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The impact of board of directors effectiveness on greenhouse gas disclosure: Evidence from Saudi Arabia

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ABSTRACT

This study investigates the impact of the board of directors' effectiveness on greenhouse gas (GHG) disclosure among listed firms in Saudi Arabia, a resource-rich emerging economy transitioning towards sustainability under Vision 2030 and the 2060 net-zero pledge. Guided by stakeholder and legitimacy theories, board effectiveness was measured as a composite index comprising independence, size, gender diversity, and meeting frequency. Using a purposive sample of 150 high-impact firms across 750 firm-year observations (2020–2024), GHG disclosure was assessed through a novel, context-specific disclosure index developed via content analysis of publicly available reports, capturing both breadth and quality. The random-effects regression results indicate that board effectiveness (BOE) has a strong and positive effect on GHG disclosure ($\beta = 0.0630$, $t = 8.82$, $p < 0.01$), confirming that well-functioning boards drive climate transparency. This suggests that firms with more independent, diverse, and active boards are better positioned to oversee climate-related strategies, ensure the credibility of environmental reporting, and respond effectively to growing stakeholder and regulatory demands for sustainability accountability. The findings further underscore the pivotal role of robust governance in enhancing climate-related transparency, delivering actionable insights for policymakers crafting regulations, corporate executives shaping sustainable strategies, and researchers exploring governance impacts. The limitations include the study's sector-specific focus, reliance on secondary disclosures, and temporal scope, suggesting future research avenues in cross-country comparisons, longitudinal analysis, and governance climate strategy integration.

Contribution/ Originality: The present study is relevant because it establishes a new, context-specific GHG disclosure index and offers empirical data from Saudi Arabia on how board effectiveness increases climate transparency. It contributes to the literature on governance and the environment, minimizes bias in CDP, and provides valuable policy implications for policymakers and companies in resource-abundant emerging economies.

1. INTRODUCTION

Climate change is one of the most complex and pressing global concerns, with substantial environmental, economic, and societal implications ever since the beginning of the 21st century (Giannarakis, Zafeiriou, Arabatzis, & Partalidou, 2018). High temperatures worldwide, loss of glaciers, rising ocean levels, and increased intense weather patterns have raised concerns about the future sustainability of human activities (Hussin, Yusri, Awang, & Selamat, 2025). According to the Intergovernmental Panel on Climate Change (IPCC), the current pace of greenhouse gas (GHG) emissions is incompatible with the climate requirements envisaged by various countries at an international level, and urgent actions are needed to reduce the release of such gases and enhance environmental management (Mubarak, Elhadi, & Abdelrahman, 2023). Therefore, large publicly traded corporations, which correspond to the

scope of the IPCC definition of actors as being economically significant, are faced with increasing pressure to recognize and manage their environmental impacts by investors, regulatory agencies, consumers, and civil society organizations (Kuvvet, 2024). One of the high-profile representations of this accountability incorporates the embracement of transparent and credible disclosure of GHG emissions (Cohen, Kadach, & Ormazabal, 2023). This type of disclosure enables stakeholders to question the vulnerability of firms to climate-related hazards, assess the effectiveness of control plans, and verify whether they are on track to achieve goals of reduced emissions (Moshashai, Leber, & Savage, 2020). Open reporting of GHG not only supports the basis of informed decision-making but also builds trust in the capital markets and strengthens the basis of accountability (Giannarakis et al., 2018).

In the current disclosure context, corporate governance has been identified as a key factor in establishing the extent and quality of environmental reporting (Cornelius, 2005). The board of directors, being the top governing board of the corporation, is charged with the responsibility of setting the course, overseeing management, and safeguarding the interests of stakeholders (Helfaya & Moussa, 2017). In practice, throughout their history, the focus of boards was exercised through the lens of financial oversight, assurance of compliance, and risk management; however, over the past few decades, the mandate has expanded to embrace environmental and climate-related issues (Al-Ahdal & Prusty, 2020; Rahman & Mohamed, 2019). Empirical studies show that the effectiveness of boards in these areas is enhanced when they achieve an optimal configuration, thus portraying structural integrity, diversity, independence, functional expertise, and proactive regular attendance (Abdalla, Salleh, Hashim, Zakaria, & Rahman, 2024; Akbaş & Canikli, 2019; Liao, Luo, & Tang, 2015). Although the relationship between board effectiveness and non-financial reporting has already been discussed in previous research, most studies have involved environmental, social, and governance (ESG) reporting or corporate social responsibility (CSR) reporting in general terms (Chijoke-Mgbame, Mgbame, Akintoye, & Ohalehi, 2020; Velte & Stawinoga, 2020). Although such forms of reporting are desirable, they often rely on a mixed set of qualitative and broadly defined indicators, making it difficult to make systematic statements regarding the exact environmental performance of a firm (Borghei, 2021).

Although GHG emissions are measurable, observable, and scientifically grounded indicators directly connected to climate change, it is necessary to focus separate and specific attention on them. However, empirical studies explicitly including board effectiveness as a factor in GHG disclosures are limited (Bae Choi, Lee, & Psaros, 2013). The consequence of this gap is especially significant as the world shifts towards greater emphasis on climate-related transparency, with increasing pressures on regulating and investing parties to ensure precise, accurate, and comparable emissions measurements. Furthermore, most previous studies measuring GHG disclosure used the Carbon Disclosure Project (CDP) questionnaire as a principal proxy (Alsaifi, Elnahass, & Salama, 2020). Although the CDP is recognized as a standardized, stakeholder-based approach to climate reporting, its voluntary nature is a drawback because only companies that choose to participate are included in the database, thus introducing selection bias (Abdalla, Salleh, Hashim, Zakaria, & Rahman, 2024). Additionally, despite their utility, CDP scores and responses do not always include the exhaustive information provided in other publicly available sources such as annual reports, integrated reports, sustainability reports, and corporate websites (Carbon Disclosure Project, 2022). These reports often include an emissions inventory, reduction plan, performance pattern, methodological information, and assurance statement that are not covered through CDP participation (Cormier, Magnan, & Gutierrez, 2024). Relying solely on CDP-based measurements risks underreporting the depth, breadth, and quality of GHG disclosure and may result in a significant loss of information regarding cross-firm and cross-industry variance in disclosure (Abdalla et al., 2024). Therefore, other holistic and context-specific measurement methods are necessary.

To realize this goal, this study examines 750 firm-years belonging to 150 companies in various sectors listed on the Saudi Stock Exchange. The results show that there is a strong and positive linkage between board effectiveness and the depth of greenhouse-gas disclosure: the more effective the board, the greater the breadth of GHG-disclosed information. Such findings can be regarded as an important addition to the existing academic findings on corporate governance and climate-related disclosure. First, they apply the governance-environment nexus literature to GHG

reporting, thus filling a substantial theoretical gap (Mubarak et al., 2023). Therefore, focusing on GHG disclosure, which is a quantitatively defined aspect of environmental performance, provides original information on the influence of board-level governance dynamics on the formation of a crucial institutional environmental indicator.

Further, the current study makes a noteworthy contribution to methodological practice because a tailor-made Greenhouse-Gas Disclosure Index is created via an extensive content analysis of publicly available corporate documents, such as annual reports. Unlike previous studies, whose primary source of data is the Carbon Disclosure Project survey (Carbon Disclosure Project, 2022), this method can include both surveyed and non-surveyed companies, thus reducing the selection bias typical of voluntary disclosure data (Abdalla et al., 2024; Borghei, 2021). The developed disclosure index combines aspects of breadth and quality of disclosure, amalgamating emissions inventories, emissions reduction goals, performance trends, methods of calculation, and the practice of assurance (Alfani & Diyanty, 2020). Such a multidimensional and context-sensitive structure provides a more comprehensive and detailed disclosure measurement tool that can be applied to other developing markets and industries portrayed and researched against each other (Abdalla et al., 2024; Abdalla et al., 2024).

This study makes a significant contribution because it examines corporate climate-related disclosure in the Saudi context, an emerging market with peculiar economic, environmental, and corporate governance properties. Saudi Arabia, one of the world's largest oil-producing nations, is at the crossroads of global energy markets and is responsible for balancing economic growth and environmental consciousness (Chebbi & Ammer, 2022; Nurunnabi, 2017). The strategic importance of corporate engagement in climate issues can be illustrated by the fact that the Vision 2030 framework and the national pledge to reach net-zero emissions by 2060 reaffirm the country (Moshashai et al., 2020). However, empirical studies on the factors behind climate disclosure in Saudi Arabia are lacking (Umar, Firmansyah, Danlami, & Al-Faryan, 2024). The evaluation of the connection between the effectiveness of the board and the reporting of GHGs would unlock ideas that can find their application not only in Saudi Arabia but also in resource-rich economies as they undergo transitions toward the attainment of sustainability.

The remainder of this paper is organized as follows. Section 2 discusses the institutional context of the study, and Section 3 reviews the relevant literature. Sections 4 and 5 present the theoretical framework and research hypotheses, respectively. Section 6 describes the data, variables, and methodological approach, followed by Section 7, which reports the empirical results and their interpretation. Finally, Section 8 summarizes the conclusions of this study.

2. BACKGROUND OF STUDY

Saudi Arabia is among the international hydrocarbon producers and exporters, meaning that its economy has long been supported by the revenues generated by the fossil fuel industry (Tawfik, Alkhateeb, Ahmad Sultan, & Mahmood, 2017). However, increased international interest in climate change and the subsequent transition to renewable energy sources has created the need for a wider economic reorientation (Chebbi & Ammer, 2022). Over the last few years, the Kingdom has expressed impressive sustainability commitments, including its commitment to achieve net-zero greenhouse gas emissions from development operations by the year 2060 (Moshashai et al., 2020). Strategic initiatives such as Vision 2030 and the Saudi Green Initiative are examples of strategic shifts to focus on environmental stewardship, renewable energy, carbon capture technology, and overall emission reduction efforts (Alquraini, 2022). These commitments are an indicator of Saudi Arabia following the international goal in climate and, at the same time, an already established protocol for making institutions focus more on the sustainability of companies and increased disclosure (Aladwey & Alsudays, 2023).

Parallel to these national targets, the government's regulatory framework has changed to enhance governance and disclosure systems (Mubarak et al., 2023). The Capital Market Authority (CMA), which was founded in 2003, has provided elaborate Corporate Governance Regulations that extend the roles of directors to include ESG factors (Umar et al., 2024). This evolution can be compared to a more global shift where boards of directors increasingly rely

on climate-related risk tracking and reporting and providing such information, thereby ensuring that the environmental impacts of the firm and its response to these challenges are discussed (Helfaya & Moussa, 2017). Despite these gains, the Saudi governance landscape also continues to have peculiar features, such as a high concentration of ownership models, enterprises run by a family unit, and extensive state influence (Mubarak et al., 2023). These aspects inform the comparative efficiency of boards in encouraging corporate transparency, which makes research on board dynamics especially relevant in this context.

In Saudi Arabia, GHG disclosure is still in the fledgling stage, with irregular adoption rates among listed companies (Mubarak et al., 2023). Although companies voluntarily disclose emissions information through global reporting bodies, including CDP or state GHG measures on sustainability reports aligned with reporting frameworks such as the Global Reporting Initiative (GRI), there is still significantly low compliance, especially in emerging markets (Borghei, 2021). The focus of analyses on the data reported to the CDP potentially neglects those organizations that choose not to take part in voluntary programmes, so it can lead to a miscalculation of disclosure ratings in the Saudi corporate sphere (Abdalla et al., 2024). In line with this, more extensive methods that evaluate emission reporting in a broader sample of publicly available corporate documents provide a more complete view of the quality of reporting and coverage (Pitrakkos & Maroun, 2020). Hence, the Saudi context presents a unique and interesting environment to establish how board effectiveness affects GHG reporting. With the resource-based nature of the economy and the urgent demand of the country to balance growth preferences with increased environmental duty, the regulatory environment is constantly resilient, and corporate governance mechanisms are evolving (Moshashai et al., 2020; Nurunnabi, 2017). However, fundamental ownership patterns and governance relationships are very different from those in most developed jurisdictions.

3. LITERATURE REVIEW

3.1. Greenhouse Gas Disclosure

Greenhouse gas (GHG) disclosure has become a staple of corporate environmental reporting, as investors, regulators, and other stakeholders seek to gain more visibility into the role of firms in contributing to climate change (Cohen et al., 2023). GHG disclosures typically involve the quantification and reporting of emissions, both directly sourced from corporate activities and indirectly related to corporate activities, and strategies that aim to reduce environmental impact (Bae Choi et al., 2013). These disclosures have many purposes: they provide investors with the opportunity to assess climate-related financial risks, enable regulators, facilitate compliance with environmental regulations, and demonstrate that companies are committed to sustainability (Orazalin, Ntim, & Malagila, 2024). GHG disclosure is promoted by international frameworks and voluntary disclosure efforts such as the CDP, GRI, and the disclosure recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) (Borghei, 2021). Such instruments also provide uniformity in the measurements, checks, and reporting of emissions, thus making them comparable among firms and industries within and across industries (Velte, 2020). Adoption levels and disclosure quality vary substantially in one region compared to another, depending on industry, firm size, and corporate governance structure (Peters & Romi, 2014).

Empirical research has explored the determinants of GHG disclosure and its impact, and found that emissions information is supplied in greater detail by firms facing increased regulatory attention or increased environmental risk (Cohen et al., 2023; Hussin et al., 2025; Ilhan, Krueger, Sautner, & Starks, 2023). Moreover, organizations that have higher standards of governance, especially independent and diverse boards, are more lenient in delivering detailed GHG reports (Gulluscio, Puntillo, Luciani, & Huisingh, 2020). Despite these results, previous studies have primarily focused on voluntary disclosure in established markets, where participation in CDP is the prevailing proxy for GHG disclosures (Abdalla et al., 2024). This emphasis can hinder the understanding of disclosure practices in new world economies or among companies interacting with such activities. Accordingly, it has increasingly been recognized that more comprehensive and differentiated practices should be developed for GHG disclosure, which

reflect the veritable matter and quality of emissions reporting as opposed to those based on voluntary databases (Giannarakis et al., 2018). These approaches are more accurate in describing differences in disclosure across different regulatory and institutional backgrounds and provide a clearer depiction of the triggers behind climate transparency (Alsaifi et al., 2020).

3.2. Board of Directors Effectiveness

The board of directors plays an important role in the development of corporate governance regimes, strategic orientation, the direction of risk management, and the disclosure of companies (Al-Ahdal & Prusty, 2020). The effectiveness of the board or its ability to discharge its oversight duties, provide strategic directions, and hold management accountable depends on attributes that relate to each other: the independence of the board, its diversity, expertise, size, and frequency of meetings (Chijoke-Mgbame et al., 2020; Hamad et al., 2022; Rahman & Mohamed, 2019). These factors contribute to the board's capability to govern. Independence of the board of directors (often measured by the percentage of non-executive or independent directors) remains key to the objective management and mitigation of possible conflicts of interest (Cornelius, 2005; Htay, Aung, Rashid, & Adnan, 2012). Conversely, boards characterized by diversity, especially in terms of sex, professional experience, and sectors of origin, present an expanded range of viewpoints and, as such, enhance the overall quality of decisions and responsiveness to new threats, including environmental threats (Kampoowale, Kateb, Salleh, & Alahdal, 2024; Liao et al., 2015).

Empirical studies have consistently pointed out that highly effective boards enhance transparency and accountability in their disclosure practices (Chung & Zhang, 2011). In environmental reporting, the necessity of effective boards means that they play an important role in facilitating the efficient disclosure of accurate, timely, and comprehensive information on the firm and its environmental effects and policies on sustainability initiatives (Nair, Muttakin, Khan, Subramaniam, & Somanath, 2019; Velayutham, Krishnamurti, & Hoque, 2017). Through active participation in climate-related risks and opportunities, boards can improve their quality of disclosure, which allows firms to address stakeholders and regulatory demands (Helfaya & Moussa, 2017). Despite the previous literature on the connection between effectiveness in the board and broad ESG disclosures or CSR reporting, there is a lack of research on the narrower, though hugely important, aspect of environmental reporting, specifically the correlation between effectiveness in the board and disclosures of GHG emissions, which is a fraction of environmental transparency (Kampoowale et al., 2024; Mubarak et al., 2023). In addition, most past studies have focused mainly on developed markets, leaving scant knowledge on the effect of board characteristics on climate-related disclosure in emerging economies (Singhania & Bhan, 2025). Thus, this study aims to fill these gaps by examining the correlation between various facets of board effectiveness and the level and quality of GHG disclosure in Saudi Arabia, a rapidly evolving environment concerning developing corporate governance frameworks and environmental challenges.

4. THEORETICAL FRAMEWORK HYPOTHESES DEVELOPMENT

4.1. Stakeholder Theory

Stakeholder theory provides an analytical framework for evaluating how well the efficacy of the board of directors can influence the disclosure of GHG. Originally proposed by (Freeman, 2010), this theory argues that any firm must consider the interests and concerns of all the parties affected by its actions, including shareholders, the workforce, clients, vendors, governments, societies, and the environment (Mubarak et al., 2023). A more comprehensive understanding of corporate responsibility also questions the shareholder-based paradigm, which reveals the need for transparency and accountability to various stakeholders (Kuvvet, 2024). In the climate-change environment, stakeholders are increasingly demanding that companies disclose credible and detailed environmental reporting, notably that related to GHG emissions (Borghei, 2021). This is why the board plays a central role: it must oversee that management integrates the interests of stakeholders within corporate strategy and disclosure practices. According to empirical evidence, boards that have mechanisms to ensure their members are independent, diverse,

knowledgeable, and actively engaged are in a better position to identify salient stakeholder concerns, balance among competing interests, and oversee sound environmental reporting (Abdalla et al., 2024).

Stakeholder theory also posits that such boards engage in communication and negotiation between the firm and stakeholders, thereby developing trust and legitimacy. These duties take on elevated importance regarding climate-related disclosure, where publicity on emissions and sustainability benchmarks may impact a firm's presence, capacity to source capital, and long-lasting sustainability (Alsaifi et al., 2020). Improving the effectiveness of the board increases the chances that firms will be more likely to disclose in a manner that meets stakeholders' expectations of being comprehensive, accurate, and relevant, thereby strengthening their social license to operate (Singhania & Bhan, 2025). Accordingly, the underlying hypothesis, according to which the effectiveness of a board has beneficial effects on the level of GHG disclosure and the quality of GHG disclosure, is based on stakeholder theory. The theory highlights the importance of boards as intermediaries that coordinate corporate behavior and the demands of stakeholders to be accountable for climate change, hence building sustainable business practices.

4.2. Legitimacy Theory

Complementing the existing body of knowledge, legitimacy theory presents another theoretical framework that can be used to explain the correlation between board effectiveness and GHG disclosure (Akhter, Hossain, Elrehail, Rehman, & Almansour, 2023). Organizational actors must manage themselves according to the ethos and mandate of the societal settings within which they are working to enable their survival and legitimacy (Pellegrino & Lodhia, 2012). In scenarios where the actions of an organization, or even the consequences thereof, differ from societal expectations, particularly in cases where the organization faces environmental issues such as climate change, legitimacy is endangered, and, eventually, reputational and regulatory punishment or the loss of chapters among stakeholders may occur. Effective boards also play a central role in the protection of legitimacy, as directors monitor corporate disclosures that report environmental performance and continuous sustainability efforts (Helfaya & Moussa, 2017).

Independent, diverse, relevant expertise, and actively engaged boards have better chances of identifying developing societal concerns about climate change and steering management into transparent reporting of GHG emissions. Critical yet complete disclosure allows firms to demonstrate that they do not conflict with the values and expectations of societal groups, thus ensuring or reversing legitimacy. According to legitimacy theory, GHG disclosure has a strategic purpose for companies, as it responds to external pressures and justifies its activity due to growing environmental attention (Akhter et al., 2023). The process is determined by board effectiveness, which helps the firm better predict stakeholder interests, cope with information asymmetry, and send a message of accountability (Cornelius, 2005). Thus, effective boards covering the subject of sustainability play an instrumental role in helping a firm gain social approval, reputation, competitiveness, and access to resources (García-Sánchez, Hussain, Khan, & Martínez-Ferrero, 2022). Therefore, the current study lends credence to the idea that an effective board has a positive influence on the level and quality of GHG disclosure by influencing the securing and maintaining of organizational legitimacy during an era of amplified environmental awareness and control.

4.3. Board of Directors Effectiveness and Greenhouse Gas Disclosure

Stakeholder theory argues that a corporation beyond the shareholder-value maximization mandate owes duties to a larger group of stakeholders, such as regulators, investors, employees, customers, and society in general, who increasingly demand greater disclosure of the environment-related activities of corporations (Aluchna, Roszkowska-Menkes, Kamiński, & Bosek-Rak, 2022; Freeman, 2010). GHG disclosure has become a key part of this new paradigm, providing stakeholders with the information they need to determine a company's exposure to risks associated with climate change and to gauge the extent of its investment in sustainability (Cohen et al., 2023). Successful responses to this complex stakeholder environment hinge upon effective boards of directors characterized by independence,

diversity, expertise, and active oversight (Bae Choi et al., 2013). These boards should incorporate environment-related issues into their corporate strategies and report accurate, complete, and timely GHG disclosures (Akbaş & Canikli, 2019). This kind of responsiveness also serves to build stakeholder trust, enhance corporate legitimacy, and underpin long-term value creation (Liu, Zheng, Qiu, & Jiang, 2022).

Similar pieces of wisdom are laid out in the theory of legitimacy, which underlines the importance of ensuring that there is a fit between the activities of a firm and the existing norms, values, and expectations prevalent in society (Abdalla et al., 2024). When the environmental disclosures of an organization are inadequate or perceived as inauthentic, organizations risk losing legitimacy during times of increased environmental awareness and more focused regulatory attention (Akhter et al., 2023). Furthermore, the best boards are likely to value reputational and legal risks on the themes of insufficient climate transparency. Such boards encourage thorough GHG disclosures through watchful supervision and strategic management, thus indicating responsibility and environmental stewardship to outsiders (Abdalla et al., 2024; Abdalla et al., 2024). This disclosure provides the maintenance and creation of a firm's competitive advantage by maintaining its social license to operate and improving its reputation and stakeholder relations (Cohen et al., 2023).

In the available literature that addresses corporate governance, both empirical and theoretical evidence points to the conclusion that, with strong governance mechanisms in place, reporting disclosures of environmental information can be significantly expanded and enhanced in quality (Giannarakis et al., 2018; Gulluscio et al., 2020; Tang, 2019). The boards of directors, who are effective in the sense that they have a high level of independence, expertise, and psychosocial competence, install a culture of accountability as they monitor the performance of the executives in an environmental context and demand high levels of intensive, transparent reporting (Caby, Ziane, & Lamarque, 2020). Oversight of this nature would mean that corporate action is not only compliant with the prescriptions of regulators but also in line with the emerging expectations of a diverse group of stakeholders, such as investors, regulators, customers, and civil society, all of whom monitor climate-related risks and sustainability claims (Mou & Ma, 2023). Moreover, effective boards promote the development of organizational legitimacy in the eyes of the population and among key stakeholders, a condition for securing social approval and maintaining long-term survival, achieved by prioritizing openness (Halkos & Skouloudis, 2016). Corporate disclosure and pressure towards legitimacy thus provide an incentive for firms to provide detailed, accurate, and decision-useful information regarding GHG emissions, mitigation strategies, and climate-related risks (Pellegrino & Lodhia, 2012). Effective boards are therefore a crucial tool for driving climate-related transparency, which strengthens corporate governance and supports greater environmental and societal goals (Abdalla et al., 2024). Therefore, this study proposes the following hypothesis:

H_1: The effectiveness of the board of directors is positively associated with the extent and quality of greenhouse gas disclosure among listed firms.

5. METHODOLOGY

5.1. Study Sample and Data Collection

The current analysis covers an exposure group of 150 Saudi-listed firms deemed to be highly polluting by the Saudi Exchange. These industries include the energy, materials, transportation, industrial manufacturing, and utilities sectors. These sectors were purposively selected because they are carbon-intensive, face heightened environmental scrutiny, and play a pivotal role in achieving national sustainability targets under Vision 2030 and the 2060 net-zero pledge. Focusing on high-impact industries ensures the results capture the firms most relevant to greenhouse gas disclosure and governance effectiveness. Firms that operate within these sectors have significant social and environmental risks; especially regulatory risks associated with carbon emissions and liability concerns related to climate change. In response, these companies will be required to initiate a holistic ESG and sustainability-related disclosure regime, with a particular focus on board governance as the oversight system of such disclosures (Abdalla et al., 2024). Purposive sampling is used to draw particular attention to businesses in these sectors with high

impact, which is consistent with its intent to investigate GHG disclosure and board effectiveness. Such a methodology guarantees focused insight into entities that most apply to the goal of the study, thereby offering a narrower and more definite overview of the mechanisms of governance and their impacts on climate-related transparency (Mubarak et al., 2023).

The study period was 2020-2024, which is a significant period that came after 2016, when Saudi Vision 2030 was announced (Moshashai et al., 2020; Topal, 2019). Several policy reforms had been implemented by 2020, which explains why their quantitative assessment was practical (Topal, 2019). The focus of the introduction of reforms was on the enhancement of corporate governance and the perfection of sustainability disclosure requirements (Umar et al., 2024). This period, characterized by increased interest in environmental and governance agendas, reflected high levels of attention on measures that would enhance board performance and institutional accountability (Moshashai et al., 2020). To measure the connection between board performance and GHG disclosure, this study used secondary information collected from the annual reports of the sampled companies. Using the content analysis approach that is popular in the non-financial disclosure literature, this study analyzes the extent, quality, and profundity of GHG-related disclosures and pays attention to contextual nuances (Borghei, 2021). To support reliability, this study uses a structured coding scheme based on established theories (Abdalla et al., 2024). The initial set of data consisted of 900 firm-year observations of 180 listed firms, but 30 firm-years were dropped because of irregular annual reporting, resulting in a final sample of 750 firm-years and 150 firms. To obtain accuracy and consistency in all data, all information about board composition and GHG disclosure was extracted manually based on publicly available reports.

5.2. Variable Measurement

5.2.1. Greenhouse Gas Disclosure

The nature of the measure definition and the measure of the quality and proficiency of disclosure bring additional methodological issues, as neither of them can be measured objectively but are rather subject to circumstances. The lack of a standard international theoretical model has limited the development of standardized measures for these constructs. Therefore, indirect empirical estimates have been used in prior studies, which implicitly consider that the observed level or quality of disclosure adequately represents the disclosure level or quality (Bae Choi et al., 2013). Quantitative studies of disclosure in environmental reporting have also used disclosure indices based on the assumption that information released can be used as an indicator of the quality of environmental reporting, although this may come at the cost of volume-substituting substances. However, they are still indispensable to organizational reporting because numerical and quantitative data provide verifiable facts that can be used to promote credibility and elicit trust. Following this line of reasoning, the investigations of the present study regularly use a well-structured disclosure scoring system that enables the breadth and depth of corporate environmental reporting, especially GHG reporting (Borghei, 2021).

Empirical research in the field has largely been based on predetermined checklists or third-party ratings, such as sustainability, Bloomberg Disclosure Scores, Refinitiv Disclosure Scores, and CDP. In contrast, the current study develops a customized GHG disclosure index by combining international best-practice guidelines with Saudi local reporting requirements (Bae Choi et al., 2013; Helfaya & Moussa, 2017; Peters & Romi, 2014; Tsang, Frost, & Cao, 2023). The development of the index comprised a process of several steps, where criteria based on the Tadawul ESG Index, Saudi Central Bank ESG Risk Management Guidelines, GRI standards, and TCFD were consolidated. These sources encompass universal GHG disclosure aspirations in addition to Saudi GHG-specific resultative requirements (Akbaş & Canikli, 2019). The first draft of 80 items was consulted with experts in the areas of sustainability, climate change reporting, corporate governance, and GHG disclosure. The final index was 67 items after dropping seven items that were redundant or irrelevant, in addition to six items that were never reported. A scoring scheme used in past research, which was unweighted, where GHG disclosure was scored 1 and zero when non-disclosed, was adopted.

This scoring process eschews subjective weighting, meets international and local reporting guidelines, and creates objective grounds for measurement.

5.2.2 Board of Directors Effectiveness

This research measures the efficiency of the board of directors as a composite index, which is complemented by four governance measures: board independence, board size, board gender diversity, and frequency of board meetings. This is a multi-dimensional construct, appreciating that no one attribute is capable of holistically summarizing the oversight capacity of the board (Helfaya & Moussa, 2017; Liao et al., 2015). Independence of the board is necessary as it enables the board to be more dedicated to stakeholders, as the independent members have less interest in interfering with managerial operations (Cornelius, 2005). Board size: The optimal board size has the potential to maximize the effectiveness of reaching a decision by including various perspectives and maintaining coordination within limits (Abdalla et al., 2024). Empirical evidence indicates that gender diversity enhances board deliberations and makes board decision-making more inclusive and thus aligned with increased interest in sustainability and social responsibility (Kampoowale et al., 2024). The frequency of meetings also serves as a sign of hard work and monitoring level because more frequent meetings enable them to pay more attention to corporate strategies, risk control, and climate-related risks (Singhania & Bhan, 2025). This composite score is calculated between 1 and 4, where a higher score indicates better board performance. The combined nature of the given attributes generates a comprehensive evaluation of the quality of governance, which is not applied individually to the components (Al-Ahdal & Prusty, 2020). This strategy is especially relevant to the disclosure of GHGs that require boards to balance strategic decision-making, regulatory treatment, and dialogue with stakeholders in providing transparent and high-quality reporting (Cohen et al., 2023; Orazalin et al., 2024).

5.2.3. Control Variables

This study examines whether board directors' effectiveness observably affects corporate reporting of GHG emissions. To attain this goal, a set of firm-specific independent variables is included in the estimation framework: firm size, firm age, a measure of the return on assets (ROA), liquidity, leverage, and audit quality. These variables are commonly denoted as significant determinants of voluntary and mandatory disclosure via empirical research (Bae Choi et al., 2013; Cohen et al., 2023). The econometric model and Table 1 outline the study model, measurement, and operational definitions of the study variables.

$$GHGDit = \beta 0 + \beta 1BOEit + \beta 2SIZEit + \beta 3AGEit + \beta 4ROAit + \beta 5LIQit + \beta 6LEVit + \beta 7AUDQit + \varepsilon it \quad (1)$$

Table 1. Measurement of variables.

Variable	Symbol	Measurement
Greenhouse gas (GHG) disclosure	GHGD	Measured using a self-constructed GHG disclosure index comprising 67 items. Each item is scored unweighted (1 if disclosed, 0 if absent), with the total score reflecting the extent of GHG disclosure.
Board of directors' effectiveness	BOE	Measured using a composite index based on four governance indicators. The composite score ranges from 1 to 4, with higher values indicating greater effectiveness.
Firm size	SIZE	Typically measured by the logarithm of total assets.
Firm age	AGE	Measured as the number of years since the firm's establishment.
Return on assets (ROA)	ROA	Measured as net income divided by total assets, reflecting firm profitability and resource availability for disclosure.
Liquidity	LIQ	Measured as the ratio of current assets to current liabilities.
Leverage	LEV	Measured as the ratio of total debt to total assets.
Audit quality	AUDQ	Binary variable, 1 if audited by a Big Four firm Deloitte, PwC, Ernst & Young, or KPMG; 0 otherwise.

6. EMPIRICAL RESULTS

6.1. Descriptive Statistics

Descriptive statistics, as shown in Table 2, indicate that there is an average GHG disclosure of 0.2280, which means that the sampled firms generally showed low levels of disclosure. The Board of Directors Effectiveness (BOE) was, on average, 2.51, which accounted for observations that varied between 0 and 4, indicating diversity in board performance. Firm size was recorded as the logarithm of the means of firm assets, with an average of 8.40, depicting a population with a variety of small and large firms. The average age of the firms was 33 years, with the youngest being 5 years and the oldest 85 years. The average profitability (ROA) is 0.1680, implying some degree of non-excessive return. The measure of liquidity was variable, with a mean of 2.72 and a maximum of 27.93, indicating that some companies have exceptionally high current ratios. The leverage averaged 0.485, with the highest figure being 1.45, which clearly highlights the variation in capital structure. The Big 4 affiliation value, upon which audit quality was measured, had a mean of 0.611, meaning that around 61% of the firms were audited by Big 4 firms.

Table 2. Descriptive statistics

Variables	Mean	Std. Dev.	Minimum	Maximum
GHGD	0.2280	0.1622	0.0600	0.7385
BOE	2.5113	0.93588	0.000	4.0000
FSIZE	8.4023	1.3403	1.1071	10.5186
AGE	33.1148	12.9573	5.000	85.000
PRO	0.1679	0.1148	0.0405	0.5400
LIQ	2.7213	3.4906	0.1234	27.9284
LEV	0.4847	0.2037	0.0665	1.4511
AUDQ	0.6114	0.4877	0.0000	1.000

Note: Greenhouse gas (GHG) disclosure = GHGD: Board of directors' effectiveness = BOE: Firm size = SIZE: Firm Age = AGE: Return on assets = ROA: Liquidity = LIQ: Leverage = LEV: Audit quality = AUDQ

6.2. Correlation Matrix

The correlation coefficients between the variables of study, as well as the Variance Inflation Factors (VIF) used to investigate the occurrence of multicollinearity, are presented in Table 3. The results show that Greenhouse Gas Disclosure (GHGD) is positively and moderately correlated with Board of Directors Effectiveness (BOE) (r = 0.3398), profitability (PRO) (r = 0.3933), and audit quality (AUDQ) (r = 0.3867).

Therefore, companies with better-performing boards, greater profitability, and Big 4 auditors tend to disclose more information related to GHG. A small positive correlation also exists between GHG emission disclosure (GHGD) and firm age (AGE) (r = 0.1663) and leverage (LEV) (r = 0.0662), while a negative correlation is observed with firm size (SIZE) (r = -0.1399) and liquidity (LIQ) (r = -0.0806); thus, larger and more liquid firms report less on GHG emissions.

The relationship between BOE and other control variables is insignificant, except for profitability, where the strongest positive relationship is noted (r = 0.2203). It is also notable that liquidity (LIQ) and leverage (LEV) are negatively related, with a significant negative correlation (r = -0.5881), indicating that higher leverage is associated with lower liquidity.

Regarding multicollinearity, all variables in the regression analysis have VIF values below 1.56, well under the acceptable threshold of 10, which is considered sufficient in this context; therefore, multicollinearity is not an issue in the present study, as supported by (Abdalla et al., 2024).

Table 3. Correlation matrix.

Variables	GHGD	BOE	SIZE	AGE	PRO	LIQ	LEV	AUDQ	VIF
GHGD	1.0000								-
BOE	0.3398	1.0000							1.08
SIZE	-0.1399	0.0795	1.0000						1.07
AGE	0.1663	-0.0337	-0.1106	1.0000					1.03
PRO	0.3933	0.2203	-0.1422	-0.0313	1.0000				1.15
LIQ	-0.0806	-0.0803	0.0737	-0.0616	-0.1017	1.0000			1.56
LEV	0.0662	0.0701	-0.0424	-0.0312	0.1023	-0.5881	1.0000		1.54
AUDQ	0.3867	0.1546	-0.1590	0.0382	0.2740	-0.1238	0.0818	1.0000	1.12

Note: Greenhouse gas (GHG) disclosure = GHGD: Board of directors' effectiveness = BOE: Firm size = SIZE: Firm age = AGE: Return on assets = ROA: Liquidity = LIQ: Leverage = LEV: Audit quality = AUDQ.

7. REGRESSION FINDINGS AND DISCUSSION

Splitting of the regression analysis was conducted by applying the random-effects model to the standard errors, which were robust and clustered at the firm level. This approach was used to account for potential heterogeneity and autocorrelation among firms over time, ensuring that the standard errors were accurately estimated. The random-effects model was selected over the fixed-effects alternative based on the Hausman test results, which indicated no significant systematic differences in coefficients between the two estimators. Additionally, the random-effects model allows for the inclusion of time-invariant covariates and captures both within-firm and between-firm variation simultaneously. This methodology provides a more reliable estimate of the standard errors and mitigates bias related to unobserved heterogeneity that may vary over time across firms. The low values of Variance Inflation Factors (VIFs), ranging from 1.03 to 1.56, confirm that multicollinearity among the explanatory variables is not a concern, thereby enhancing the model's validity. As shown in Table 4, the regression results indicate a statistically significant positive impact of Directors Effectiveness (BOE) on GHG disclosure. Specifically, the coefficient of BOE (0.0630, t = 8.82) suggests that a one-unit increase in the board effectiveness index is associated with a 6.3 percentage-point increase in the GHG disclosure score. These empirical findings support the hypothesis that companies with more effective boards tend to engage in more comprehensive GHG reporting. The results align with stakeholder theory, as effective governance frameworks, particularly active and well-organized boards, facilitate firms' responses to stakeholder demands for transparency and environmental disclosure (Aluchna et al., 2022; Freeman, 2010). The strategic importance of justifying corporate activities by disclosing management actions that conform to societal values and expectations is another form of accomplishing proper board performance based on legitimacy theory (Akhter et al., 2023; Pellegrino & Lodhia, 2012). The current findings are in line with earlier studies, such as those conducted by Peters and Romi (2014), who also found that board effectiveness is a key factor in determining an increase in environmental and sustainability disclosure, and Abdalla et al. (2024), who arrived at the same conclusion. As for control variables, firm age (AGE) also makes a positive and statistically significant contribution to GHGD, showing a coefficient of 0.5499 and a p-value of 0.0052. It is probable that older firms report more GHG information because more GHG information is likely to be disclosed due to built-up experience, established networks, and/or relationships with stakeholders, and mature reporting systems. The second explanatory factor, profitability (PRO), has an estimate of 0.3278 as positive with high significance (t = 5.33), which means that more profitable firms invest more resources to prepare environmental reporting, which is the same as legitimacy motives and resources to provide qualitative reporting disclosures. Liquidity (LIQ) and leverage (LEV) also show positive, albeit less pronounced, links with GHGD, reflecting that companies enjoying greater financial flexibility or covering larger debt amounts are under more scrutiny by creditors and investors, thus making disclosures more pronounced. Lastly, the level of audit quality, as determined by Big 4 auditors (AUDQ), is also positive and significant at the 1 percent significance level, which further supports the idea that reputable auditors facilitate greater disclosure quality, contributing to increased transparency and credibility.

Table 4. Regression results.

Variables	Coefficients	t-sat
BOE	0.0630	8.82***
SIZE	- 0.0082	-1.20
AGE	0.0052	6.10***
PRO	0.3278	5.33***
LIQ	0.0047	2.60**
LEV	0.0797	2.23*
AUDQ	0.1113	7.25***
Constant	- 0.2082	-3.06**
R^2	0.29	
Number of observations	750	
Prob > chi2	0.0000	
Wald chi2(7)	360.87	

Note: Greenhouse gas (GHG) disclosure = GHGD: Board of directors' effectiveness = BOE: Firm size = SIZE: Firm age = AGE: Return on assets = ROA: Liquidity = LIQ: Leverage = LEV: Audit quality = AUDQ = *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

8. CONCLUSION

The issue of GHG disclosure has become a topical concern among listed companies in developing economies that are simultaneously attempting to make economic development and environmental protection an economic growth goal. This study examines how the effectiveness of the board of directors affects GHG disclosure in the environment of Saudi Arabia, a nation that must meet the demands of Vision 2030 and its net-zero endeavour in 2060. Using a purposive high-impact sample of 150 high-impact firms with 750 firm-year observations during the calendar years 2020-2024, a new metric of the GHG Disclosure Index was created through intensive content analysis of publicly reported materials and may thus provide a more complete and detailed measurement relative to existing metrics based on the CDP dataset. The findings show that there is a strong positive relationship between the effectiveness of boards and the scope and quality of GHG reporting, thus supporting the hypothesis that the stronger boards govern a firm, the more likely it is to fairly report climate-related information. The overall findings support the idea that when well-governed, mechanisms of accountability and legitimacy are enhanced in times characterized by increased climate accountability.

This study has important implications for policy, practice, and research. The results highlight the centrality of robust governing systems in the realization of environmental transparency, which could be used to support the claim that regulatory changes in emerging economies must enhance the necessity of board composition and the engagement factor. At the corporate leadership level, evidence shows that the decision to invest in board capacity, especially by way of diversity, independence, and energetic supervision, will serve as a strategic lever in delivering stakeholder expectations and cementing a reasonable organizational linguistic process. This experiment demonstrates the usefulness of context-specific, multidimensional indices of disclosure that can measure the depth and credibility of environmental reporting beyond the scope of voluntary databases.

This research provides substantive policy, practice, and research implications. The results highlight the central importance of effective governance structures in promoting environmental transparency and demonstrate that regulatory changes in developing economies should pre-empt board structure, interactions, and control systems. Board capacity, in terms of diversity, independence, and active supervision at the corporate level, is a strategic tool to meet stakeholder expectations, enhance accountability, and promote sustainable decision-making. Moreover, the research reveals the usefulness of context-specific, multidimensional indices of disclosure in providing a more holistic and reliable report on environmental reporting than traditional voluntary databases. These lessons reaffirm that governance practices should be aligned with the sustainability agenda, and that well-designed boards not only improve the quality of disclosures but also enhance legitimacy, stakeholder trust, and long-term organizational performance. Nevertheless, this study has some limitations. The focus on Saudi-listed firms in high-impact industries limits the generalizability of the findings to other sectors or national contexts. Content analysis, while systematic,

cannot fully capture the intent or quality of internal environmental governance practices. Additionally, the cross-sectional design constrains the ability to infer long-term causal relationships. Future research could adopt longitudinal designs to explore causality, extend the model to other emerging economies, and examine the interactions between board culture, climate strategy, and disclosure quality to deepen understanding of governance–environment linkages.

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