significantly contribute to establishing a resilient risk management framework and internal control system. Subsequently, this can effectively improve investor confidence (Buallay and Al-Ajmi, 2020). Moreover, members of the AC who possess the required knowledge and expertise can offer competent opinions on the opinions of directors and auditors, thereby helping to ensure effective monitoring of the financial reporting process of an organisation (Sultana *et al.*, 2015; Mukhlasin, 2018; Velte, 2018). This expertise can also increase the likelihood of detecting errors in management operations and financial statements, thus improving CG (DeFond *et al.*, 2005). Furthermore, Persons (2005) showed that financial expertise on the AC is not linked to increased fraud occurrence.

In the context of CSR, Khan *et al.* (2013) argue that the presence of an AC positively affects CSR disclosures. This is particularly relevant given that environmental risks can result in considerable financial consequences, such as environmental penalties and expenses related to pollution control and the implementation of environmentally friendly technologies (Freedman and Patten, 2004), ACs that consist of members who possess financial expertise are more inclined to possess the necessary readiness to provide informed guidance to the board regarding the formulation of policies and strategies aimed at mitigating and managing these risks. According to the research conducted by Goodstein and Boeker (1991), it is proposed that the distinct skills and abilities possessed by individual board members play a significant role in shaping the decision-making process and the overall agenda of the board. As a result, this influences the strategic choices and operational measures adopted by the management team. According to Hillman *et al.* (2000, p. 241), members with financial expertise can be classified as "support specialists." These specialists provide specialised knowledge and valuable connections in specific domains to assist the firm in implementing its strategic objectives. AC members who possess financial expertise have the ability to aid a company in assessing its financial and regulatory risks associated with CSR. They can also work alongside management to create effective strategies for managing and reporting these CSR-related risks. Financial experts serving on ACs have the potential to exert influence on companies by advocating for adherence to the GRI guidelines pertaining to environmental and social reporting. Additionally, they can advocate for the integration of financial and non-financial reporting, as well as the promotion of external auditing of the CSR report. These actions are aimed at improving the quality and performance of CSR reporting (Shaukat *et al.*, 2016).

The relationship between the expertise of ACs and their ability to influence CSR disclosures and performance is a topic that has yielded mixed directions. Several studies found a positive correlation between the financial expertise of ACs and CSR performance. Shaukat *et al.* (2016) find that the presence of directors having financial expertise in the AC increases the possibility of formulating an inclusive CSR strategy. Wang and Sun (2022) find that expertise in AC has a positive effect on CSR reporting. Moreover, Pozzoli *et al.* (2022) indicate a positive connection between AC expertise and environmental and social performance. Nevertheless, Musallam (2018) and Buallay and Al-Ajmi (2020) have reported such findings. The research conducted by Othman *et al.* (2014), Madi *et al.* (2014), Li *et al.* (2012) and Appuhami and Tashakor (2017), provided results that do not support a

statistically significant relationship between the financial expertise of ACs and the extent of voluntary or intellectual capital disclosure. Given the discussion above, the third hypothesis is posited in the following manner:

H3a: Carbon emissions disclosure is likely to be positively affected by ACs with at least one financially literate member.

H3b: Carbon performance is likely to be positively affected by ACs with at least one financially literate member.

2.2.4 Audit committee meetings frequency. The frequency of AC meetings throughout the financial year plays a central role in achieving the AC's objectives and enhancing its function's efficiency and reliability (Adegboye *et al.*, 2020). An increase in the number of meetings provides ample time for members to discuss and understand differing opinions, thereby improving the reliability of the committee. In addition, regular meetings allow members to report and take necessary action on any emerging issues (Appuhami and Tashakor, 2017). Research by Bicer and Feneir (2019) has demonstrated a positive correlation between the number of AC meetings and the quantity and quality of financial disclosures, with a higher number of meetings resulting in higher levels of disclosure. Furthermore, the regularity and consistency of AC meetings may lead to more effective monitoring and a broader scope of voluntary corporate disclosures (Persons, 2009).

Research has also shown that the regular attendance of AC members at meetings is positively associated with their effectiveness in carrying out their oversight role (Karamanou and Vafeas, 2005). Furthermore, active participation in regular meetings allows members to discuss and evaluate issues related to the firm's financial reporting practices (Chariri *et al.*, 2018; Chariri and Januarti, 2017; Vafeas, 2005). Studies have also found that AC meetings, with at least four per year, significantly impact voluntary disclosures (Allegrini and Greco, 2013; Li *et al.*, 2012). Therefore, it can be inferred that the greater the number of members attending regular AC meetings, the higher the level of carbon emissions disclosure. As such, the fourth hypothesis is proposed as follows:

H4a: Carbon emissions disclosure is likely to be positively affected by the frequency of annual AC meetings.

H4b: Carbon performance is likely to be positively affected by the frequency of annual AC meetings.

3. Methodology

3.1 Data sources and sample selection

This research examines a representative sample of European firms publicly traded on the STOXX Europe 600 index from 2012 to 2022, specifically focusing on the region's keen interest in environmental issues and high participation in CSRD. The STOXX Europe 600 index, established by STOXX Ltd, includes 600 stocks from 17 European countries, encompassing large, mid-size and small-cap firms and accounting for roughly 90% of the European stock markets' free-float market capitalisation. Notably, the index's highest-represented countries include the UK, France, Switzerland, Germany, Denmark, Norway, The Netherlands, Austria, Sweden, Belgium, Italy, Portugal, Spain, Finland, Luxembourg, Ireland and Poland.

The exclusion of financial firms is a common practice in governance and environmental studies due to the financial sector's unique regulatory frameworks and reporting requirements, which differ significantly from those of non-financial firms (Haque and Ntim, 2018; Dwekat

et al., 2022b). Including financial firms could introduce structural heterogeneity that might confound the analysis of AC attributes and carbon-related disclosures and performance. This exclusion ensures that the findings remain generalisable to non-financial industries, where governance mechanisms are more directly comparable.

The study's data was collected from various sources at different stages, focusing on the Refinitiv Eikon database for data on the Audit expertise and meetings, GHG emissions and firm-level data. AC size and independence were collected from the Bloomberg database. The initial sample contained 6,441 observations of non-financial firms listed on the STOXX Europe 600 index, but some observations were excluded due to incomplete data or issues in merging data, resulting in a final sample of 5,668 firm-year observations.

3.2 Variables measurement

3.2.1 Dependent variables. 3.2.1.1 Carbon emission reporting. Several methods and data sources can be used to measure the disclosure of carbon emissions. For this study, a binary measure has been used based on the proposal by Matsumura *et al.* (2014) and Román *et al.* (2021). A company is assigned a value of one if it has reported its carbon emissions during a given year and zero if it has not. This binary method is based on data availability and offers a clear and straightforward distinction between companies that disclose carbon-related information and those that do not.

3.2.1.2 Carbon emission performance. To measure a firm's carbon emission performance, the study relies on an emission category score provided by the Refinitive Eikon database. This metric assesses the level of firms' effectiveness in their efforts to minimise environmental emissions during manufacturing and operational activities (Velte, 2021). The higher the number, the more practical and effective measures and strategies the company takes to reduce GHG emissions.

3.2.2 Independent variables (audit committee attributes). This study focuses on four AC attributes: size, independence, financial expertise and meeting frequency. The size of the AC is determined by the total number of members appointed to the committee for a particular year and company (Dwekat *et al.*, 2022a). Independence is measured by the ratio of independent members to the total number of members (Juhmani, 2017). Financial expertise is determined by the ratio of members with degrees in accounting, financial management, or financial and banking sciences to the total number of members (Dwekat *et al.*, 2022a). Meetings frequency is measured by the natural logarithm of the number of times the AC meets annually (Mishra and Malhotra, 2016).

3.2.3 Control variables. To ensure the robustness of our analysis, we control for several variables that prior research has found to be related to CSR disclosure (Kansal *et al.*, 2014; Alshorman *et al.*, 2024; Alia *et al.*, 2024). Firstly, we include the natural logarithm of annual sales to capture the effect of firm size on CSR disclosure, as shown by Ghaleb *et al.* (2020) and Khatatbeh *et al.* (2024). Secondly, we control for leverage, which is measured as the ratio of total debt to total assets (Dwekat *et al.*, 2025). This variable is included because previous studies have shown that companies in financial distress may increase their CSR disclosure (Goss and Roberts, 2011; Omran *et al.*, 2021; Al Natour *et al.*, 2023). To account for profitability, we incorporate return on equity (ROE) into our analysis. ROE is determined by dividing net income by total equity (Carmona *et al.*, 2022; Alta'any *et al.*, 2024a; Mardawi *et al.*, 2024; Achiro *et al.*, 2024; Kayed *et al.*, 2024).

3.3 Empirical model(s)

Following Román *et al.* (2021) and Haque (2017), the first model uses a logit regression to examine the association between AC characteristics and carbon emission disclosures. The

second model uses a panel linear regression to analyse the relationship between AC characteristics and carbon emission performance with a continuous dependent variable:

$$Carbon\_Disc_{it} = \alpha_0 + \beta_1 AC_{SIZEit} + \beta_2 AC_{INDit} + \beta_3 AC_{EXPit} + \beta_4 AC_{MEETINGit} + \beta_5 SIZE_{it} + \beta_6 LEV_{it} + \beta_6 ROE_{it} + \text{Fixedeffects} + \varepsilon_{it} \quad (1)$$

$$Emission\_score_{it} = \alpha_0 + \beta_1 AC_{SIZEit} + \beta_2 AC_{INDit} + \beta_3 AC_{EXPit} + \beta_4 AC_{MEETINGit} + \beta_5 SIZE_{it} + \beta_6 LEV_{it} + \beta_6 ROE_{it} + \text{Fixedeffects} + \varepsilon_{it} \quad (2)$$

Table 1 defines the independent and dependent variables, while ε represents the error term and βk denotes the regression coefficients.

4. Data analysis and results

4.1 Descriptive statistics and univariate analysis

The variables used in this study's analysis are summarised in the descriptive statistics shown in Table 2. The results indicate that approximately 75% of the firms in the sample voluntarily disclose their carbon emissions information (CARBON_DISC). Concerning the composition of the AC, the average size of an AC is four members (AC_SIZE) and around 79% of them are independent (AC_IND), with at least one member having financial expertise (AC_EXP). Furthermore, the number of AC meetings held throughout the year is approximately 5 (AC_MEETING).

To assess the presence of multicollinearity among the variables in the study, Pearson's correlation was used and is displayed in Table 3. The findings suggest a strong positive correlation of 0.5356 between the Emission_score and SIZE. Furthermore, the variance inflation factor (VIF) was used as another method to determine the presence of multicollinearity. The findings in Table 4 indicate that the VIF values for all independent variables are below 2. which is well below the commonly used threshold of 10 (Belsley *et al.*, 2005), suggesting that the issue of multicollinearity does not exist between the independent variables.

4.2 Multivariate analysis

4.2.1 Audit committee attributes and carbon emission disclosures. In line with Román *et al.* (2021), the study uses logistic regression to analyse the relationship between AC characteristics and carbon disclosure. A Hausman test was conducted to determine whether a fixed or random effects model was appropriate, with the results favouring a fixed effects model. Models 1–4 of Table 5 examine the individual influence of AC attributes on carbon emissions reporting, whereas Model 5 examines the combined effect of these characteristics. The models used in the study also incorporated controls for the time-invariant country and industry differences by including country-fixed effects (fe) and industry-fixed effects. Additionally, outcome variations over time were accounted for by including a year-fixed effect to control for business cycles and macroeconomic fluctuations (Dwekat *et al.*, 2022a; Alta'any *et al.*, 2024b).

In greater detail, Model 1 shows a positive and significant association between AC size and carbon disclosure (coef. 0.260; $p < 0.01$), indicating that H1a is supported. This finding aligns with the perspective of agency theory, which suggests that larger ACs can better oversee a company's reporting and information system, including carbon emissions, which results in less information asymmetry and agency costs (Jensen, 1993; Appuhami and

Table 1. Variables measurement

Variables	Label	Operational definition
Dependent variables		
Carbon disclosure	*Carbon_Disc_Total*	Carbon disclosure is measured as a dichotomous variable witd a value of 1 if tde firm reports carbon emissions in tdat period and 0 otderwise (Román *et al.*, 2021; source: Refinitiv Eikon)
Carbon emission performance	*Emission_Score*	Emissions score measures a company's commitment to and effectiveness in reducing environmental emission in the production and operational processes, adjusted by the industry averages (source: Refinitiv Eikon)
Environmental performance	*ENV_Performance*	Environment pillar score is the weighted average relative rating of a company based on the reported environmental information and the resulting three environmental category scores (source: Refinitiv Eikon)
Policy emission reduction	*Policy_Emissions_Reduction*	A dummy variable takes the value of 1 if the company has the policy to improve emission reduction and 0 otherwise (source: Refinitiv Eikon)
Targets emission reduction	*Targets_Emissions_Reduction*	A dummy variable takes the value of 1 if the company sets targets or objectives for emission reduction, and 0 otherwise (source: Refinitiv Eikon)
GRI report guidelines	*GRI_report _guidelines*	A binary variable equal to 1 if the company's CSR report aligns with GRI standards and 0 otherwise (source: Refinitiv Eikon)
Independent variables		
AC size	*AC_SIZE*	The total number of AC members at the end of the fiscal year (source: Bloomberg)
AC independence	*AC_IND*	The proportion of independent board members on the AC (source: Bloomberg)
AC financial expertise	*AC_EXP*	A dummy variable equal to 1 if the firm has an AC with at least 1 "financial expert" as defined in SOXX, and 0 otherwise (source: Refinitiv Eikon)
AC meeting frequency	*AC_MEETING*	The number of AC meetings held in a year (source: Refinitiv Eikon)
Control variables		
Firm size	*SIZE*	The natural log of annualised sales revenue (source: Refinitiv Eikon "Worldscope")
Financial leverage	*LEV*	The ratio of total debt to total assets (source: Refinitiv eikon "worldscope")
Return on equity	*ROE*	The ratio of net income to total equity (source: Refinitiv Eikon "Worldscope")
Industry CSR sensitivity	*CSR_sensitive_Ind*	A dummy variable equal to 1 if the firm is part of a CSR-sensitive industry and 0 if it is part of a non-CSR-sensitive industry, based on Simnett *et al.* (2009) (source: Refinitiv Eikon "Worldscope")

Source: Authors' own work

Table 2. Descriptive statistics of variables

Variables	Mean	SD	Min.	Max.
Carbon_Disc_Total	0.75	0.43	0	1
Emission_Score	63.54	27.95	0	99.78
ENV_PERFORMANCE	56.75	25.16	0	98.72
POLICY_EMISSION	0.87	0.34	0	1
TARGETS_EMISSION	0.62	0.48	0	1
AC_SIZE	3.87	1.11	2	8
AC_IND	78.87	29.18	0	100
AC_EXP	0.78	0.41	0	1
AC_MEETING	5.28	2.29	2	14
SIZE	15.28	1.51	5.89	19.78
LEV	0.23	0.17	0	2.7
ROE	14.76	22.48	−65.42	124.27

Source: Authors' own work

Table 3. Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Carbon_Disc_Total	1								
(2) Emission_score	0.4886*	1							
(3) AC_SIZE	0.1016*	0.2089*	1						
(4) AC_IND	0.1403*	0.0659*	−0.1973*	1					
(5) AC_EXP	0.1228*	0.0835*	0.0195	0.1733*	1				
(6) AC_MEETING	0.0580*	0.2119*	0.0356	0.0423*	0.0203	1			
(7) SIZE	0.3535*	0.5356*	0.2976*	−0.0282	0.0065	0.2751*	1		
(8) LEV	−0.037	−0.0275	−0.0024	0.0694*	0.0562*	0.0662*	0.0770*	1	
(9) ROE	0.012	−0.0036	0.0015	0.0592*	−0.0034	−0.0867*	−0.1116*	0.0177	1

Notes: The presented Table displays the Pearson's correlation coefficients between the dependent and independent variables. The variables used in this study are consistent with the definitions provided in Table 1. The statistical significance level used in this study is set at $p < 1\%$, using two-sided *t*-statistics
Source: Authors' own work

Table 4. Variance inflation factor

Variable	VIF
AC_SIZE	1.16
AC_IND	1.11
AC_EXP	1.04
AC_MEETING	1.11
SIZE	1.23
LEV	1.04
ROE	1.02
Mean VIF	1.1

Note: Refer to Table 1 for variables definition
Source: Authors' own work

Table 5. The impact of audit committee attributes on the carbon emission reporting

Variables	(1) Carbon_Disc_Total	(2) Carbon_Disc_Total	(3) Carbon_Disc_Total	(4) Carbon_Disc_Total	(5) Carbon_Disc_Total
AC_SIZE	0.260*** (0.0575)				0.240*** (0.0644)
AC_IND		0.00497** (0.00214)			0.00496** (0.00236)
AC_EXP			0.620*** (0.124)		0.565*** (0.144)
AC_MEETING				−0.0232 (0.0293)	−0.0518 (0.0364)
SIZE	0.801*** (0.0582)	0.888*** (0.0633)	0.868*** (0.0613)	0.867*** (0.0575)	0.764*** (0.066)
LEV	−1.355*** (0.43)	−1.440*** (0.481)	−1.080** (0.484)	−1.207*** (0.43)	−1.368*** (0.504)
ROE	0.00894*** (0.00284)	0.00850*** (0.00318)	0.00879*** (0.00309)	0.0115*** (0.00291)	0.00706** (0.00321)
Constant	−13.50*** (0.98)	−13.34*** (1.07)	−13.17*** (1.032)	−12.88*** (0.965)	13.41*** (1.123)
Year fe	Yes	Yes	Yes	Yes	Yes
Country fe	Yes	Yes	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes	Yes	Yes
Observations	5,668	5,668	5,668	5,668	5,668
Pseudo R^2	0.24	0.18	0.22	0.23	0.24

Notes: The presented Table displays the findings of the logit regression models applied to a sample comprising European companies listed on the STOXX 600 index between the years 2012 and 2022. The influence of AC size, independence, financial expertise and meeting frequency on the probability of disclosing carbon emissions is tested in Models 1, 2, 3 and 4, respectively. In this study, Model 5 investigates the impact of all attributes of AC on the probability of disclosing carbon emissions. For a comprehensive understanding of the variables used in the model, please refer to Table 1. To address potential endogenous interdependence, all explanatory variables have lagged by one year. The regressions were conducted using country-year clustering to account for potential heteroscedasticity and to obtain robust standard errors. ***Statistical significance at 1% level; **statistical significance at 5% level; *statistical significance at 10% level

Source: Authors' own work

Tashakor, 2017; Chen and Jaggi, 2000; Sultana *et al.*, 2015). Furthermore, larger ACs have greater knowledge of CG, including ESG aspects, due to their diverse skill sets and expertise (Bé dard *et al.*, 2004, Sultana *et al.*, 2015; Bedard and Gendron, 2010). Due to a more evenly distributed workload, they are better equipped to supervise the company's reporting processes, particularly non-financial disclosures such as carbon emissions information (Dhaliwal *et al.*, 2010).

The findings for AC independence presented in Model 2 show a highly significant positive relationship with carbon disclosure (coef. 0.00496; $p < 0.05$), thereby supporting *H2a*. Firms showing a larger proportion of independent AC members demonstrated a better tendency to disclose information regarding carbon emissions. This finding aligns with the perspectives of agency theory, as well as previous studies that have linked independent ACs to voluntary disclosure, including carbon emissions (Jensen and Meckling, 1976; Al-Shaer and Zaman, 2018; Dwekat *et al.*, 2022a; Fama and Jensen, 1983). The reasoning behind this direction is that independent AC members contribute significantly to the quality of carbon disclosure practices in companies. As independent AC members lack personal or financial connections to the firms they service, they can operate objectively, unaffected by management (Musallam, 2018). This objectivity improves the quality of carbon-related information disclosure and protects stakeholders from potential misinformation (Mangena and Pike, 2005).

The outcomes for AC financial expertise in Model 3 also showed a significant positive association with carbon disclosure (coef. 0.620; $p < 0.01$), supporting *H3a*. This suggests that the inclusion of a member possessing financial expertise within the AC enhances the carbon disclosure process, as has been concluded by previous studies (Chariri *et al.*, 2018; Dwekat *et al.*, 2020; Pucheta-Martínez *et al.*, 2021). In addition, members of the AC with financial expertise are equipped with the essential skills to assess the firm's financial and regulatory risks associated with CSR, including environmental commitments and carbon emissions (Shaukat *et al.*, 2016). Their ability to understand complex financial data and implications enables them to collaborate efficiently with management to develop comprehensive carbon disclosure strategies, ensuring a high level of transparency in reporting (Bedard and Gendron, 2010; Li *et al.*, 2012).

Contrary to hypothesis (*H4a*), the results showed no correlation between the AC meetings and carbon disclosure. One possible explanation for this non-significance is the qualitative aspect of meeting discussions, which may vary significantly in terms of agenda and focus. As suggested by (Kent and Stewart, 2008), the frequency of meetings alone may not guarantee enhanced disclosure unless accompanied by substantive discussions on ESG-related matters. Further research could explore the content of these meetings to identify their specific influence on disclosure practices.

4.2.2 Audit committee attributes and carbon emissions performance. Table 6 presents the leaner regression outcomes for the AC attributes-carbon emissions performance nexus. The findings show that ACs not only oversee financial matters but also significantly influence sustainability initiatives, offering critical guidance to the board in addressing environmental challenges. Consistent with prior studies, governance mechanisms such as ACs have been shown to positively impact organisational sustainability performance (Al-Shaer and Zaman, 2016).

Furthermore, it has been argued that there is a positive connection between CSR performance and CSR disclosure level. Alsayegh *et al.* (2020) prove that firms with robust ESG reporting can strengthen their sustainability performance. Therefore, when AC improves carbon reporting, it will lead to better carbon performance. The findings align with the fundamentals of agency theory, which posits that well-governed companies should outperform poorly governed counterparts (Brown and Caylor, 2006).

Table 6. The impact of audit committee attributes on the carbon emission performance

Variables	(1) Emission_score	(2) Emission_score	(3) Emission_score	(4) Emission_score	(5) Emission_score
AC_SIZE	2.843*** (0.349)				2.933*** (0.345)
AC_IND		0.0433*** (0.0161)			0.0620*** (0.0167)
AC_EXP			6.159*** (0.912)		3.294*** (0.932)
AC_MEETING				0.594*** (0.175)	0.675*** (0.18)
SIZE	10.19*** (0.277)	10.84*** (0.274)	10.93*** (0.271)	10.57*** (0.288)	9.638*** (0.298)
LEV	−12.82*** (2.976)	−15.96*** (3.055)	−14.75*** (3.098)	−13.40*** (2.973)	−14.64*** (2.98)
ROE	0.0969*** (0.0165)	0.104*** (0.0172)	0.103*** (0.0171)	0.115*** (0.0166)	0.108*** (0.0165)
Constant	−108.8*** (5.96)	−101.8*** (5.696)	−103.4*** (5.681)	−97.97*** (5.791)	−108.3*** (5.981)
Year fe	Yes	Yes	Yes	Yes	Yes
Country fe	Yes	Yes	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes	Yes	Yes
Observations	5,668	5,668	5,668	5,668	5,668
R-squared	0.388	0.378	0.38	0.384	0.399

Notes: The provided Table displays the outcomes of linear panel data models applied to a sample of European companies listed on the STOXX 600 index from 2012–2022. Models 1, 2, 3 and 4 examine the impact of AC size, independence, financial expertise and frequency of meetings on carbon emissions performance, respectively. Model 5 investigates the impact of all AC attributes on the carbon emissions performance, as outlined in Table 1 for the definitions of the variables. The regressions were conducted using country-year clustering to account for potential heteroscedasticity and to ensure the robustness of the standard errors. ***Statistical significance at 1% level; **statistical significance at 5% level; *statistical significance at 10% level

Source: Authors' own work

More specifically, AC size has a strong positive effect on carbon emissions performance (coef. 2.843, $p < 0.01$), reflecting the benefits of diverse expertise in larger committees. A broader composition allows for more effective oversight of environmental strategies and ensures adequate attention to sustainability issues (Bédard *et al.*, 2004). Similarly, AC independence in Model 2 significantly enhances carbon performance (coef. 0.0433; $p < 0.01$) by providing unbiased oversight and reducing managerial opportunism, ensuring accountability and alignment with stakeholder demands (Al-Shaer and Zaman, 2018; Khan *et al.*, 2013).

AC financial expertise is particularly impactful, with the strongest relationship to carbon performance (coef. 6.159; $p < 0.01$). Financially skilled members enable efficient resource allocation, improve regulatory compliance and optimise the cost-effectiveness of sustainability projects (Shaukat *et al.*, 2016) (Shaukat *et al.*, 2016). Finally, AC meeting frequency significantly improves carbon emissions performance (coef. 0.594; $p < 0.01$). Frequent meetings ensure consistent monitoring of sustainability progress and timely interventions to address emerging challenges (Al-Shaer and Zaman, 2018; Zaman *et al.*, 2021). However, the effectiveness of meetings depends on their focus and substantive discussions.

These results also support the positive link between CSR performance and CSR disclosure, with robust ESG reporting shown to strengthen firms' sustainability outcomes (Alsayegh *et al.*, 2020). The findings align with agency theory, which suggests that well-governed firms outperform their counterparts through reduced information asymmetry and better accountability (Brown and Caylor, 2006).

Overall, Table 6 confirms that AC size, independence, financial expertise and meeting frequency collectively enhance carbon emissions performance. These attributes underline the evolving role of ACs as critical drivers of sustainability, helping organisations meet stakeholder expectations while creating long-term environmental and financial value.

Accordingly, all hypotheses (*H1b, H2b, H3b* and *H4b*) were supported by the models' findings in Table 6.

4.3 Robustness tests

4.3.1 Controlling for sensitivity of industry to CSR. Following Dwekat *et al.* (2022a, 2022b), companies were classified as either CSR-sensitive or non-CSR-sensitive to account for the potential influence of each industry. As outlined by Dwekat *et al.* (2022a, 2022b), companies involved in mining, utilities and production were deemed CSR-sensitive, or "carbon sensitive", given their greater impact on the environment and stronger incentives to project a favourable social image (Al-Shaer and Zaman, 2019; Dwekat *et al.*, 2024).

After adjusting for industry-specific effects, we re-evaluated hypotheses *H1*, *H2*, *H3* and *H4* to explore the link between AC characteristics and carbon disclosure. The outcomes, as displayed in Table 7, demonstrate that the regression coefficients of the key variables remain consistent with the prior results performed in Tables 5 and 6.

The findings in Table 7 demonstrate a significant positive correlation (coef. 0.861; $p < 0.01$) between CSR_sensitive_Ind and carbon disclosure, as well as (coef. 1.609; $p < 0.05$) between CSR_sensitive_Ind and carbon performance, confirming prior studies (Garcia *et al.*, 2017). These results show that companies categorised as CSR-sensitive are more inclined to disclose their carbon emissions and be more environmentally responsible.

Further building on these findings, our study demonstrates a relationship between industry responsiveness to CSR and not only increased levels of carbon disclosure but also enhanced carbon performance. Industries classified as CSR-sensitive due to their substantial environmental impact encounter increased demands and stakeholder scrutiny (García-

Table 7. Additional test – control for CSR-sensitive industries

Variables	(1) Carbon_Disc_Total	(2) Emission_score
AC_SIZE	0.235*** (0.0642)	2.555*** (0.348)
AC_IND	0.00492** (0.00234)	0.0657*** (0.0163)
AC_EXP	0.571*** (0.143)	2.937*** (0.939)
AC_MEETING	−0.055 (0.0359)	0.484*** (0.176)
SIZE	0.745*** (0.0649)	9.614*** (0.292)
LEV	−1.284*** (0.469)	−16.27*** (2.846)
ROE	0.00716** (0.00322)	0.101*** (0.0165)
CSR_sensitive_Ind	0.861*** (0.137)	1.609** (0.712)
Constant	−13.84*** (1.085)	−112.6*** (5.734)
Year fe	Yes	Yes
Country fe	Yes	Yes
Industry fe	No	No
Pseudo R^2	0.23	–
R-squared	–	0.38

Notes: The presented Table displays the outcomes of the regression models conducted on a sample comprising European companies listed on the STOXX 600 index from 2012–2022. The analysis accounts for the influence of CSR-sensitive industries. Models 1 and 2 examine the impact of variables such as AC size, independence, financial expertise, size and meeting frequency on the likelihood of disclosing carbon emissions and carbon emission score, respectively. Model 1 investigates the correlation between various AC attributes and the likelihood of disclosing carbon emissions. On the other hand, Model 2 assesses the effect of AC attributes on carbon performance. Please refer to Table 1 for the definitions of the variables. In Model 1, all the explanatory variables have been lagged by one year to address the potential issue of endogenous interdependence. The regressions were conducted using country-year clustering to account for potential heterogeneity, and robust standard errors were used to address potential issues with model specification. ***Statistical significance at 1% level; *statistical significance at 5% level; *statistical significance at 10% level
Source: Authors' own work

Sánchez and García-Meca, 2017; Abu Alia *et al.*, 2024b). The intense examination incentivises these corporations to go beyond mere disclosure of their carbon emissions and undertake concrete measures to reduce their negative environmental impact (Kuo *et al.*, 2012). This highlights the significant influence that societal pressures and expectations can exert in guiding corporate behaviour towards environmental responsibility (Abweny *et al.*, 2024b). This finding implies that industries that have historically been linked to significant environmental risks have the potential to lead in terms of environmental responsibility as long as they prioritise CSR.

4.3.2 Alternative measures and proxies of climate change initiatives. This study investigates the effect of AC attributes on carbon emission disclosure and performance. However, it is acknowledged that AC attributes could also influence other carbon-related variables. To address this, the dependent variables are replaced with three alternative variables in three separate models.

The first model presented in Table 8 uses the environmental performance score as the dependent variable. The findings indicate that AC attributes, including AC meeting frequency, positively and significantly impact environmental disclosure scores. This suggests that AC attributes can serve as an internal CG mechanism to improve the credibility of environmental disclosures and, thus, higher carbon performance (Al-Shaer *et al.*, 2017; Helfaya and Moussa, 2017).

Similarly, the results also support the positive influence of AC attributes when carbon disclosure variables are replaced with policy emission reduction and target emission

Table 8. Additional test – alternative measures and proxies of climate change initiatives

Variables	(1) ENV_Performance	(2) Policy_Emiss_Reduction	(3) Targets_Emiss_Reduction	(4) GRI_report_guidelines
AC_SIZE	1.104*** (0.313)	0.340*** (0.075)	0.290*** (0.0452)	0.0917** (0.041)
AC_IND	0.0514*** (0.0147)	0.00579** (0.00259)	0.00068 (0.0018)	0.00541*** (0.00189)
AC_EXP	3.819*** (0.821)	0.264* (0.15)	0.546*** (0.111)	0.560*** (0.115)
AC_MEETING	0.475*** (0.158)	0.0652* (0.0388)	0.0731*** (0.0254)	0.0952*** (0.0254)
SIZE	9.378*** (0.262)	0.838*** (0.0691)	0.938*** (0.0514)	0.838*** (0.0429)
LEV	−18.54*** (2.622)	0.194 (0.475)	−0.739** (0.33)	−1.344*** (0.354)
ROE	0.0886*** (0.0142)	0.00620** (0.00251)	0.00978*** (0.00218)	0.00516** (0.00201)
Constant	−98.10*** (5.083)	−11.83*** (1.303)	−15.66*** (0.837)	−12.41*** (0.756)
Year fe	Yes	Yes	Yes	Yes
Country fe	Yes	Yes	Yes	Yes
Industry fe	Yes	Yes	Yes	Yes
R-squared	0.39	–	–	
Pseudo R^2	–	0.23	0.23	0.31

Notes: This Table presents the results derived from a sample of European companies listed on the STOXX 600 index during the period 2012–2022. Model 1 explores the impact of AC attributes on environmental performance. Model 2 investigates the influence of AC attributes on emission reductions achieved through policy implementation. Model 3 evaluates the effect of AC attributes on targeted emission reductions. Model 4 examines the impact of AC attributes on alignment with GRI reporting standards as an alternative measure of carbon disclosure quality. For detailed definitions of the variables, please refer to Table 1. Statistical significance levels are indicated as follows: ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$
Source: Authors' own work

reduction[1]. These variables reflect the firm's behaviour and commitment towards reducing its environmental impact (Helfaya and Moussa, 2017). Moreover, it is worth noting that the positive effect of AC attributes extends beyond the mere disclosure of carbon emissions. These attributes have a significant connection in both policy-driven emission reduction efforts and target-based emission reduction variables. These variables encompass a facet of a company's environmental dedication focused on taking action, demonstrating its efforts to reduce its environmental footprint (de Abreu *et al.*, 2023). The prominent significance of AC in this particular context highlights its crucial role in establishing a framework for environmental accountability within the organisation. Therefore, AC's attributes play a crucial role in influencing a company's environmental strategies, reinforcing AC's expanding role in contemporary CG. This profound realisation can make a substantial scholarly contribution and offer practical guidance, emphasising the significance of a well-structured AC in promoting sustainable corporate practices.

To address concerns regarding the binary nature of the carbon disclosure measure, this study also considers firms' alignment with reporting frameworks such as the Global Reporting Initiative (GRI) to measure disclosure quality. GRI is a globally recognised standard for sustainability reporting, offering a comprehensive framework to ensure greater depth, quality and comparability of disclosures (Hahn and Kühnen, 2013). Firms were classified based on their adherence to GRI guidelines, with data sourced from the Refinitv Eikon database. Model 4 in Table 8 presents that the analysis using GRI-aligned disclosures yielded results consistent with those obtained using the binary carbon disclosure variable, thereby validating the robustness of the main findings.

4.4 Controlling for endogeneity bias

From an econometric realm, it is well-articulated that the overwhelming majority of dilemmas that encounter research in accounting and finance refer to endogeneity concerns. In this vein, static panel data estimators Pooled OLS, fixed effect and random effect are not solid enough to suppress the detrimental influence of endogeneity. Therefore, we rerun the study regression by using a two-step system generalized method of moments (GMM) estimator. The GMM was developed by Arellano and Bond (1991) and Blundell and Bond (1998) to control the endogeneity bias and offer robust outcomes. More importantly, it is worth mentioning that the GMM will be superior when considering the dynamic effect of the dependent variable in the prior period on the model's right side. Literally, carbon emission reporting is not merely driven by the current year's AC effectiveness, but the prior year's carbon emission reporting affects the aforementioned nexus. In this sense, the full dynamic model for carbon emission reporting can be outlined as follows:

$$Carbon\_Disc_{it} = \alpha_0 + \beta_1 Carbon\_Disc_{it}(t-1) + \beta_2 AC_{SIZEit} + \beta_3 AC_{INDit} + \beta_4 AC_{EXPit} + \beta_5 AC_{MEETINGit} + \beta_6 SIZE_{it} + \beta_7 LEV_{it} + \beta_8 ROE_{it} + \text{Fixedeffects} + \varepsilon_{it} \quad (3)$$

The full dynamic model for carbon emission performance can be expressed as follows:

$$Emission\_score_{it} = \alpha_0 + \beta_1 Emission\_Score_{it}(t-1) + \beta_2 AC_{SIZEit} + \beta_3 AC_{INDit} + \beta_4 AC_{EXPit} + \beta_5 AC_{MEETINGit} + \beta_6 SIZE_{it} + \beta_7 LEV_{it} + \beta_8 ROE_{it} + \text{Fixedeffects} + \varepsilon_{it} \quad (4)$$

Tables 9 and 10 present the empirical findings of the GMM. As shown in the tables, the outcomes are somewhat similar to the main findings reported in Tables 5 and 6. Hence, the findings of the baseline models are robust to the GMM results.

5. Conclusion

This study investigates the effect of attributes of ACs, such as size, independence, expertise and frequency of meetings, on the carbon emissions disclosure and performance of European companies that are included in the STOXX Europe 600 index during the period spanning from 2012 to 2022. The regression analysis results indicated that AC members' size, independence and expertise had a positive and statistically significant effect on carbon emissions disclosure. This supports the predictions of agency theory, as a larger AC size may decrease the information asymmetry level and the independence of AC members can enhance their objectivity and impartiality in overseeing the management's practices, including carbon emissions disclosure and AC expertise in finance and accounting can facilitate the collection and analysis of high-quality data on carbon emissions. However, the findings indicate that AC meeting frequency was not related to carbon emissions disclosure. Furthermore, when AC attributes are tested with carbon performance, the findings show that AC size, independence, expertise and meeting frequency positively and significantly impact carbon performance, proxied using a carbon emission reduction score.

This paper has several significant contributions to the existing literature. Firstly, this paper examines the influence of AC characteristics on carbon disclosure and performance, an area that

Table 9. The impact of audit committee attributes on the carbon emission reporting using GMM

Variables	(1) Sub-model	(2) Full model
Carbon_Disc_Total ***(t - 1)***	0.439*** (0.039)	0.508*** (0.035)
AC_SIZE	0.017*** (0.004)	0.001 (0.005)
AC_IND	0.002*** (0.000)	0.001*** (0.000)
AC_EXP	0.114 (0.082)	0.091 (0.088)
AC_MEETING	−0.075** (0.030)	−0.058* (0.031)
SIZE		0.038** (0.016)
LEV		−0.001 (0.038)
ROE		0.003*** (0.000)
Constant	14.94 (5.52)***	9.52 (5.67)*
Year fe	Yes	Yes
Country fe	Yes	Yes
Industry fe	Yes	Yes
Number of observations	5,668	5,668
Arellano–Bond test for AR (2) *p*-value	0.444	0.294
Sargan-Hansen test of over-identification *p*-value	0.521	0.166

Notes: This Table presents empirical findings of two-step system GMM estimator. Carbon_Disc_Total (*t* - 1) one year lagged value of carbon emission reporting, the estimated coefficients and *t* statistics are two-way system GMM. Arellanoe–Bond for AR (2) test of the null hypothesis of no serial correlation in the first-differenced residuals was examined. The findings show that the *p*-value for the AR (2) test is > significance level. This plainly points out that the null hypothesis of no serial correlation is accepted. Furthermore, Sargan-Hansen test of overidentifying restrictions was checked. The null hypothesis of this test is that all instruments included in the GMM estimator are valid "exogenous". The findings show that the *p*-values of this test are more than the significance level, implying that the instruments are valid. Superscripts *,**and *** statistically significant at 0.10, 0.05 and 0.01 levels, respectively

Source: Authors' own work

Table 10. The impact of audit committee attributes on the carbon emission performance using GMM

Variables	(1) Sub-model	(2) Full-model
Emission_Score ***(t - 1)***	0.589*** (0.063)	0.569*** (0.075)
AC_SIZE	1.992*** (0.349)	2.744*** (0.608)
AC_IND	0.058* (0.034)	0.090** (0.035)
AC_EXP	6.221 (5.976)	4.801 (6.718)
AC_MEETING	−5.119** (2.087)	−5.417* (3.112)
SIZE		1.817 (1.372)
LEV		−6.178* (3.917)
ROE		0.016 (0.019)
Constant	1247.72 (338.91)***	1374.95 (430.76)***
Year fe	Yes	Yes
Country fe	Yes	Yes
Industry fe	Yes	Yes
Number of observations	5,668	5,668
Arellano–Bond test for AR (2) *p*-value	0.371	0.434
Sargan-Hansen test of over-identification *p*-value	0.427	0.351

Notes: This Table presents empirical findings of two-step system GMM estimator. Emission_Score (*t* - 1) one year lagged value of carbon emission performance, the estimated coefficients and *t* statistics are two-way system GMM. Arellanoe–Bond for AR (2) test of the null hypothesis of no serial correlation in the first-differenced residuals was examined. The findings show that the *p*-value for the AR (2) test is > significance level. This plainly points out that the null hypothesis of no serial correlation is accepted. Furthermore, Sargan-Hansen test of overidentifying restrictions was checked. The null hypothesis of this test is that all instruments included in the GMM estimator are valid "exogenous". The findings show that the *p*-values of this test are more than the significance level, implying that the instruments are valid. Superscripts*****,******and ******* statistically significant at 0.10, 0.05 and 0.01 levels, respectively
Source: Authors' own work

has been largely neglected in previous literature concentrated on CSR or broader environmental reporting (e.g. Al-Shaer and Zaman, 2018; Helfaya and Moussa, 2017). Secondly, this study extends the geographical scope of current literature that has primarily concentrated on the UK, US and Australia by analysing companies listed on the STOXX 600 index and from 17 European countries. Such analysis offers a valuable understanding of how firms function under the EU's stringent environmental guidelines, providing unique perspectives on governance and sustainability-related issues in this influential region (Velte, 2023). Thirdly and theoretically, this study promotes the agency's theoretical perspective by investigating its relevancy to CG mechanisms and environmental reporting in different-size organisations, underlining the contribution of AC characteristics in directing non-financial reporting. Finally, the results highlight the role of ACs in improving carbon disclosures' accuracy and reliability, promoting transparency and enriching our knowledge of CG in environmental sustainability.

Based on these contributions, the study has theoretical and practical implications. In terms of theoretical implication, this study advances the agency's theoretical perspective by showing how specific AC characteristics (i.e. size, independence and financial expertise) reduce agency issues and improve transparency and trust, especially in non-financial reporting. By connecting these attributes to carbon disclosure and emission performance, the study underscores the role of ACs in promoting accountability and driving environmental sustainability (Al-Shaer and Zaman, 2016; de Villiers *et al.*, 2022). Carbon disclosure is defined as reporting carbon emissions practices that reflect firms' transparency (Román *et al.*, 2021), while carbon emission performance estimates the efficacy of emission

reduction efforts relative to industry benchmarks. These dimensions underscore the dual effect of AC on disclosure practices and actual environmental outputs.

From a practical perspective, this study offers significant implications for firms, policymakers and society. For instance, firms can improve their carbon reporting practices and performance by creating specific attributes for ACs. Our results, for example, show that increasing AC size permits an extensive scope of expertise and enables better workload distribution, enhancing supervision (Zaman and Valentinčič, 2019). Similarly, establishing independence within the AC promotes impartial decision-making. Also, increasing financial expertise among AC members enables them to effectively manage the complexities of carbon-related issues (Liao *et al.*, 2015). This, in turn, improves carbon disclosures' quality and strengthens the company's commitment to decreasing emissions.

For policymakers, the results of this study suggest that robust regulations should be implemented to direct companies to maintain their ACs' governance. For example, mandatory disclosures about AC attributes allow various stakeholder groups to assess governance activities critically. In addition, establishing minimum criteria for AC independence and financial literacy can lead to better governance structure and enhance carbon-related results. Aligning these directions with frameworks like the EU Directive 2014 / 95/EU on non-financial reporting could achieve consistency and overall adoption of best practices (Birindelli *et al.*, 2018).

Finally, enhanced carbon reporting and performance have significant societal implications. Transparent carbon disclosure can improve society's trust in corporate sustainability efforts, while enhanced emission performance illustrates a vital commitment to environmental management. In turn, this may attract sustainable investors, enabling greater capital allocation to environmental-oriented firms. In this regard, future studies could investigate how these governance mechanisms shape public attitudes and support societal actions to handle climate change issues.

Although this study has valuable contributions and implications, it has some limitations that future studies can address. Firstly, because of the data availability, carbon emissions disclosure measurement was limited to a binary variable (i.e. the presence or absence of such carbon disclosure "in tons" in a given year). Thus, future studies should use more comprehensive measurements (e.g. the one offered by CDP) to gain a more in-depth comprehension of carbon reporting measures. Secondly, this research controlled for industry-level CSR sensitivity but not country-level CSR sensitivity, which could also influence carbon emissions disclosure and performance. Therefore, future research can consider country-level CSR sensitivity to address this limitation. Thirdly, several attributes of ACs (e.g. gender diversity, education, nationality and the gender of the AC chair) were not considered because of the data availability. Hence, future studies can investigate these characteristics to understand ACs' role further. Finally, as this paper examines European companies, the results may not be fully generalisable to other regions with various institutional frameworks and regulations. In fact, the stringent environmental regulations in Europe, exemplified by the EU Directive 2014 / 95/EU, form a unique governance environment promoting higher accountability and transparency. Thus, conducting a comparative analysis with companies in regions such as North America or Asia, where cultural approaches and regulations to environmental governance differ, can demonstrate significant contrasts. Such analysis can enrich our understanding of governance mechanisms across diverse contexts and show the extent to which regional contexts shape the ACs' role in affecting carbon disclosure and performance.

Note

1. These variables are defined in Table 1.

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