Journal of International Accounting, Auditing and Taxation 55 (2024) 100618

Contents lists available at ScienceDirect

Journal of International Accounting, Auditing and Taxation

Does female director expertise on audit committees matter for carbon disclosures? Evidence from the United Kingdom

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ARTICLE INFO

Keywords:
Gender diversity
Accounting experts
Non-accounting experts
Audit committees
Carbon disclosures

ABSTRACT

We investigate whether accounting and non-accounting female financial experts on audit committees influence carbon disclosures. Based on a sample of listed firms from the United Kingdom for 2009–2015, our findings show that non-accounting female experts on audit committees increase carbon disclosures. Our results support the view that non-accounting female experts possess greater business knowledge and are skilled in foreseeing the impact of management's decisions, thus, enhancing carbon disclosures. Furthermore, our results are robust to alternative estimation techniques and endogenous concerns. We also find that firms in less carbon-intensive industries benefit from higher carbon disclosure in the presence of female non-accounting experts on audit committees. This study contributes to the recent research on corporate governance and carbon disclosures. Further, it extends recent studies identifying the specific characteristics of female directors that enhance environmental disclosures. Moreover, we respond to the calls for research on the personal attributes of directors and carbon disclosures by examining whether the accounting and non-accounting expertise of female directors on audit committees affects carbon disclosures.

1. Introduction

We investigate the research question of whether the accounting and non-accounting expertise of female directors on audit committees influence carbon disclosures. Given the increased levels of environmental risk and health hazards driven by carbon emissions (Li et al., 2018), stakeholders, such as shareholders, employees, governments, and local communities, demand greater carbon information from firms (Bravo & Reguera-Alvarado, 2019; Bui et al., 2020). Therefore, carbon disclosures act as a medium "*through which firms can demonstrate their oversight and accountability to stakeholders*" (Bui et al., 2020, para.1). Consequently, firms' carbon emission disclosures provide relevant information for stakeholders' decision-making (Liao et al., 2015). Carbon reporting has also been proposed as a solution for mitigating carbon emissions, given that it enables stakeholders to provide critical feedback on a firm's carbon policies (Velte et al., 2020).

The primary duty of an audit committee is to oversee financial reporting quality. However, a stream of research argues that the actual performance of audit committee responsibilities is paradoxical and contextual, as audit committee members act primarily as directors of firms and interact with executives and auditors outside the documented meetings (Wu et al., 2014). Audit committees have been associated with better firm performance (Al-Okaily & Naueihed, 2019). As a result, there is no clear boundary[1] between the role of an audit committee member and the role of a corporate director given that these functions are performed by the same individuals (Wu et al., 2014). In brief, an effectively composed audit committee could well manifest itself beyond the financial reporting domain.

Considering the current environmental crisis, which is likely to affect the business environment, most stakeholders now expect audit

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[1] An audit committee member is primarily a corporate director as well as a member of a sub-committee (such as an audit committee or a sustainability committee). Wu et al. (2014) report that audit committee members work in an overlapping capacity, where audit committees do not consist of financial and accounting experts only, but also include directors with advisory expertise, and such qualities are not mutually exclusive.

https://doi.org/10.1016/j.intaccaudtax.2024.100618

Available online 19 April 2024
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committees to oversee the reporting of non-financial information.[2] As a result, the audit committee's role has expanded beyond monitoring financial reports (Al-Shaer & Zaman, 2018; Bravo & Reguera-Alvarado, 2019). A recent survey conducted by Ernst & Young (EY) finds that most institutional investors consider it essential for audit committees to review sustainability reporting (EY, 2014). Audit committees are, therefore, increasingly focusing on sustainability disclosures (Al-Shaer & Zaman, 2018). Consequently, audit committees are expected to influence carbon disclosures, as their oversight helps present more accurate and complete carbon information (Trotman & Trotman, 2015).

Empirical evidence suggests that female directors on audit committees influence environment disclosures positively (Appuhami & Tashakor, 2017; Bravo & Reguera-Alvarado, 2019). Proponents of gender diversity posit that females hold unique communal values compared to males and are more concerned with the firm's environmental impact (Haque, 2017; Nadeem et al., 2017). Further, females usually show a more stakeholder-centric approach than men; thus, they are more likely to consider stakeholder demands for enhanced sustainability disclosures (Arayssi et al., 2016). However, according to the resource dependence theory, the different backgrounds of directors may influence the effectiveness of female directors on audit committees (Dhaliwal et al., 2010). Elmaghri et al. (2019) and Ramon-Llorens et al. (2020) substantiate that the effectiveness of female directors in sustainability disclosures is contingent on whether the female directors possess specific characteristics. Thus, it is crucial to analyze the impact of female directors' accounting and non-accounting expertise of audit committees on environmental reporting. The motivation for this study stems from the debate on whether accounting or non-accounting female experts on audit committees are effective in the current environment of broader corporate reporting and disclosures.[3] Prior literature (Abbasi et al., 2020) fails to consider such debate in the setting of carbon disclosures.

We focus specifically on accounting and non-accounting experts because the evidence is mixed in terms of whether accounting or non-accounting experts are effective in audit committees (García-Sánchez et al., 2017; Ghafran & O'Sullivan, 2017). In addition, the United States (US) Securities and Exchange Commission (SEC) considers both accounting and non-accounting financial experts to be acceptable for meeting the requirement to include a financial expert on the audit committee, although only accounting (financial) experts were acceptable initially (Bilal et al., 2018). Although Al-Shaer and Zaman (2018) report that audit committee members' attributes, such as financial expertise, are positively associated with sustainability reporting, they fail to segregate financial experts into accounting and non-accounting experts. Velte et al. (2020) also called for research on the relationship between the personal characteristics of particular directors and carbon disclosures.

Ascui and Lovell (2012) posit that climate change has raised concerns about economic and social sustainability and acknowledge the growing role of accounting expertise in emission trading schemes: carbon accounting and carbon pricing. A stream of corporate governance research consistently argues that carbon disclosure requires a comprehensive knowledge of accounting standards and procedures. The audit committee is the primary authority able to facilitate resources and oversee carbon disclosure practices in the financial reporting process. Also, Tingbani et al. (2020) report that gender-diverse firms are likely to report carbon disclosure voluntarily but fail to establish a role for the audit committee in carbon disclosure. Considering two streams of research, we argue that female audit committee members with accounting expertise are vital to the practice of carbon disclosure in the financial reporting process. On the other hand, non-accounting experts may enhance carbon disclosures owing to their better understanding of business operations and know-how of firm valuation (Bilal et al., 2018; Abbasi et al., 2020). Therefore, accounting and non-accounting expertise offer distinct mechanisms through which they could influence carbon disclosures.

Utilizing FTSE (Financial Times Stock Exchange) 350 non-financial firms from the period 2009 to 2015 and applying ordinary least square (OLS) regression analysis, we find that female non-accounting experts on audit committees positively affects carbon disclosures, while there is no significant association between female accounting experts on audit committees and carbon disclosures. Our results are robust to endogenous concerns as we have consistent results when using two-stage least squares regression, propensity score-matched regression analysis, and generalized method of moments methodology.

Interesting results emerge when we separate the samples into different dimensions. First, we divide the sample between carbon-intensive and less carbon-intensive industries. Our results suggest that female non-accounting experts on audit committees improve carbon disclosures only in the case of less carbon-intensive industries. Second, our findings show a positive association between carbon disclosure and non-accounting female expertise on audit committees for all firms regardless of whether they have corporate social responsibility (CSR) committees, confirming that the existence of a CSR committee does not usually enhance carbon disclosure. Third, we split the sample between pre-mandate and post-mandate regimes to address whether rules requiring gender diversity impact a firm's disclosure of its carbon disclosure. Our main findings continue to hold, which suggest that a female audit committee member with non-accounting experience would enhance carbon disclosure. Finally, based on tokenism analysis, we conclude that carbon disclosure increases in scenarios where an audit committee includes two female members with expertise in either accounting or non-accounting areas.

This study offers several contributions to the existing literature. *First*, our findings extend the current literature on the impact of corporate governance and carbon disclosure programs (e.g., Prado-Lorenzo & Garcia-Sanchez, 2010; Liao et al., 2015; Bui et al., 2020). Haque (2017) and Liao et al. (2015) examine the impact of female board diversity on carbon disclosure scores and find that firms' carbon disclosures are enhanced in the presence of female board directors. However, Prado-Lorenzo and Garcia-Sanchez (2010) find no link between female directors and carbon disclosures, suggesting that certain characteristics of female directors may drive the above-mentioned positive association. For example, Bui et al. (2021) acknowledge that other dimensions of gender diversity may also affect the relationship between female directors and carbon reporting. Therefore, we extend the research by assessing whether female directors' accounting and non-accounting expertise on audit committees affect the carbon disclosure score reported by CDP. *Second*, we contribute to the literature (Elmaghri et al., 2019; Ramon-Llorens et al., 2020) identifying specific characteristics of female directors that influence environment disclosures. Elmaghri et al. (2019) assess the age and education of female directors in terms of environmental disclosures. Ramon-Llorens et al. (2020) tests the relationship of CSR disclosures with three types of female directors: advisors (those with specialization in their respective fields), community leaders, and industry experts. Our study differs from these studies as we focus specifically on carbon disclosures, which are considered to have a far-reaching impact on the environment. *Finally*, we also have evidence

[2] A corporate board operates through several sub-committees. The UK Corporate Governance Code (Financial Reporting Council, 2018b) recommends that firms should establish audit, remuneration, and nomination committees, and often those committees make recommendations for action to the full board. While none of these sub-committees is solely responsible for overseeing environmental compliance, audit committees generally have greater control over the information disclosure in annual reports. Recently, the role of the audit committee has broadened to include oversight of the company's overall risk management efforts, which includes financial risk and other significant risks, such as carbon disclosures.

[3] Following the emergence of climate change issues, stakeholder pressure has led corporations to disclose environmental, social, and governance (ESG) performance along with financial information (Climate Disclosure Standards Board (CDSB), 2012; Dumay et al., 2016).

that carbon disclosure practice improves in the presence of non-accounting female expert audit committee members, irrespective of the existence of a CSR committee. Thus, arguably, firms have a beneficial effect on carbon disclosure from female directors on audit committees with non-accounting expertise.

Our study is structured in the following manner. Section 2 provides the background of this study and develops hypotheses. Section 3 details the methodology used in this research, while Section 4 presents the empirical results. Section 5 explains additional analyses. Lastly, Section 6 concludes this study.

2. Institutional environment, theory, and hypotheses development

2.1. UK regulatory environment

In 1997, the Kyoto Protocol was introduced as the first major international regulatory emission trading scheme outlining primary strategies for reducing carbon emissions. Therefore, in 2005, the European Emission Trading Scheme (EU ETS) was launched to support the EU-wide goal of reducing carbon emissions to the level required by the Kyoto Protocol (European Commission, 2015). The EU ETS is a cornerstone of the EU's policy to combat climate change and a key tool for reducing, on a cost-effective basis, greenhouse gas (GHG) emissions from the regulated sectors. PHASE ONE was launched to tackle climate change issues by cutting carbon emissions in 2005–2007 and included industries such as oil refineries, coke ovens, and iron and steel plants, as well as cement, glass, lime, bricks, ceramics, pulp, paper, and cardboard production. The agreement was novel for its clear long-term plan to limit temperatures for the planet, in combination with a straightforward method for achieving this aim, with more than 800 of the largest listed firms around the world favoring a global deal to reduce GHG emissions (CDP, 2016).

In addition, there has been increased adoption of national and international climate change mitigation policies, such as pricing carbon emissions in the form of carbon taxes as well as mandatory process and product standards (Bebbington & Larrinaga-Gonzalez, 2008). As a result, businesses, especially those in carbon-intensive industries, are facing increased risks in the form of increased costs (Eleftheriadis & Anagnostopoulou, 2015). Nevertheless, carbon emission reporting is not standardized and is largely inconsistent across firms. Even leading firms from the most environmentally sensitive industries make vague emissions disclosures with unexplained figures and discordant methodologies (Dragomir, 2012). This is potentially troubling, as the lack of comparability across firms can limit the ability of stakeholders to accurately assess differences in carbon emission performance (Liesen et al., 2015), and may lead to ineffective responses from financial markets (Clarkson et al., 2015). In an attempt to achieve consistency, in July 2018, the Financial Reporting Council (2018a) issued guidance on reporting carbon emissions in financial reports.[4]

2.2. Theoretical background

Prior studies have used a variety of theories, including agency theory, resource dependency, legitimacy theory, and stakeholder theory, to give an in-depth understanding of carbon performance (Liao et al., 2015; Elmaghri et al., 2019). In a related study, Elmaghri et al. (2019) contend that the contribution of women directors towards environmental disclosures stems from the multi-theoretical lens. Following Nuber and Velte (2021) and Elmaghri et al. (2019), we use several theories to support our investigation since one theory might not adequately explain the framework of our hypotheses. In addition, the multi-theory lens help to analyze a more realistic relationship between women's expertise in audit committee and carbon disclosure, as Nuber and Velte (2021) suggested.

Agency theory contends that agency conflict results from divergent aims and risk preferences between the principal (owner) and agent (manager), which are rooted in the disproportionateness of information. Elmaghri et al. (2019) point out that female directors may help curtail agency conflicts and reduce the information asymmetry between managers and shareholders. Moreover, the agential view postulates that females are more cautious in safeguarding well-being and environmental hazards (Davidson & Freudenburg, 1996) and more capable of thinking independently compared to males (Adams & Ferreira, 2009). This aids females in acting as better monitors concerning ecological statements, such as reports on GHG emissions.

Resource dependence theory (RDT) postulates that directors act as resources for attaining firms' sustainability objectives by providing advice and counsel (Al-Shaer & Zaman, 2018; Elmaghri et al., 2019). This theory suggests that such resources enable firms to take advantage of the unique capabilities of directors and, thereby, attain competitiveness through better sustainability reporting (Bear et al., 2010). RDT posits that directors' input into environmental disclosures may reflect the different backgrounds of female directors (Ramon-Llorens et al., 2020), such as expertise, experience, and knowledge (Lawati et al., 2021). This helps mitigate the informational asymmetry between boards of directors and shareholders, as the audit committee members' human capital conveys the reliability of the information disclosed in annual reports (Lawati et al., 2021). In line with RDT, females possess specific characteristics that may act as resources from which firms are likely to benefit (Abbasi et al., 2020).

Following the legitimacy view, Elmaghri et al. (2019) suggest that the firm success can be affected by factors such as a company's ability to adapt to the unique geographic and cultural norms and legislative regulations of the countries in which it operates. In this vein, Rosener (1995) contends that women are flexible, which shows their ability to work under equivocal conditions, which helps them adapt to any institutional changes that might occur within or outside a country. According to the neo-institutional perspectives, businesses are under intense institutional pressure to improve environmental performance to adhere to sound statutory and worldwide environmental management practices (Wang et al., 2018). Undoubtedly, embedding external standards, rules, and practices inside an organization's processes and procedures can provide credibility to such actions (Shahab et al., 2018). Since there is evidence that having more women on boards leads to better environmental performance (Shahab et al., 2018), female board members might boost a company's reputation and strengthen the company's legitimacy in society.

Stakeholder theory indicates that stakeholders (who either influence companies or are affected by the activities of corporations) may demand that companies disclose how their actions have affected the climate and any steps adopted to mitigate their environmental impact (Gray, 2000). This is then likely to lead firms to provide carbon disclosures. For instance, females may adopt a more stakeholder-oriented approach than men, enabling them to consider the interests of multiple stakeholders (Arayssi et al., 2016; Haque, 2017). This is likely to result in improved reporting on the environmental impacts of firms, given that such enhanced disclosures cater to the needs of stakeholders (Tingbani et al., 2020).

Gender identity theory postulates that, owing to their unique upbringing, females are inculcated with values aligning with care and compassion, and thus, they are more likely than men to consider the adverse consequences of corporations' impact on the environment. Moreover, women directors are expected to be more ethical, suggesting more transparent disclosures (Zalata et al., 2018). Furthermore, these directors are more likely to be risk-averse and less overconfident (Abbasi et al., 2020), which translates into enhanced environmental reporting

[4] The Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 is available at https://www.legislation.gov.uk/ukdsi/2013/9780111540169/contents.

monitoring. Moreover, regulators are increasingly implementing female quotas for Board of Directors membership (Lai et al., 2017). Hence, it could be argued that female directors on audit committees improve the carbon reporting process. Empirical evidence also finds a positive association between female directors on audit committees and environmental disclosures (Appuhami & Tashakor, 2017; Bravo & Reguera-Alvarado, 2018). Overall, due to the above characteristics, such as supervisory skills, resources, caring, flexibility, and shareholder orientation, female directors may improve the corporate governance quality, enhance carbon reporting, and have the propensity to make environmentally friendly decisions.

2.3. Hypotheses development

2.3.1. Accounting experts

Accounting experts may possess unique skills and techniques, such as numeracy, as well as understanding assets and liabilities, company risks, reporting, and logic, that could prepare them for enhancing carbon disclosures. In addition, accountants' professional culture and training suggest that they possess highly specialized knowledge and valuable expertise for better carbon reporting (Lovell & MacKenzie, 2011). Several professional accounting bodies, such as the Association of Chartered Certified Accountants (ACCA) and the Institute of Chartered Accountants in England and Wales (ICAEW), are increasingly undertaking steps to ensure that their members are aware of climate change reporting (Lovell & MacKenzi, 2011; Ascui & Lovell, 2012;). For instance, ACCA has published a report providing detailed guidelines for adopting full environmental costs (Bebbington et al., 2001). CPA Australia and the Chartered Accountants Australia and New Zealand (CAANZ) offer professional training courses and organize workshops and seminars related to climate change (Lovell & McKenzie, 2011). Deloitte puts all staff through a mandatory climate change course (PQ Magazine, 2021, p. 8).

Haslam et al. (2014) added that accountants have a competitive advantage in managing sustainability, as they are legitimate agents of accountability and can quantify the impact of emissions expressed in tons or other units of measurement. Such efforts from professional bodies and accounting firms, and their professional accountability, can make accountants experts in carbon reporting. In addition, corporate governance research on gender diversity suggests that boards and subcommittees represented by female directors have better corporate disclosure and financial reporting quality.[5] As a result, it is expected that female accounting experts on audit committees will improve the quality of environmental reporting. Furthermore, the presence of female accounting experts on audit committees brings strategic resources to the audit committees on which they serve and enhances voluntary disclosures, like carbon reporting, by generating new ideas, promoting effective monitoring, and upholding ethical standards (Abbasi et al., 2020; Lawati et al., 2021). Stakeholder orientation, ethical standards, and the communal values of female accounting experts could lead to superior ability compared to men in enhanced sustainability reporting, even in equal professional positions (Arayssi et al., 2016; Haque, 2017; Nadeem et al., 2017). Therefore, we propose the following hypothesis:

H1: There is a positive association between female accounting experts on audit committees and carbon disclosures.

2.3.2. Non-accounting experts

A team performing a carbon assurance engagement needs a variety of skill sets in addition to accounting knowledge. In November 2008, the Association of Consulting Engineers Australia (ACEA) submitted the following as part of the Department of Climate Change external audit consultation process:

> Much of the efficacy of the audit process will be dependent upon and relate to the engineering qualifications and competency of auditors, and less on the contributions of corporate law, business management and financial accounting … We feel the full involvement of engineering and related practitioners offers the genuine understanding of the physical processes that lead to the various types of emissions. (Huggins et al., 2011, p. 7)

Empirical research suggests that non-accounting qualifications are not mutually exclusive but highly valuable for implementing climate disclosure programs. Channuntapipat et al. (2020) argued that non-accountancy directors might have more expertise in sustainability-related subject matter owing to their industry experiences or specific background. In addition, non-accounting experts with finance backgrounds, such as those who have held or hold financial management positions, are experienced in dealing with capital markets. Thus, they are more capable of ascertaining the consequences of business strategies (Dhaliwal et al., 2010) and more likely to be aware of the impact of poor carbon disclosures on firm value, thereby improving carbon disclosures. Evidence shows that audit committee members with chief executive officer (CEO) experience (non-accounting expertise) possess business and industry knowledge that may contribute to the overall effectiveness of audit committees (Dhaliwal et al., 2010; Bilal et al., 2018; Abbasi et al., 2020). Bravo and Alcaide-Ruiz (2019) showed that non-accounting experts on audit committees positively affect forward-looking financial disclosures. The appointment of female non-accounting experts on audit committees brings diversity, improves board effectiveness, and enhances accountability and transparency, hopefully ensuring the accuracy of carbon reporting. Therefore, we propose the following hypothesis:

H2: There is a positive association between female non-accounting experts on audit committees *and carbon disclosures.*

3. Methodology

3.1. Sample

We choose the UK regulatory environment to examine our research questions. The UK is one of the largest emitters of GHG among G7 countries, and a significant proportion of UK companies have agreed proactively on Scopes 1 and 2 emission disclosures, suggesting their relevance to our research question (Alsaifi et al., 2020a). Our sample comprises non-financial FTSE 350 firms. We exclude financial companies from the analysis owing to their different regulatory and disclosure regulations (Appuhami & Tashakor, 2017; Ghafran & O'Sullivan, 2017). Moreover, FTSE 350 firms are covered by relatively stringent corporate governance regulations compared with non-FTSE 350 firms; hence, we focus on companies that are continuously listed on the FTSE 350 index (Ghafran & O'Sullivan, 2017; Abbasi et al., 2020). Our study covers the period of 2009–2015. The global financial crisis "might have forced companies to be involved in more social activities to legitimize their existence" (Jizi, 2017, p.642). Therefore, we begin our sample period from 2009 to avoid the impact of the financial crisis of 2007–08 (Hassanein et al., 2019; Alsaifi et al., 2020b). Our data for the carbon disclosure was collected from the CDP website. In 2016, there was a substantial amendment made by CDP to its scoring methodology. The CDP's report in 2016 states that the "2016 scoring approach is fundamentally different from 2015, and different information is requested, so 2015 and 2016 scores are not directly comparable" (CDP, 2016, p.11; Alsaifi et al., 2020a). Therefore, following Alsaifi et al., (2020a,2020b), we collect our data through the end of 2015 to maintain data consistency. Corporate governance data was hand-collected from the annual reports, while financial characteristics were collected from the Osiris

[5] The regulatory pressure to increase gender diversity, combined with the limited supply of female directors, can cause firms to appoint qualified, but informationally disadvantaged directors (Mobbs et al., 2021). Sultana et al. (2020) argues that there is a limited supply of female accountants in Australia, resulting in limited roles for female accounting experts on audit committees.

Table 1
Sample distribution by industry and year.

Industry	Observations	Year	Observations
Energy	60	2009	105
Materials	90	2010	120
Industrials	265	2011	122
Consumer discretionary	212	2012	126
Consumer staples	96	2013	131
Health care	43	2014	132
Information Technology	50	2015	132
Communication services	19		
Utilities	33		
Total Firm-year observations	868		868

and Datastream databases. Owing to missing information related to the variables in our model, this study comprises 868 firm-year observations. Table 1 presents the sample distributions.

3.2. Model

To test our hypotheses, we use the following OLS regression analysis model:

$$\begin{aligned} carbondisclosure_t = {} & \alpha_0 + \alpha_1 femaleaccount + \alpha_2 femalenonaccount \\ & + \alpha_3 otherfemale + \alpha_4 boardfemale + \alpha_5 boardsize \\ & + \alpha_6 ACmeet + \alpha_7 ACsize + \alpha_8 boardindependent \\ & + \alpha_9 CSRcommittee + \alpha_{10} leverage + \alpha_{11} ROA + \alpha_{12} size \\ & + INDUSTRYeffect + YEAReffect + \varepsilon_t \cdots\cdots\cdots\cdots \end{aligned} \quad (1)$$

To construct our independent variables of interest (female accounting financial experts and female non-accounting financial experts on audit committees), we follow Bilal et al. (2018) and Ghafran and O'Sullivan (2017) in distinguishing the expertise. Accounting financial experts are ascertained as female audit committee members who have held or hold accounting-related positions, such as chartered accountants, chief financial officers (CFOs), and auditors. Non-accounting financial experts are defined as female audit committee members who have held or hold company president, CEO, or financial management positions.[6] The US SEC differentiates between accounting financial experts and non-accounting financial experts (Bilal et al., 2018). Hence, although non-accounting financial experts encompass those financial experts who possess limited accounting knowledge, they do possess certain characteristics that may affect carbon disclosures (as explained in Section 2). In addition, if an audit committee member possesses accounting financial and non-accounting financial expertise, it could be argued that she is likely to utilize her accounting knowledge to further carbon disclosures, given the specialist knowledge acquired through attaining professional accountancy qualifications.

All of the above variables are defined in the appendix. Our primary variables of interest are $\alpha_1 femaleaccount$ and $\alpha_2 femalenonaccount$, which examines our two hypotheses H_1 and H_2, respectively. We calculate the *female account* as a proportion of female accounting experts on the audit committee to the size of the audit committee, and calculate *female nonaccount* as a proportion of female non-accounting (financial) experts on the audit committee to the size of the audit committee.

Our dependent variable (*carbon disclosure*) is a count variable based upon the CDP's carbon disclosure score. We follow Alsaifi et al., (2020a), Bui et al. (2020), and Liao et al. (2015) in using the CDP database to ascertain the carbon disclosure of firms. CDP is an independent and non-profit organization that works with institutional investors and companies to disclose the carbon emissions information of corporations (Alsaifi et al., 2020a; Cotter & Najah, 2012).[7] CDP scores carbon disclosures from 0 to 100 (higher scores depict a higher quality of disclosures), based on the firms' responses to the annual questionnaire devised by CDP (Ben-Amar & Mcllkenny, 2015). Questions in the questionnaire range from binary to those requiring narrative answers that are scored based on the standardized methodology developed by CDP (Luo & Tang, 2014), thereby capturing both the extent and quality of carbon information provided by the firm (Cotter & Najah, 2012). For example, companies are awarded a higher score if "firms disclose specific details of costs or investments in particular initiatives or state the financial implications of a certain risk or opportunity" and if the "importance and materiality of specific information to certain users" are incorporated (Bui et al., 2020, para.21). CDP's carbon disclosure scoring "is considered as the most credible corporate environmental disclosure rating system in the world" (Bui et al., 2020, para.20).

We also use several control variables in our model. A greater frequency of audit committee meetings (*AC meet*) increases monitoring intensity (Zaman et al., 2011) and, thereby, aids members in evaluating disclosures. Further, large audit committees (*AC size*) suggest a greater talent pool (Zalata et al., 2018) and, therefore, enhanced ability to monitor disclosures effectively. While the number of audit committee members measures audit committee size, the number of audit committee meetings is determined by the number of audit committee meetings each year (Al-Shaer & Zaman, 2018). We also include female directors on audit committees apart from accounting and non-accounting financial experts in order to control for other characteristics of female directors affecting carbon disclosures (Elmaghri et al., 2019). As a result, this study utilizes the proportion of female directors on audit committees who are non-financial experts (do not possess accounting or non-accounting financial expertise) (*other female*). We do not predict the direction for this variable because certain characteristics may affect carbon disclosures positively while others could have a negative association.

With their diverse expertise, larger boards may enhance carbon disclosures with their diverse expertise (Zalata et al., 2018). We utilize board size (*board size*) as a control variable and compute it as the number of directors on the board (Nadeem et al., 2020). Moreover, independent directors' lack of financial or personal association with firms (Abbasi et al., 2020) is likely to affect carbon disclosures positively. We measure board independence (*board independent*) as the proportion of independent directors on the board (Nadeem et al., 2020). Gender diversity at the board level may also affect carbon reporting, as Liao et al. (2015) document that females on boards are associated with higher carbon emission reporting. Therefore, we control the variable of female board members (*total board female*) to see the incremental effect of female accounting/non-accounting expertise. We follow the procedure of Lai et al. (2017), wherein they controlled for the effect of female board members when studying the impact of female audit committee directors (*total female AC*). In line with Lai et al. (2017), this study determines the

[6] Non-accounting experts include supervisory experts (such as CEOs) and finance experts (such as financial analysts). Categories of accounting experts and non-accounting experts are mutually exclusive. Biographical details of female audit committee members were thoroughly read to separate the ones with accounting specializations. For example, if someone is a member of a professional accounting body and currently holding a financial management position, then she is deemed to be an accounting expert.

[7] CDP, originally known as the Carbon Disclosure Project, is a global non-profit organization that drives companies and governments to reduce GHG emissions, safeguard water resources, and protect forests. CDP invites companies to participate in the project by supplying carbon information using a well-designed questionnaire. However, companies can decide to accept or decline the offer to participate in the questionnaire. Hence, the CDP scores represent a voluntary reporting context because the firm is not under a statutory obligation to respond to the request. CDP data goes through a much more rigorous cleaning process because CDP analysts are in direct contact with the company and check the data as it is submitted.

Table 2
Descriptive statistics of model variables.

Variables	Mean	Standard Deviation	Minimum	Maximum
carbon disclosure	58.363	32.420	0	100
total female AC	0.207	0.183	0	0.75
female account	0.035	0.096	0	0.667
female nonaccount	0.131	0.158	0	0.667
other female	0.042	0.101	0	0.500
total board female	0.274	0.185	0	1
board female	0.066	0.080	0	0.300
board size	9.382	2.234	4	19
AC meet	4.406	1.578	1	15
AC size	3.892	1.009	2	8
board independent	0.558	0.106	0	0.857
CSR committee	0.304	0.460	0	1
leverage	0.602	0.211	0.001	1.331
ROA	0.096	0.102	−0.932	0.537
size	14.82	1.471	11.700	19.242

Note: For variable definitions, see Appendix.

female board members as the percentage of female directors who do not form part of the audit committee (*board female*). Lai et al. (2017) argue that this methodology helps determine the incremental effect of female audit committee members.

Owing to their greater visibility to stakeholders, large-scale firms are expected to disclose more information on carbon emissions (Yunus et al., 2016). Consequently, firm size (*size*) is included as a control variable and measured as the log of total assets (Nadeem et al., 2020). Carbon reporting may be costly for firms owing to the resources required for collecting information (Choi et al., 2013). Hence, the financial health of a firm could be an influential factor in making carbon disclosures. We use firm performance and leverage to depict the financial condition of firms (Zalata et al., 2018). Thereby, poorly performing and highly leveraged firms may affect carbon reporting negatively. Firm performance is measured as return on assets (*ROA*), and leverage (*leverage*) is defined as the ratio of total debt to total assets (Abbasi et al., 2020; Ghafran & O'Sullivan, 2017). Moreover, the presence of the CSR committee suggests that the firm is more active and willing to address the stakeholders' demand for greater carbon reporting. Hence, companies with CSR committees are more likely to disclose information about carbon emissions (Elsayih et al., 2018). Consequently, this study includes a binary variable, *CSR committee*, coded 1 if the firm constitutes the CSR committee, and otherwise 0 (Nadeem et al., 2020). Lastly, we control year and industry effects following Bravo and Reguera-Alvarado (2019) and Nadeem et al. (2017).

Table 4
OLS regression analysis – Accounting and non-accounting female experts on audit committees and carbon disclosures.

Variables	(1) Carbon Disclosure	(2) Carbon Disclosure	(3) Carbon Disclosure
female account	−0.241	–	−0.112
	(−1.25)		(−0.57)
female nonaccount	–	0.295***	0.276***
		(3.11)	(2.85)
other female	0.262*	0.407***	0.387***
	(1.77)	(2.69)	(2.81)
board female	0.273	0.462**	0.427*
	(1.21)	(2.120)	(1.88)
board size	1.021	1.019	1.082
	(1.13)	(1.19)	(1.24)
AC meet	−0.835	−0.071	−0.076
	(−0.74)	(−0.66)	(−0.67)
AC size	0.023*	0.075*	0.070
	(1.85)	(1.81)	(1.17)
board independent	0.064	−0.064	−0.054
	(0.19)	(−0.31)	(−0.074)
CSR committee	0.101***	0.943***	0.951***
	(3.05)	(2.84)	(2.95)
leverage	0.132*	0.111	0.118
	(1.78)	(1.46)	(1.51)
ROA	−0.038	−0.097	−0.077
	(−0.25)	(−0.61)	(−0.60)
size	0.059***	0.054***	0.057***
	(4.26)	(4.00)	(3.96)
Constant	0.760***	0.66***	0.67***
	(4.09)	(3.62)	(3.63)
Year fixed effects	YES	YES	YES
Industry fixed effects	YES	YES	YES
Firm-years	868	868	868
Adjusted R^2	38.5	39.6	39.7
F-statistics	18.84***	19.69***	19.55***
Chow test	$\chi 2 = 6.04$ and $p < 0.004$		

Notes: In Column 1 and Column 2, female accounting experts and female non-accounting experts are tested, respectively, while in Column 3, both are tested jointly. Standard errors are clustered at the firm level, and *t*-statistics are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10. For variable definitions, see Appendix.

4. Results and discussion

4.1. Descriptive statistics and correlation analysis

Table 2 shows that around 21 % of audit committee members are female directors, which suggests a greater presence of female directors

Table 3
Pearson correlations variable matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) carbon disclosure	1.000												
(2) female account	−0.000	1.000											
(3) female nonaccount	0.238*	−0.152*	1.000										
(4) other female	0.073*	−0.028	−0.171*	1.000									
(5) board female	0.230*	−0.115*	−0.110*	−0.092*	1.000								
(6) board size	0.372*	0.025	0.083*	−0.008	0.252*	1.000							
(7) AC meet	0.217*	0.048*	0.114*	−0.104*	0.098*	0.317*	1.000						
(8) AC size	0.191*	0.052*	0.217*	0.101*	−0.168*	0.376*	0.083*						
(9) board independent	0.279*	0.105*	0.141*	−0.052*	0.286*	0.380*	0.392*	0.338*					
(10) CSR committee	0.352*	0.063*	0.133*	−0.065*	0.109*	0.341*	0.322*	−0.041	0.204*	1.000			
(11) leverage	0.132*	0.096*	0.091*	−0.041	0.024	0.102*	0.028	0.075*	0.082*	0.149*	1.000		
(12) ROA	−0.151*	0.051*	−0.023	0.076*	0.023	−0.030	−0.081*	0.003	−0.010	−0.143*	−0.043	1.000	
(13) size	0.463*	0.016	0.160*	−0.073*	0.259*	0.639*	0.430*	0.215*	0.494*	0.445*	0.132*	−0.233*	1.000

Notes: * Indicates significance at the 0.10 level. For variable definitions, see Appendix.

on audit committees in the UK than in the US (Zalata et al., 2018). Female accounting financial experts, female non-accounting financial experts, and other female directors (non-financial experts) on audit committees are 3.5 %, 13.1 %, and 4.2 %, respectively, suggesting a greater presence of female directors with non-accounting expertise on audit committees. Around 27 % of board members are female. Among those, only 6.6 % of female board directors are not part of the audit committee, indicating that most UK female directors are on audit committees. Furthermore, Cotter and Najah (2012) report 59.6 as the mean value for CDP's carbon disclosure score, similar to our sample's mean value of 58.4. Our descriptive statistics imply that female directors may be inducted on the audit committee for monitoring, given that this committee is responsible for overseeing financial and non-financial reports. As a result, our study captures the female audit committee effect rather than the female board effect. We can infer from the policy implication point of view that firms are making an effort towards a greater presence of female directors by appointing them to boards and delegating them to sub-committees, such as audit committees, in capacities where they could contribute most effectively.

Table 3 presents the correlation matrix. It reports a positive correlation between female non-accounting experts on audit committees and carbon disclosures, but no significant correlation between female accounting experts on audit committees and carbon disclosures. Our study is unlikely to be affected by multicollinearity issues because the maximum variation inflation factor (VIF) is 2.99, which is considerably below the limit of 10 (Jackling & Johl, 2009).

4.2. Results of OLS regression analysis

Table 4 reports the findings of OLS regression. Column 3 of Table 4 reports a positive and significant association between female non-accounting experts on audit committees and carbon disclosures. At the same time, it documents no significant association between female accounting experts on audit committees and carbon disclosures. Therefore, hypothesis 1 is rejected. Our research findings have some plausible explanations, as a parallel stream of researchers suggests climate reporting is a complex area both qualitatively and, potentially, quantitatively different from other issues (International Federation of Accountants, 2021). In an ICAEW (2004) survey, 47 % view environmental issues as being outside the accountant's realm. The accounting profession is intrinsic to generally accepted accounting principles (GAAP) and the audit process (Channuntapipat et al., 2020), and unsuitable for the qualitative nature of sustainability. Therefore, it is assumed that carbon reporting tasks do not require a high degree of accounting sophistication. In regard to hypothesis 2, our results confirm that, although non-accounting experts do not possess specialist knowledge of accountancy, they possess certain other expertise/human capital (CEO and financial management experience), which results in enhanced carbon disclosures (Dhaliwal et al., 2010; Bilal et al., 2018; Abbasi et al., 2020;). Our descriptive statistics find far more female non-accounting experts than female accounting experts on audit committees. Thus, the non-significant result for female accounting experts may stem from the limited role of accounting experts that is attributable to the dominance of non-accounting experts in audit committees (Sultana et al., 2020; Lawati et al., 2021). Additionally, in Columns 1 and 2 of Table 4, we analyze our two hypotheses separately and find consistent results.

Some control variables are also significant and in line with our expectations. Large firms are positively linked with carbon disclosures. This supports the argument that large firms, given their greater visibility to stakeholders, increase carbon disclosures (Yunus et al., 2016). CSR committees are positively associated with carbon disclosures, which confirms that firms with CSR committees are more willing to address the demand for greater carbon reporting, leading to enhanced carbon disclosures (Elsayih et al., 2018). Moreover, other female directors on audit committees are significantly associated with carbon disclosures, suggesting that other characteristics of female directors influence carbon disclosures. Board-level gender diversity is also positively associated with carbon disclosures, affirming that female directors are more sensitive to environmental issues.

In addition, we perform the Chow test to assess whether there is significant structural difference between the two regression models (columns 1 and 2). We perform the Chow test to determine whether the audit committee female non-accounting expert member has more influence on carbon disclosure than the audit committee female accounting expert member. We use the following model.

$$Chow = [FEMACC_{mean}] - [FEMNONACC_{mean}] = 0 \quad (2)$$

Where $FEMACC_{mean}$ is the mean coefficient of carbon disclosure multiple by the independent variable of female audit committee accounting expert member. $FEMNONACC_{mean}$ is the mean coefficient of carbon disclosure multiple by the independent variable of female audit committee non-accounting expert member. *Chow* is the Wald value that is extracted from Equation (2). The null hypothesis is that there is no statistically significant difference between the coefficients. Since the Chow test results show that the coefficient of female non-accounting expert audit committee members differs statistically from that of female accounting expert audit committee members in terms of carbon disclosure ($\chi 2 = 6.04$, $p < 0.004$), we reject the null hypothesis. the effect of female non-accounting expert audit committee members on carbon disclosure is significantly greater than that of female accounting expert audit committee members, supporting H_2.

4.3. Endogeneity test

4.3.1. Two-stage Heckman model

Selection bias problems may arise as badly performing companies probably do not voluntarily report on carbon disclosures. This bias creates an endogeneity problem, which can be addressed with a Heckman two-stage model. Following Feng et al. (2009), we employ the two-stage Heckman (1979) approach to investigate the issue of sample-selection bias. Using probit regression, we first estimate the factors that affect female accounting experts in the audit committee (*FADUM*). By considering all of the control variables as predictors of gender diversity in the audit committee, we estimate probit regression for *FADUM*. After estimating this probit regression for *FADUM*, we compute the Inverse Mills Ratio (*MILLS*). Using *MILLS* as the independent variable, we estimate our primary regression. In order to eliminate the endogeneity concern, we also incorporate instrumental variables. The instrument variables in this regression must meet the requirements for potential endogeneity and relevance. In our case, the instrument variable should be correlated with the decision to have female audit committee expertise but should not be correlated with the carbon disclosure. We list two instruments as *PREV_ACFEM* and *INDAVGACFEM*. *PREV_ACFEM* is a dummy variable coded 1 if a firm has a female audit committee accounting expert and 0 otherwise. *INDAVGACFEM* is the industry average female audit committee expertise.

$$\begin{aligned} FADUM_t = {} & \gamma_0 + \gamma_1 boardsize + \gamma_2 ACmeet + \gamma_3 ACsize + \gamma_4 boardindependent \\ & + \gamma_5 CSRcommittee + \gamma_6 leverage + \gamma_7 ROA + \gamma_8 size \\ & + \gamma_9 PREV_ACFEM + \gamma_{10} INDAVGACFEM + INDUSTRYeffect \\ & + YEAReffect + \varepsilon_t \cdots\cdots\cdots\cdots \end{aligned} \quad (3)$$

Table 5
Two-stage Heckman Regression and Generalized Method of Moments Estimation.

Variables	(1) female account	(2) Carbon disclosure	(3) Carbon disclosure	(4) Carbon disclosure	(5) Carbon disclosure
carbon disclosure (lagged)	–	–	–	–	0.719*** (8.166)
female account	–	−1.31	–	−0.725	10.800
		(−1.53)		(−1.00)	(0.804)
female nonaccount	–	–	0.243***	0.313**	28.550**
			(2.68)	(2.49)	(2.310)
other female	–	0.952*	0.762*	0.551*	1.965
		(1.85)	(1.85)	(1.69)	(0.092)
board female	–	0.839	0.258*	0.485*	51.490**
		(1.31)	(2.00)	(1.66)	(2.244)
board size	0.021**	1.065**	0.940	0.987	−0.180
	(2.28)	(2.11)	(0.95)	(1.06)	(−0.178)
AC meet	0.172**	−0.378	−0.432	−0.412	2.329
	(2.21)	(−1.31)	(−0.36)	(−0.64)	(1.380)
AC size	1.213***	0.677***	1.287*	0.892*	2.960*
	(6.17)	(2.92)	(1.79)	(1.95)	(1.898)
board independent	0.963*	0.855	0.368	0.698	−17.000
	(1.87)	(1.42)	(0.99)	(0.87)	(−0.981)
CSR committee	0.057*	0.624***	0.538***	0.885***	12.080*
	(1.88)	(2.92)	(2.96)	(2.98)	(1.822)
leverage	−0.089**	0.941***	0.887*	1.015*	−26.640**
	(−2.42)	(8.17)	(1.89)	(1.74)	(−2.144)
ROA	0.874	0.698***	0.754**	0.829*	−12.230
	(1.28)	(2.82)	(2.29)	(1.84)	(−0.855)
size	0.035**	0.587***	0.645***	0.952***	−5.041
	(2.38)	(2.96)	(2.99)	(2.86)	(−1.621)
PREV_ACFEM	1.756***	–	–	–	–
	(11.16)				
INDAVGACFEM	1.627***	–	–	–	–
	(3.10)				
MILLS	–	0.797***	0.721	0.852*	–
		(3.18)	(1.58)	(1.74)	
constant	0.512	0.752*	0.598*	0.950*	96.790*
	(1.17)	(1.69)	(1.81)	(1.75)	(1.820)
Year fixed effects	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES
Firm-years	753	753	753	753	753
Pseudo R^2/Adjusted R^2	58.04	37.54	37.60	37.88	–
chi2/F-statistics	202.25***	17.78***	14.54***	14.84***	–
AR (2) test (*p*-value)	–	–	–	–	0.852
Hansen-J test (*p*-value)	–	–	–	–	0.209

Notes: This table shows the results of two-stage least squares regression. The first stage is presented in Column 1, wherein female directors on audit committees are regressed on two instruments (the industry average of female directors and last year value of female directors on audit committees) and control variables. The second stage results are shown in Columns 2, 3, and 4. Column 5 shows the results after applying the Generalized Method of Moments estimation technique. Standard errors are clustered at the firm level Standard errors are clustered at the firm level, and *t*-statistics are presented in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. For variable definitions, see Appendix.

$$\begin{aligned} carbondisclosure_t = {} & \beta_0 + \beta_1 femaleaccount + \beta_2 femalenonaccount \\ & + \beta_3 otherfemale + \beta_4 boardfemale + \beta_5 boardsize \\ & + \beta_6 ACmeet + \beta_7 ACsize + \beta_8 boardindependent \\ & + \beta_9 CSRcommittee + \beta_{10} leverage + \beta_{11} ROA + \beta_{12} size \\ & + \beta_{13} MILLS + INDUSTRYeffect + YEAReffect \\ & + \varepsilon_t \cdots\cdots\cdots\cdots \end{aligned} \tag{4}$$

Table 5 reports the findings using a restricted sample. *PREV_ACFEM* represents the presence of female directors in the previous year, serving as an independent variable in Equation (2). However, due to the starting year of our sample being 2009, we lack observations from the previous year within our sample. Consequently, we cannot include this variable in the analysis for the year 2009. The total number of observations used in the two-stage Heckman regression model is 753. Column (1) reports the findings of first-stage regression, which suggests instrument variables (*PREV_ACFEM* and *INDAVGACFEM*) are relevant. Column (2) to (4) reports the findings of the second stage of regression, and are consistent with our earlier baseline results.

4.3.2. Generalized method of moments (GMM) estimation

Endogeneity is a common problem in corporate governance and finance literature. The endogeneity problem may arise owing to omitted variable bias and measurement errors. Reverse causality between dependent and explanatory variables may also create an endogeneity problem. In our case, endogeneity may arise because female (accounting and non-accounting) experts on audit committees improve carbon reporting, while firms with poor carbon disclosures may choose to induct such directors. The Generalized Method of Moments (GMM) estimation can control endogeneity problems effectively (Alam et al., 2020; Elmaghri et al., 2019; Nadeem et al., 2020). However, the application of GMM is dependent on the use of valid instruments. Following Blundell and Bond (1998), a set of equations is used to generate instruments, both at differences and *levels* for lagged dependent variables and the other independent and control variables separately. The Hansen-J test statistic confirms that the instruments are valid in the models. We applied a two-step system GMM rather than the one-step system GMM estimation as it is more efficient, but standard errors are downward biased. To fix the possible downward bias, we applied the Windmeijer (2005) finite-sample corrected covariance matrix. Moreover, the AR (2) test is not significant, suggesting that our GMM model is not affected by second-order autocorrelation (Alam et al., 2019). These

Table 6
Additional analysis: Carbon intensive (high vs low) and CSR committee.

	(1) High Carbon intensive	(2) Less Carbon intensive	(3) Firm has no CSR committee	(4) Firm has CSR committee
female account	−0.126	−0.284	−0.243	−0.192
	(−0.392)	(−0.629)	(−0.08)	(−0.89)
female nonaccount	0.148	0.489**	0.311***	0.225***
	(0.742)	(2.325)	(2.87)	(2.63)
other female	0.917**	0.671***	0.267***	0.464***
	(2.357)	(2.569)	(2.75)	(3.22)
board female	−0.139	0.722	0.450	0.265
	(−0.170)	(1.514)	(1.55)	(1.27)
board size	−0.023	−0.016	0.172	0.261
	(−1.436)	(−0.814)	(1.49)	(1.07)
AC meet	−0.019*	−0.008	0.498	−0.1238*
	(−1.914)	(−0.286)	(0.25)	(−1.67)
AC size	−0.02	−0.04	0.528	−0.723
	(−0.765)	(−1.42)	(0.24)	(−0.50)
board independent	−0.679**	−0.183	0.206	−0.242
	(−1.969)	(−0.434)	(0.82)	(−1.19)
CSR committee	0.103	0.175***	–	–
	(0.994)	(2.669)		
leverage	−0.16	−0.209	0.108	0.926
	(−0.818)	(−1.145)	(1.14)	(1.02)
ROA	−0.397**	−0.078	−0.245	0.329
	(−2.351)	(−0.189)	(−0.09)	(0.34)
size	0.108***	0.114***	0.772***	0.275*
	(2.646)	(3.224)	(3.63)	(1.76)
Constant	−2.270***	−1.413***	−1.082***	2.595
	(−4.612)	(−2.833)	(−3.87)	(0.19)
Year fixed effects	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES
Firm-years	183	685	603	265
Adjusted R^2	29.5	20.2	31.9	55.5
Wald test/F-statistics	314.39***	203.27***	10.83	12.67

Notes: This table shows the results after the sample is divided into carbon-intensive and less carbon-intensive industries. Energy, material, and utility industries are considered to be carbon-intensive industries. Standard errors are clustered at the firm level, and *t*-statistics are presented in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. For variable definitions, see Appendix.

tests provide confidence in our estimations derived from the GMM model. GMM estimation analysis reports the finding using a restricted sample. The independent variable "carbon disclosure (lagged)" denotes the carbon disclosure score from the previous year. However, since our sample begins in 2009, we cannot include this variable in the analysis for the year 2009. The total number of observations used in the GMM estimation is 753. Column 5 of Table 5 suggests that our findings are robust after applying the GMM estimation. However, other female directors on audit committees have no significant association with carbon disclosure, whereas in OLS models the association is significant. This significant correlation in the OLS models could be attributable to a spurious association that fades away after controlling for endogeneity (Wintoki et al., 2012).

5. Additional analysis

5.1. Carbon-intensive industries

Empirical research shows mixed evidence regarding the carbon disclosure practice of industries. The findings of Stanny and Ely (2008) suggest that carbon-intensive industries have decreased or failed to increase their disclosures, while non-intensive industries have become increasingly transparent. Alsaifi et al., (2020b) find that the voluntary carbon disclosure for firms operating in carbon-intensive industries is almost equal to the response rate for firms in non-intensive industries. Therefore, whether the role of female accounting expertise in carbon-intensive industries varies or not is an open question. Following Liao et al. (2015), we consider energy, material, and utility industries to be carbon-intensive industries. We divide our sample between carbon-intensive and less carbon-intensive industries and perform regression analysis on each of the two sets of samples. Among the total of 868 firm-year observations in our sample, 685 observations are classified as less carbon −intensive firms, while 183 observations are classified as high carbon intensive firms. Our results in Columns 1 and 2 of Table 6 suggest that female non-accounting experts on audit committees improve carbon disclosures only in the case of less carbon-intensive industries. This result stems from the recent attention towards the environmental consequences of corporations, even if they are categorized as less carbon-intensive. The result also corresponds with results reported by Akbas and Canikli (2018), who find that firms in less carbon-intensive industries have a greater tendency to submit CDP questionnaires (which involve providing information about their carbon emissions). However, we caution that our non-significant association in the sample comprising carbon-intensive industries may be attributable to the relatively fewer (183) firm-year observations.

5.2. CSR committee vs non-CSR committee: A non-accounting female expert on audit committee

An independent CSR committee indicates that a firm is more vigilant and aims for effective CSR policies that improve strategic planning and overall CSR objectives. In addition, extant CSR research suggests that the CSR committee's effective presence will control the carbon footprint more efficiently and is likely to enhance carbon disclosure. Therefore, it is essential to understand the effect of non-accounting female audit committee expertise in the absence of a CSR committee. We split the sample of 868 firm-year observations into 603 observations without a CSR committee and 265 observations with a CSR committee. Then, we re-run the primary regression model in order to understand whether the existence of CSR committees drives our prior findings. Columns 3 and 4 of Table 6 present the results. Our findings show a positive association between carbon disclosure and non-accounting female expertise on

Table 7
Propensity Score Matching Test for accounting and non-accounting female experts on audit committees and carbon disclosures).

Panel A: Descriptive statistics: Covariate matching

Variables	(1) Treated (Caliper 0.001) N = 242	(2) Control (Caliper 0.001) N = 172	(3) t-statistics (Caliper 0.001 Matched)
board size	9.677	9.491	1.21
AC meet	4.241	4.202	0.76
AC size	4.130	4.010	1.04
board independent	0.549	0.537	1.35
CSR committee	0.250	0.250	0.00
leverage	0.596	0.561	1.17
ROA	0.093	0.096	−0.29
size	14.652	14.621	0.85

Panel B: Propensity Score Matching Test

Variables	(1) Carbon disclosure Nearest-Neighbor	(2)	(3) Carbon disclosure Calipers (0.001)	(4)
female account	−0.229	–	−0.281	–
	(−1.25)		(−1.04)	
female nonaccount	–	0.363***	–	0.454***
		(3.17)		(4.13)
other female	0.202	0.337**	0.116*	0.257*
	(1.28)	(2.11)	(1.69)	(1.94)
board female	0.230	0.496*	0.093	0.246
	(1.01)	(1.89)	(0.49)	(1.37)
board size	1.321	1.319	1.727*	1.531*
	(1.49)	(1.59)	(1.73)	(1.92)
AC meet	−0.664	−0.540	−0.722	−0.499
	(−0.50)	(−0.43)	(−0.69)	(−0.37)
AC size	0.296**	0.231	0.218*	0.208
	(1.96)	(1.56)	(1.89)	(0.90)
board independent	−0.102	−0.133	−0.113	−0.134
	(−0.50)	(−0.66)	(−0.89)	(−0.98)
CSR committee	0.106***	0.095***	0.167***	0.127***
	(2.94)	(2.67)	(4.12)	(4.15)
leverage	0.760	0.594	−0.367	−0.354
	(0.81)	(0.65)	(−0.36)	(−0.81)
ROA	−0409	−0.035	−0.068	−0.601
	(−0.26)	(−0.64)	(−0.39)	(−0.64)
size	0.760***	0.271***	0.579***	0.517***
	(4.02)	(3.81)	(2.98)	(2.92)
constant	−1.795***	−1.702***	−1.759***	−1.264***
	(−3.31)	(−2.89)	(−3.21)	(−2.98)
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Firm-year Observations	712	712	414	414
Adjusted R^2	38.0	39.5	33.0	36.8
F-statistics	14.98	14.84	8.27	9.61

Notes: **Panel A** presents the descriptive statistics of treatment and control groups which were created through the propensity score matching (PSM) method. Columns 2 and 3 show the mean values of each variable in the treatment and control groups, respectively. In Column 3, the significance between the means of both groups is assessed. **Panel B** shows the results on the PSM sample of treatment and control groups. Columns 1 and 2 uses the nearest neighbor method, and columns 3 and 4 utilizes the caliper technique. Standard errors are clustered at the firm level, and *t*-statistics are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.10. For variable definitions, see Appendix.

audit committees for firms with both with and without CSR committees. Thus, we confirm that the existence of a CSR committee does not drive the previous findings.

5.3. Propensity score matching (PSM) tests

Our previous discussion suggests a positive association between carbon disclosure scores and non-accounting female expertise on the audit committee. However, the finding may have model misspecification or omission variable bias, which may violate the assumptions of the ordinary least squares model. To mitigate such concerns, we deploy propensity score matching (PSM) analysis and create a closely matched sample to check whether firms with and without female audit committee membership differ from one another in terms of carbon disclosure. We regard firms with female audit committee membership (*FEMACMEM* = 1) as the treatment group. We then use PSM to identify a control group based on all the control variables, such as audit committee size (*AC size*), audit committee meeting frequency (*AC meet*), firm leverage (*leverage*), firm performance (*ROA*), the existence of a CSR committee (*CSR committee*), proportion of independent directors on the board (*board independent*) and firm size (*size*) in the regression analysis. Using the nearest neighbor approach, we find 284 treatment firms and 428 control firms.

We identify the optimal match based on the Caliper (0.001) technique, where the Caliper is the distance that is acceptable when matching treated and non-treated groups. Because of a relatively small sample size, we use the shortest distance to the treated sample, which leads to a smaller bias. Using caliper 0.001, we find 242 treatment firms matched with 172 control firms. Caliper matching determines the radius or maximum propensity score difference between the treatment and control groups. Observations outside the Caliper are dropped in the matching process. Table 7, Panel A, reports a proper balance between the treatment and control groups in the matched sample, as none of the covariates' mean differences are statistically significant. Table 7 Panel B reports the PSM sample's OLS results, showing that firms benefit from a higher carbon disclosure when a board has more non-accounting female experts on the audit committee. Therefore, the PSM analysis confirms our previous inference.

5.4. Tokenism – Female audit committee member

According to the critical mass theory, having a single female board member (or female audit committee member) might be perceived as a token presence, making it difficult for them to contribute meaningfully to decision-making. An extension of the token status theory, the critical mass theory asserts that "one is a token, two is presence, and three is voice" (Kristie, 2011, p. 22). In line with these arguments, we anticipate that an audit committee that has a critical mass of female accounting experts will make greater efforts for carbon disclosure than an audit committee that only has one female accounting expert member. We construct *ACFEMACC_1*, *ACFEMACC_2* and *ACFEMACC_3* as three additional dummy variables to test the token and critical mass assumptions. *ACFEMACC_1* is a measure of the critical mass of female accounting audit committee members and equals 1 if there are one female accounting audit committee member and 0 otherwise. *ACFEMACC_2* is a dummy variable that equals 1 if there are two female accounting audit committee members and 0 otherwise. *ACCFEMACC_3* is a dummy variable that equals 1 if there are three female accounting audit committee members and 0 otherwise. Similarly, for the non-accounting expertise in the audit committee, we construct the three alternative dummy variables of *ACFEMNONACC_1*, *ACFEMNONACC_2*, and *ACFEMNONACC_3*. We conducted a sub-sampling[8] analysis by excluding firm-year observations that have an individual female audit committee member with expertise in both accounting and non-

[8] Our sub-sample analysis involves variations in sample size. Because we compare firm-years with audit committees that lack any female accounting audit committee members ('0′) to firm-years that have a single female accounting audit committee member ('1′), for example comparing '0′ vs '1′. Additionally, we extend this comparison to include '0′ vs '2′ and '0′ vs '3′, representing firm-years with two and three female accounting audit committee members, respectively. Similarly, we conduct a separate analysis for female non-accounting audit committee members.

Table 8
Regression analysis – impact of tokenism on carbon disclosure.

Variables	(1) Carbon disclosure	(2) Carbon disclosure	(3) Carbon disclosure	(4) Carbon disclosure	(5) Carbon disclosure	(6) Carbon disclosure
Constant	−0.94***	−0.93***	−0.92***	−0.94***	−0.84***	−0.86***
	(−8.68)	(−8.63)	(−8.25)	(−8.76)	(−7.63)	(−7.84)
ACFEMACC_1	−0.054	–	–	–	–	–
	(−1.04)					
ACFEMACC_2	–	0.081**	–	–	–	–
		(2.09)				
ACFEMACC_3	–	–	0.134	–	–	–
			(1.26)			
ACFEMNONACC_1	–	–	–	0.093***	–	–
				(3.03)		
ACFEMNONACC_2	–	–	–	–	0.12***	–
					(3.38)	
ACFEMNONACC_3	–	–	–	–	–	0.17
						(1.42)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	No	No	No
Industry fixed effects	No	No	No	No	No	No
Firm-years	801	700	692	716	483	430
F-statistics	32.07	31.89	32.15	33.38	33.74	33.23
Adjusted R^2	22.28	22.19	23.04	23.72	23.91	22.91

Notes: This table presents the results after incorporating the potential bias stemming from tokenism. Standard errors are clustered at the firm level, and *t* statistics are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Column 1 compares carbon disclosure between two groups of samples: firm-years with no female accounting audit committee members and firm-years with exactly one female accounting audit committee member. Similarly, Column 2 compares carbon disclosure between firm years with no female accounting audit committee members and firm years with exactly two female accounting audit committee members. This pattern continues for subsequent columns, with each column comparing carbon disclosure between different groups based on the number of female (non) accounting audit committee members present in the firm year. For variable definitions, see Appendix.

accounting areas, which allows us to focus without the influence of audit committee members with dual expertise.

Table 8 compares tokenism and the critical mass of female accounting audit committee members. For the group of female accounting expert groups, carbon disclosure increases (coefficient 0.081, $p < 0.05$) when the audit committee has two accounting expert female audit committee members. While the coefficient is positive for *ACFEMACC_3*, the findings are not statistically significant. For the group of female non-accounting expert groups, carbon disclosure increases (coefficient 0.093 and 0.12; $p < 0.01$) when the audit committee has one non-accounting expert female audit committee member (coefficient 0.093$p < 0.01$). Also, the coefficient is positive and statistically significant for *ACFEMNONACC_2*, indicating carbon disclosure increases when the audit committee has two non-accounting female experts. Overall, carbon disclosure increases when an audit committee has two female accounting and non-accounting experts. This is in line with Ben-Amar et al. (2017), which finds that female board participation needs to reach a critical mass of two before it starts influencing voluntary carbon disclosures.

5.5. Regulation of mandatory female director on the board

The Corporate Governance Code 2012, Section B.2.4 advises that UK firms disclose their board gender diversity policy (Financial Reporting Council, 2012), and The UK implemented the environmental, social, and governance (ESG) mandatory disclosure in 2013 (Krueger et al., 2021). Martinez-Garcia et al. (2022) report that following the implementation of mandatory regulation, listed firms appoint directors with diversified expertise. A stream of research find evidence that firms with a higher representation of female directors have better carbon disclosure policy, but empirical research in the UK setting has yielded mixed findings. For example, Prado-Lorenzo and Garcia-Sanchez (2010) did not find a significant relationship between gender diversity and GHG emission level disclosure. Conversely, Liao et al. (2015) demonstrated that female representation positively influenced carbon disclosure in the UK. To step forward, we split the sample between pre-mandate and post-mandate regimes to address whether rules requiring gender diversity impact a firm's disclosure of its carbon disclosure. We determine that the firm-year observations from 2009 to 2012 are pre-mandate and from 2013 to 2015 are post-mandate.

The results of company carbon disclosure in pre- and post-mandate regimes are presented in Table 9. Our findings coincide with the preliminary findings, which suggest that a female audit committee member with non-accounting experience would enhance business carbon disclosure. The coefficient of female nonaccountants is 0.54** (*t-statistics* 2.23; $p < 0.05$) in the pre-mandate years and 0.71* (*t-statistics* 1.76; $p < 0.10$) in the post-mandate years of gender diversity regulations. In the developing field of carbon disclosure, including GHG measurement and reporting, subject-matter and technical expertise are critical for scientific estimation uncertainties, and such expertise is reinforced by auditors' abilities to assess the risks of substantial misrepresentation to reporting companies. Huggins et al. (2011) posit that a multidisciplinary team of subject matter experts from fields like engineering and environmental science along with assurance experts with accounting backgrounds will be needed to ensure the success of most complex engagements. Our findings are consistent with the argument of Huggins et al. (2011) as are our contributions.

6. Conclusion

Owing to the heightened attention of stakeholders towards carbon reporting, it may be vital to study characteristics influencing carbon disclosures. Unlike prior literature, this study analyses the characteristics of female directors on audit committees in the context of carbon reporting. Given that accounting and non-accounting expertise offer a separate mechanism through which they could influence carbon reporting, this study examines whether accounting and non-accounting female experts on audit committees affect carbon disclosures. We find that female non-accounting experts on audit committees enhance carbon disclosures, while female accounting experts on audit committees are not significantly associated with carbon disclosures.

Therefore, management aiming to augment environmental disclosures should include non-accounting female directors as part of audit committees, but emphasis should also be given to the elevation of accounting expertise. Moreover, our results are consistent with some regulators' current female quota policy and support the holistic view of

Table 9
Regression analysis – pre & post mandatory female regulation and carbon disclosure.

	(1)	(2)	(3)	(4)
	Carbon Disclosure		Carbon Disclosure	
	Pre-regulation 2009—2012	Post-regulation 2013–2015	Pre-regulation 2009—2012	Post-regulation 2013–2015
female account	−0.23	0.58	–	–
	(−1.09)	(0.53)		
female nonaccount	–	–	0.54**	0.71*
			(2.23)	(1.76)
other female	1.08	−0.175	−0.257	−0.600
	(0.66)	(−0.78)	(−1.45)	(−0.76)
board female	1.01*	1.08**	1.23	0.65**
	(1.68)	(2.03)	(1.63)	(2.17)
board size	1.286*	−0.398	1.211	−0.507
	(1.68)	(−0.40)	(1.59)	(−0.51)
AC meet	−1.428*	1.024	−1.312	1.090
	(−1.70)	(0.93)	(−1.57)	(0.98)
AC size	0.472	0.204***	0.701	0.678***
	(0.31)	(3.09)	(0.49)	(3.25)
board independent	0.496	−1.190	0.314	−0.269
	(0.33)	(−0.07)	(0.39)	(−0.01)
CSR committee	0.278***	0.052***	0.177***	0.336***
	(2.73)	(4.99)	(2.72)	(5.07)
leverage	0.72*	0.143	0.137	0.032
	(1.88)	(1.01)	(1.59)	(1.13)
ROA	0.232	−0.932	−0.366	−0.210
	(0.31)	(−0.43)	(−0.03)	(−0.45)
size	0.844***	0.858***	0.908***	0.015***
	(6.33)	(3.10)	(6.41)	(3.19)
constant	−1.36***	−1.39**	−1.99***	−1.93**
	(−6.14)	(−2.21)	(−6.27)	(−2.34)
Year fixed effects	No	No	No	No
Industry fixed effects	Yes	Yes	Yes	Yes
Firm-years	474	394	474	394
Adjusted R^2	29.77	22.24	32.39	24.65
F-statistics	19.23	11.32	20.03	11.93

Notes: This table shows the results after separating the sample into pre- and post-regulation (mandatory female regulation). Columns 1 and 2 show the results before the mandatory female regulation, while Columns 3 and 4 present the results after the implementation of the female director regulation. Standard errors are clustered at the firm level, and *t* statistics are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. For variable definitions, see Appendix.

policymakers in appointing females to the audit committees.

Our research findings have several other implications. From the aspect of overall board-level gender diversity, they suggest that policymakers should encourage gender-diverse boards in order to attain higher quality non-financial information reporting on carbon disclosure. Regulators and policymakers may also enable firms to constitute audit committees combining female directors with diverse expertise other than accounting skills. The UK's Corporate Governance Best Practice Code recommends that the audit committee focus on accounting expertise. However, corporate risk management nowadays encompasses issues that are more diverse than financial reporting risk. Therefore, an audit committee composed of members with diversified skills, such as CEOs, financial managers, and legal and industry experts, should be encouraged in corporate governance guidelines. Our study may also be beneficial for stakeholders, such as investors and environmental pressure groups. Stakeholders striving for improved carbon reporting may pressure firms to constitute audit committees to include female directors with non-accounting expertise.

The findings of this research should be interpreted with caution. Our sample covers the FTSE 350 firms, which are generally the largest in market capitalization. However, carbon disclosure practices might differ for firms that do not belong to the FTSE 350 group and, therefore, we encourage future research on this aspect. In addition, extending this research to other countries with different corporate governance environments may help provide further policy implications. For example, the UK's financial reporting and corporate governance regulatory environment are relatively robust. Therefore, academic research communities might want to explore whether the current findings are equally plausible for emerging economies. Moreover, we suggest future researchers interact with female accounting and non-accounting experts on audit committees with other characteristics, such as multiple directorships, to determine whether such characteristics moderate their impact on carbon disclosures. Finally, our sample period extends from 2009 to 2015, corresponding to the voluntary carbon disclosure regime. Therefore, future research can explore the impact of female director expertise on carbon disclosure within the mandatory regime in more recent years.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Acknowledgements

We express our sincere gratitude to Professor Robert Larson, the Editor, and two anonymous referees for their thorough and insightful comments, which have greatly enhanced the quality of this manuscript.

Appendix:. Variable definitions

Variables	Definition
carbon disclosure	Carbon disclosure score from CDP.
total female AC	Proportion of total female directors on audit committees.
female account	Proportion of female accounting financial experts on audit committees.
female nonaccount	Proportion of female non-accounting financial experts on audit committees.
other female	Proportion of female directors on audit committees who are non-financial experts.
total board female	Proportion of total female directors on the board.
board female	Proportion of female directors on boards who do not form part of audit committees.
board size	Number of directors on boards.
AC meet	Number of audit committee meetings.
AC size	Number of directors on audit committees.
board independent	Proportion of independent directors on boards.

(*continued on next page*)

(*continued*)

Variables	Definition
CSR committee	A dummy variable coded 1 if the firm constitutes a CSR committee, 0 otherwise.
leverage	Proportion of total debt to total assets.
ROA	Return on assets measures as the proportion of net income to total assets.
size	Natural logarithm of total assets.
FADUM	A dummy variable coded 1 if the firm has a female accounting expert member in the audit committee, 0 otherwise.
PREV_ACFEM	A dummy variable coded 1 if a firm has a female audit committee accounting expert, 0 otherwise.
INDAVGACFEM	Industry-year average female audit committee expertise.
MILLS	Inverse Mills Ratio is based on equation (3).
ACFEMACC_1	A dummy variable coded 1 if the audit committee has one female accounting expert member, 0 otherwise.
ACFEMACC_2	A dummy variable coded 1 if the audit committee has two female accounting expert members, 0 otherwise.
ACFEMACC_3	A dummy variable coded 1 if the audit committee has three female accounting expert members, 0 otherwise.
ACFEMNONACC_1	A dummy variable coded 1 if the audit committee has one female non-accounting expert member, 0 otherwise.
ACFEMNONACC_2	A dummy variable coded 1 if the audit committee has two female non-accounting expert members, 0 otherwise.
ACFEMNONACC_3	A dummy variable coded 1 if the audit committee has three female non-accounting expert members, 0 otherwise.
INDUSTRY effect	A set of dummy variables coded 1 for each industry, using SIC one-digit industry classification.
YEAR effect	A set of dummy variables coded 1 for each year in sample.

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