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Review

Corporate carbon disclosure: Methods, motivations, and impacts

Weidong Li, Sijia Xie, Jinyu Chen*

College of Business Administration, Capital University of Economics and Business, Beijing 100071, China
*** Corresponding author:** Jinyu Chen, 2733091828@qq.com

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Abstract: In the context of the global shift toward a low-carbon economy, carbon disclosure has emerged as a crucial tool for facilitating the low-carbon transition of firms and addressing climate change. As a result, it has become an increasingly prominent focus in academic research and policy making. This paper reviews the existing literature on carbon disclosure, examining the methods, standards, motivations, and impacts associated with current research in this area. Based on this analysis, the paper identifies key gaps in the existing literature and suggests directions for future research, aiming to contribute to the advancement of theoretical understanding and provide a valuable reference for future studies.

Keywords: carbon disclosure; disclosure motivations; economic consequences; disclosure standards; carbon disclosure theory; literature review

1. Introduction

Global warming presents a significant challenge to the natural ecological systems that are essential for human survival. The release of greenhouse gases, particularly carbon dioxide, from human activities since the mid-20th century has become the primary driver of climate change. In response to the pressing issues posed by global climate change, there is now a global consensus to promote the development of a green, low-carbon, and environmentally sustainable model. To date, 127 countries and regions have actively committed to carbon neutrality. However, as the transition to a low-carbon economy progresses, stakeholders are increasingly concerned about the potential impacts of future carbon regulations and the physical risks posed by climate change to infrastructure. This growing concern has led many organizations to begin disclosing their climate risks, carbon reduction strategies, actions, and achievements as a means of alleviating external pressures.

Carbon disclosure refers to the practice by greenhouse gas-emitting entities of publicly sharing information related to their carbon emissions with investors and the public in an accurate, comprehensive, timely, and sufficient manner, typically through regular and interim reports. In recent years, the importance of carbon information disclosure has gradually been recognized and has become a cornerstone for the development of carbon trading markets. As a result, numerous scholars, both domestically and internationally, have conducted in-depth research on the topic, generating valuable insights and recommendations. While some scholars have reviewed the literature on carbon disclosure [1], most studies have focused on specific aspects, such as corporate value, cost of capital, or financial performance, and a comprehensive, systematic discussion of the subject remains scarce. This study aims to address these gaps by synthesizing the field of carbon disclosure with richer content and a broader perspective.

Drawing on existing literature, this paper explores current measurement

approaches and theoretical frameworks related to carbon disclosure. It provides a detailed analysis of research on the motives behind carbon disclosure and the economic consequences associated with it. Furthermore, this paper seeks to identify gaps in the existing body of research and propose directions for future study, with the aim of advancing both the theoretical development and practical application of carbon disclosure.

2. Research methodology

A Systematic Literature Review (SLR) is a structured method used to identify, evaluate, and synthesize research on a specific topic [2]. It follows a clear process that includes searching for relevant studies, applying strict inclusion and exclusion criteria, and analyzing the data with predefined coding schemes to ensure consistency and minimize bias [3]. Unlike traditional reviews, which are more subjective, an SLR aims to reduce bias by being systematic and transparent [4]. Meta-analyses are often included to strengthen conclusions. The method is grounded in a robust theoretical framework that emphasizes the importance of a clear, systematic, and rigorous approach to extracting meaningful insights from the literature. This approach ensures a structured process for synthesizing complex bodies of research and deriving well-founded conclusions [5]. Since the establishment of the Carbon Disclosure Project (CDP) in 2000, research on carbon disclosure has gradually increased. Therefore, this paper employs a systematic literature review method to comprehensively review the relevant literature from 2000 to 2024. The Web of Science database extensively indexes numerous high-quality and precise literature resources. Compared to other similar databases, it exhibits greater convenience in literature retrieval and acquisition. In light of this, the present study specifically selects the Web of Science database as the primary tool for screening relevant literature.

The first step involves identifying key search terms. Through a comprehensive review of relevant studies, this paper selects a combination of key terms, including "CO_2," "carbon," "greenhouse gases," "GHG," "climate," "disclosure," "standards," and "guidelines." The second step is a preliminary literature search using these keywords, which initially yields 5259 articles. The third step involves narrowing the scope to include only relevant journals. English-language journals from the SSCI database within the Web of Science Core Collection are selected, excluding 2550 articles from other sources, leaving a total of 2709 articles. In the fourth step, the research field is further refined. By focusing specifically on management science, the number of relevant documents is reduced to 623. In the fifth section, this paper conducted a thorough reading and analysis of 623 papers, excluding those primarily focused on the construction of carbon disclosure platforms, the measurement of carbon disclosure indicators, and sustainable development status. It retained literature centered on research methods for carbon information disclosure, disclosure motivations, disclosure impacts, and the current status of disclosure. After this review, it was determined that only 158 of the articles are directly related to the topic of carbon disclosure. The flowchart of literature mining is shown in **Figure 1**.

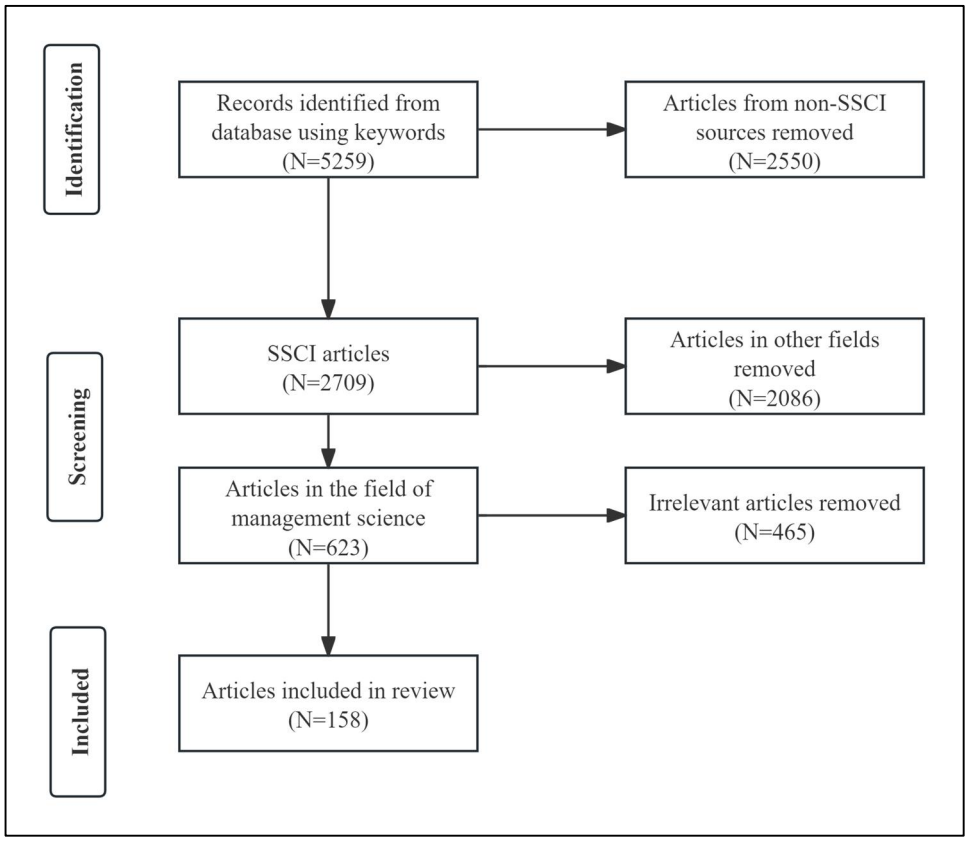

Figure 1. Methods of literature mining.

3. Carbon disclosure measurement

Most existing studies on the measurement of carbon disclosure employ empirical research frameworks. However, these approaches are marked by diversity and a lack of standardization. Based on differences in the methods of measurement, these studies can generally be categorized into the following types:

3.1. Reputation evaluation method

The reputation evaluation method gathers subjective assessments of different firms from respondents through a structured questionnaire. Respondents are asked to rate various predefined indicators, and the cumulative score for each indicator reflects the firm's reputation [6]. However, this approach has notable limitations. First, it assumes that respondents possess detailed knowledge of the firms in question, but such knowledge is often constrained by factors such as the firm's size, brand visibility, and the individual respondent's personal experiences. This can lead to significant discrepancies in the reputation scores for the same firm due to subjective biases. Second, the length of the questionnaire can be a hindrance, potentially reducing both the quality of the responses and the overall response rate, thus limiting the method's applicability in large-scale surveys.

3.2. Index method

The index method involves quantifying the level of information disclosure by constructing a composite index. The process typically follows these steps: first, the

disclosure content is categorized into several groups; second, specific subcategories are defined within each group; third, both quantitative and qualitative information within the subcategories are assigned values; and finally, the scores of the subcategories are aggregated to form an overall information disclosure index. One limitation of the index method is that many existing reports primarily consist of qualitative descriptions rather than quantitative data, resulting in uneven and non-standardized information disclosure.

3.3. Content analysis method

The content analysis method involves a detailed examination of a firm's publicly available reports or documents to assess the score or value of each specific item, thereby providing a comprehensive evaluation of information disclosure. This method offers several advantages: first, it is well-suited for large-scale sample studies; second, once the scoring criteria are established, the subsequent analysis tends to be relatively objective [7]. However, it is important to note that the process of defining disclosure items carries a degree of subjectivity, which may influence the consistency and reliability of the results.

3.4. CDP questionnaire method

The CDP questionnaire method primarily collects corporate environmental information disclosure through surveys. Currently, CDP survey questionnaires are mainly categorized into three types: climate change questionnaires, forest questionnaires, and water questionnaires. For the content related to corporate carbon information disclosure, the focus is on completing the climate change theme questionnaire.

The structure of the climate change questionnaire typically encompasses 15 core sections, in sequence: the corporate profile, governance structure, risk and opportunity analysis, business strategy planning, target and performance evaluation, emission calculation methodology, emission data overview, detailed emission breakdown, energy use, additional indicators reporting, verification process, carbon pricing strategy, collaboration and cooperation status, biodiversity conservation, and approval process. Each section is carefully designed with multiple specific questions.

The CDP questionnaire method establishes a standardized evaluation system for carbon information disclosure, which categorizes corporate scores into four levels from low to high: Disclosure Level (D and D-), Awareness Level (C and C-), Management Level (B and B-), and Leadership Level (A and A-). This evaluation system visually demonstrates the comprehensiveness of corporate information disclosure through questionnaire ratings, significantly enhancing data comparability and transparency. However, this method also has limitations, primarily in its limited flexibility, which makes it difficult to fully meet the unique needs of individual corporations. Furthermore, the process of completing the questionnaire and analyzing the data is relatively cumbersome, and the instability of questionnaire response rates may undermine the completeness and reliability of the data.

4. Theoretical foundation of carbon disclosure

Theories of carbon disclosure are primarily used to explain corporate carbon disclosure from a variety of perspectives, including stakeholder theory, legitimacy theory, signaling theory, voluntary disclosure theory, agency theory, planned behavior theory, institutional theory, asymmetric information theory, corporate social responsibility theory, sustainable development theory, reputation information theory, low-carbon economy theory, circular economy theory, shared value theory, and others. These theories are generally employed to explore the motivations behind carbon disclosure, the mechanisms through which disclosure influences corporate behavior, or to assess the tangible value and impact of carbon disclosure for firms. Among these, stakeholder theory, legitimacy theory, voluntary disclosure theory, and signaling theory are particularly prominent in the literature on carbon disclosure.

4.1. Stakeholder theory

Stakeholder theory asserts that corporate executives should not focus solely on maximizing their own interests but must also consider the broader interests of stakeholders across various dimensions when managing business operations [8]. As the low-carbon concept becomes increasingly prevalent, both government entities and the public are paying greater attention to the carbon governance and emissions reduction efforts of businesses. In this context, carbon disclosure serves as a crucial communication bridge between companies and stakeholders, enabling stakeholders to better understand corporate carbon information and assess whether their interests are being adequately protected. In this process, the government plays a vital role as a key stakeholder, ensuring the protection of other stakeholders' rights by encouraging or mandating the disclosure of carbon-related information.

4.2. Legitimacy theory

Legitimacy theory posits that a firm's survival depends on its values being accepted by the public, meaning that the company's values must align with the broader social value system. Information disclosure serves as the most direct means for companies to demonstrate their value-driven behaviors, and carbon disclosure, in particular, aims to communicate key value information, such as a company's active participation in low-carbon emission reduction efforts. This transparency helps companies gain public recognition and, consequently, organizational legitimacy [9]. On the one hand, the growing societal emphasis on low-carbon initiatives and environmental protection—along with the widespread acceptance of clean production and sustainable lifestyles—encourages businesses to disclose carbon information actively. In doing so, they can build a positive image, secure legitimate resources, and create value for the organization. On the other hand, by disclosing comprehensive carbon information, companies highlight their commitment to reducing emissions while balancing economic development with environmental protection. This not only alleviates pressures related to regulatory and normative legitimacy but also helps resolve potential legitimacy crises.

4.3. Voluntary disclosure theory

The theory of voluntary disclosure asserts that in a market economy, firms choose to disclose information beyond the statutory requirements to external stakeholders, driven by their own interest-maximization motives. This voluntary disclosure may encompass various aspects of a company's operations, including its financial condition, operating results, strategic plans, social responsibility efforts, environmental performance, and more [10]. By voluntarily disclosing information, companies can reduce transaction costs, improve operational efficiency, and meet investors' demand for transparency regarding the company's financial status, thereby mitigating agency and market risks. Moreover, comprehensive and proactive carbon disclosure not only helps distinguish a company from its competitors by presenting its commitment to low-carbon operations but also strengthens its green competitiveness. This approach can alleviate stakeholders' concerns regarding carbon-related risks, encouraging them to make economic decisions in favor of the company and ultimately securing valuable development opportunities.

4.4. Signaling theory

Signaling theory posits that important information is unevenly distributed among economic actors due to factors such as differences in their ability to acquire signals and the social division of labor [11]. In the context of the current low-carbon economy, "green and low-carbon" practices have become central to the value system and operational strategies of businesses. Through the information disclosure mechanism, companies transmit internal carbon-related information to external parties who may have limited access to such information, thereby enabling them to make more informed decisions [12]. Furthermore, the environmental goals and actions undertaken by companies signal their economic capacity to manage carbon emissions, demonstrating their potential for green and sustainable development. This not only helps stakeholders assess the company more favorably but also enhances the company's overall value by reinforcing its commitment to environmental responsibility.

5. Research on corporate carbon disclosure

5.1. Research on corporate carbon disclosure

In recent years, although scholars have yet to reach a consensus on the specific definition of carbon information disclosure, the core theme remains consistent: it emphasizes that enterprises should ensure accurate, comprehensive, timely, and sufficient disclosure of information related to their greenhouse gas emissions to the outside world through established channels. For ease of reference, this paper has compiled in the following **Table 1** the definitions of carbon information disclosure proposed by various scholars.

Table 1. Definition of carbon disclosure.

Definition	Scholar
Companies are, ideally, expected to communicate publicly regarding their carbon emissions and other activities related to environmental sustainability	Li et al. [13]; Hahn and Lülfs [14]
Listed companies are required to disclose their direct and indirect GHG emissions in their annual reports.	Downar et al. [15]
Firms react by voluntarily disclosing information on GHG emissions, using various channels of communication to do so.	Depoers et al. [16]
To legitimize their practices targeted at improving environmental performance and reducing GHG emissions, firms must measure, disclose, and communicate information about all topics related to corporate social responsibility (CSR).	Döring et al. [17]
Companies measure firms' beliefs about climate regulation, plans for future abatement, and current emissions mitigation from responses to the Carbon Disclosure Project.	Ramadorai and Zeni [18]
Enterprises disclose information related to greenhouse gas emissions through their disclosure channels (such as annual reports, consolidated reports, standalone reports, and websites), including emission volumes, reporting boundaries, accounting methods, emission targets, commitments to reporting guidelines and verification, historical emission data, and climate change policies.	Grahn [19]

5.2. The temporal evolution of research on carbon disclosure

To examine the evolving nature of carbon disclosure-related research, the literature was clustered based on keywords and analyzed through cluster analysis mapping (see **Figure 2)**. Carbon disclosure refers to the practice by greenhouse gas-emitting entities of publicly sharing information related to their carbon emissions with investors and the public in an accurate, comprehensive, timely, and sufficient manner, typically through regular and interim reports. It serves as a key mechanism through which companies adapt their management practices in response to climate change, provide valuable information to stakeholders, and enhance the legitimacy of their operations. The development of carbon disclosure is driven by growing awareness of environmental issues and the impact of climate change on human life. According to the cluster analysis mapping, research on carbon disclosure initially focused on corporate performance, gradually expanded to include topics such as climate change and greenhouse gases, and has more recently shifted towards studies on sustainable development.

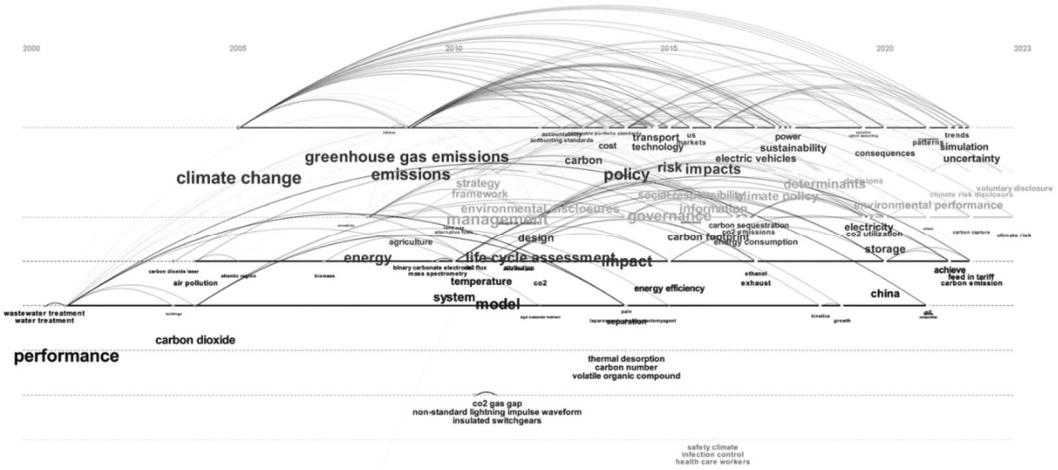

Figure 2. Temporal evolution of carbon disclosure-related research.

Note: (1) The order from left to right in the figure represents the chronological sequence of the first occurrences of these keywords; (2) The connecting lines represent associations; (3) The size of the nodes reflects the frequency of the vocabulary appearing in different years.

5.3. Research on corporate carbon disclosure standards

At the 1955 Climate Change Conference hosted by the United Nations, a heightened focus on climate issues in international politics led to the formation of several international organizations aimed at promoting corporate carbon information disclosure. Since then, the efforts of these organizations to develop carbon accounting standards have laid the groundwork for the establishment of corporate carbon disclosure frameworks. Several international bodies have proposed standards for corporate carbon disclosure: the standards issued by the Global Reporting Initiative (GRI) have become a key framework for corporate sustainability reporting; the Carbon Disclosure Project (CDP) has developed a set of questionnaires that provide a methodology for carbon disclosure; the Task Force on Climate-related Financial Disclosures (TCFD) has introduced a coherent and voluntary framework for climate-related disclosures, which is currently one of the most influential and widely adopted globally; the International Sustainability Standards Board (ISSB) will release its Climate Disclosure Guidelines in 2023, aiming to establish a global benchmark for sustainable disclosure standards. In 2023, the European Union issued the Corporate Sustainability Reporting Directive (CSRD[1]) and the European Sustainability Reporting Standards (ESRS[2]), providing firms with a clear framework to help them establish a sustainable development image in the global market. **Table 2** summarizes the current mainstream international corporate carbon disclosure standards.

Table 2. The current mainstream international corporate carbon disclosure standards.

Standard	GRI305	TCFD	SASB	CDP	CDSB	ISSB	CSRD	ESRS
Release Date	2016	2017	2018	2022	2022	2023	2023	2023
Disclosure	Carbon emissions data, impacts and ways to manage them	Climate-related governance, risks and opportunities, business strategies, targets and performance; carbon emissions methodologies, data, segmentation, etc.	Environmental Policy, Governance of the Strategy, Management Objectives, Risks and Opportunities, Sources of Impact, Performance and Comparative Analysis, Outlook.	Carbon emissions data, air quality, energy management, water and waste management, ecological impacts.	Climate-related risks and climate-based governance, impacts on strategies, indicators and targets, and identification, assessment and management of climate risks.	Governance, strategies, indicators and targets related to climate risks and opportunities and the identification, assessment and management of climate risks.	Carbon reduction plans and compliance, carbon emission data, energy usage, environmental policies and goals, social and governance assessments.	Climate-related overview, strategy, governance and materiality assessment, policies, targets, action plans and resources, emission performance measurement.
Frequency	——	Annually	——	Annually	——	Accompanying Financial Report	——	Annually

5.4. Corporate incentives to disclose carbon information

Through a comprehensive review of the existing literature, the motivations driving corporate carbon disclosure can be categorized into three main levels: macro, meso, and micro.

5.4.1. Macro level

At the macro level, corporate carbon disclosure is influenced by a range of factors,

including technological innovations (such as Industry 5.0), policy requirements, corporate ownership structure, and stakeholder pressure.

First, the advent of Industry 5.0 technology provides new opportunities for enhancing corporate carbon disclosure. By supporting more efficient and accurate disclosure practices, Industry 5.0 technologies can increase the transparency and authenticity of carbon reporting, reduce the associated costs, and improve the overall effectiveness of disclosure efforts. This technological innovation encourages companies to actively engage in carbon disclosure as part of their commitment to environmental responsibility and sustainability [20].

Second, national policy requirements play a crucial role in shaping corporate carbon disclosure practices. Firms located in countries that have ratified international agreements, such as the Kyoto Protocol, are more likely to disclose detailed carbon information compared to those in countries that have not ratified such agreements. Furthermore, the environmental policies of organizations like the WWF can significantly influence both the scope and quality of corporate carbon disclosures [21]. Fiscal policy, as a key public policy tool aimed at addressing climate change, can strengthen society's capacity to tackle environmental challenges through incentives, coordination, and compensation mechanisms, thus indirectly influencing corporate decisions to disclose carbon-related data. Under the combined influence of market dynamics and regulatory interventions, the greater the government's control over emission reduction efforts, the more likely firms are to disclose carbon information.

Stakeholder pressure is another critical factor that influences corporate carbon disclosure decisions. To meet legal requirements and align with stakeholder expectations, companies often engage in proactive carbon disclosure. This pressure not only determines whether a firm will disclose carbon information but also impacts the completeness of such disclosures [22]. Pressure from investors, environmental NGOs, and other stakeholders can positively drive companies to disclose carbon emissions data. In order to align with regulatory oversight from government agencies, investors, the media, and other interested parties, companies must also improve the quality and comprehensiveness of their disclosures [23].

Finally, cultural factors also play an important role in shaping corporate carbon disclosure behavior. Cultural characteristics such as individualism, power distance, uncertainty avoidance, and long- vs. short-term orientation, all influence a company's approach to carbon disclosure. In countries with high individualism, large power distance, and short-term orientation, firms may be less inclined to prioritize carbon disclosure and may opt to minimize the quality of their carbon reporting [24]. These cultural differences highlight the importance of companies considering cultural influences when developing their carbon disclosure strategies.

5.4.2. Meso level

At the meso level, corporate carbon disclosure behavior is primarily influenced by industry characteristics and the type of firm.

First, existing studies have consistently shown that industry attributes play a significant role in shaping carbon disclosure practices, with a notable variation in disclosure levels across different industries [25]. Specifically, companies in high-emission industries are more likely to engage in carbon disclosure. This is because

such disclosures not only allow firms to showcase their environmental performance and enhance their public image but also help reduce potential compliance costs. As a result, companies in high-emission sectors tend to be more proactive in initiating carbon disclosures and often provide more detailed information. Additionally, firms' decisions to disclose carbon information can be influenced by the actions of their competitors within the same industry. When a growing number of firms in an industry begin disclosing carbon data, other companies are likely to follow suit in order to maintain their competitive edge [26]. Furthermore, a firm's relative ranking within its industry can also affect both the quantity and quality of its carbon disclosures. Higher-ranked firms, in an effort to differentiate themselves, are more inclined to disclose more comprehensive and higher-quality carbon information [27].

Second, the type of firm also significantly impacts carbon disclosure practices. State-owned firms and private firms often exhibit differing characteristics when it comes to carbon disclosure. Some studies suggest that firms with higher levels of government ownership, such as SOEs, tend to have stronger incentives for climate change disclosure [28]. This may be due to the fact that SOEs, being government-controlled, are more likely to adhere to state policies and regulations regarding carbon disclosure. However, there is also a viewpoint that private firms are more likely to disclose information than state-owned firms [29].

Finally, the legal environment, legitimacy requirements, production factor prices, and environmental costs in the region where the firm is located all affect the quality of carbon information disclosure to a certain extent. Studies have shown that in regions with relatively lax legal supervision, firms may tend to pursue profit maximization while relatively neglecting legal constraints, thereby reducing the public disclosure of carbon information [30]. On the other hand, in contexts with lower environmental legitimacy requirements, firms may instead increase carbon information disclosure because it helps build a positive corporate image, gain the trust of investors and consumers, and possibly obtain government policy support, thereby reducing pressure related to environmental legitimacy [13]. Furthermore, low production factor prices and environmental costs in the regional environment may incentivize firms to adopt an extensive development model, excessively relying on the intensive use of tangible resources such as land [31,32]. This development model often entails substantial consumption of natural resources and environmental damage, leading to increased carbon emissions and potentially prompting firms to reduce carbon information disclosure to avoid negative attention on their environmental impact.

5.4.3. Micro level

At the micro level, corporate carbon disclosure is influenced by a variety of interrelated factors, including firm size, environmental performance, carbon performance, asset characteristics, managerial traits, corporate strategy, board structure, and prior disclosure.

First, firm size plays a significant role in shaping corporate carbon disclosure behavior [33]. Larger firms typically have more resources to invest in pollution reduction initiatives and are more likely to attract the attention of governments, regulators, and the media. As a result, they face greater societal pressure compared to smaller firms, prompting them to disclose more carbon-related information to

demonstrate their social responsibility and enhance transparency [34].

Second, the relationship between environmental performance and carbon disclosure is somewhat controversial. On the one hand, companies with poorer environmental performance may disclose more carbon information to fulfill legitimacy requirements and mitigate reputational risks [35]. On the other hand, firms with better environmental performance may be more inclined to disclose carbon information as a way to signal their genuine efforts and achievements in addressing climate change, thus strengthening their credibility.

Third, there is a positive correlation between carbon performance and carbon disclosure. Firms with excellent carbon performance are likely to view it as a point of pride and seek to distinguish themselves from lower-performing competitors by providing high-quality carbon disclosures [36]. Such disclosures serve as a form of recognition and enhance the company's public image.

Fourth, asset factors also play an important role in corporate carbon disclosure decisions. Disclosure is often seen as a key tool for building trust between managers and investors [37]. Firms with higher leverage and stronger return on assets are more likely to disclose detailed carbon information, as they seek to demonstrate both their operational performance and commitment to environmental sustainability, thereby bolstering investor confidence [38].

Fifth, managerial characteristics have a significant impact on the decision to disclose carbon information. When managers are more environmentally conscious and have a greater understanding of carbon issues and disclosure practices, they are more likely to recognize the importance of addressing environmental concerns and disclose more carbon-related information [39]. Additionally, factors such as a manager's educational background, tenure, and gender can also influence disclosure decisions. For instance, CEOs with advanced business degrees, such as an MBA, or newly appointed CEOs may be more open to making disclosures, while CEOs with legal backgrounds might resist disclosing carbon information [40]. Moreover, a higher proportion of female leaders within a company is associated with more frequent voluntary carbon disclosures, as female leaders' educational levels, financial backgrounds, and empowerment can positively influence the firm's commitment to environmental transparency [41].

Sixth, in terms of corporate strategy, firms with a strategic focus on environmental sustainability are more likely to disclose substantial and high-quality carbon information. This aligns with their goal of enhancing stakeholders' trust and demonstrating their commitment to sustainable development through transparent reporting [26]. Such firms are motivated to showcase their environmental efforts as part of their broader commitment to green growth.

Seventh, board structure also plays a critical role in carbon disclosure decisions. Independent and outside directors generally have a more favorable attitude toward carbon disclosure, as they are more likely to prioritize eco-transparency and reduce agency problems between management and shareholders [42].

Finally, prior disclosure has a significant impact on subsequent carbon disclosure behavior. Companies that have previously disclosed carbon information are more likely to continue doing so, as the effects of earlier disclosures may not be fully realized in the current period. Therefore, past disclosure practices influence future

decisions, ensuring continuity and consistency in reporting [43]. This continuity underscores the importance for companies to consider their historical track record when making future carbon disclosure decisions.

5.5. The economic consequences of corporate carbon disclosure

The literature has extensively examined the far-reaching impacts of carbon disclosure on various aspects of corporate performance, addressing key areas such as corporate reputation, financing advantages, carbon performance, corporate innovation, competitive advantage, and firm value. These impacts are discussed and refined as follows:

First, effective carbon disclosure significantly enhances a company's reputation. By actively engaging in environmental protection efforts, reducing environmental impacts, and aligning their carbon disclosure with stakeholder expectations, companies can earn social recognition and respect [44]. Notably, the timely disclosure of carbon information can help mitigate reputational risks and protect brand image, particularly when a company is undergoing environmental challenges such as organizational restructuring or operational crises [45].

Second, high-quality carbon disclosure contributes to reducing the cost of capital and increasing market value. Transparent, reliable, and comparable carbon data attracts greater market attention, providing firms with financing advantages and improving their valuation [36]. This enhances the company's ability to access capital at more favorable terms, thereby driving its long-term financial success.

Third, carbon disclosure serves as a strategic management tool that helps companies improve their carbon performance. In response to stakeholder pressures and societal expectations, firms use carbon disclosure to create internal incentives and organizational pressures that drive environmental improvements, thereby ensuring their long-term survival and success [46].

Fourth, carbon disclosure has a significant impact on corporate innovation. Studies indicate that transparent carbon reporting stimulates corporate innovation by expanding financing channels, boosting product sales, and attracting media attention. This, in turn, increases both the quantity and quality of innovation within firms [13]. While both state-owned and private firms benefit from carbon disclosure in terms of innovation, political factors may moderate the effect. Specifically, for heavily polluting firms in China, a U-shaped relationship exists between carbon disclosure and green innovation performance. Prior to a certain level of environmental information disclosure, the need for significant investments in data collection and processing may hinder green innovation. However, once this threshold is surpassed, carbon disclosure attracts stakeholder support, thereby promoting green innovation [47].

Fifth, carbon disclosure is recognized as an important factor in enhancing a firm's competitive advantage. Larger firms tend to focus on carbon risk management through disclosure, using it to mitigate political and public pressures regarding social responsibility. In contrast, smaller firms often emphasize the utilization of carbon-related opportunities to gain a sustainability-driven competitive edge for future growth [48].

Sixth, scholars hold different views on the relationship between carbon disclosure

and firm value. Some studies suggest that carbon disclosure does not significantly affect firm value [49]. However, a larger body of research argues that carbon disclosure can enhance firm value. During periods of environmental turbulence, firms that disclose carbon information tend to experience less value depreciation compared to those that do not disclose carbon data [45]. In more stable environmental conditions, increased carbon disclosure positively contributes to firm value, with public pressure acting as a moderating factor [50]. Additionally, for high-emission companies, disclosing carbon emissions is more beneficial for market value than for low-emission companies. This effect is particularly pronounced in firms participating in non-carbon market trading pilots [51]. Furthermore, collaboration in supply chain emission reduction enhances the quality development of the platform economy, contributing to value creation for firms by improving their carbon disclosure levels and increasing green R&D investments [52].

In summary, carbon disclosure plays a critical role in shaping multiple dimensions of corporate performance, from reputation management and innovation to financing advantages and long-term value enhancement.

6. Research conclusions and future prospects

6.1. Research conclusions

Carbon disclosure has emerged as a critical lever for driving the low-carbon transformation of businesses and addressing climate change, gaining increasing attention from academics, policymakers, and companies alike. Through a comprehensive review and analysis of the literature on carbon disclosure, this paper delves into the measurement methods, theoretical foundations, standards, drivers, and impacts associated with carbon disclosure. The findings reveal that while various methods exist for measuring carbon disclosure, including reputation evaluation, the index method, content analysis, and the CDP questionnaire, each approach presents distinct advantages and limitations.

Moreover, the paper examines the standards for corporate carbon disclosure and identifies key frameworks such as GRI 305, TCFD, and SASB, which provide crucial guidance for corporate carbon reporting. However, it also highlights certain limitations and discrepancies in the practical application of these standards across different industries and regions.

In terms of the drivers of carbon disclosure, the study finds that macro-level factors such as policies and regulations, meso-level factors like industry type and firm characteristics, and micro-level factors including societal expectations and stakeholder pressures, all converge to influence corporate carbon disclosure behavior.

Furthermore, the paper explores the significant impacts of carbon disclosure on corporate innovation, competitive advantage, and firm value. However, these effects are not universally applicable; instead, they are contingent on a complex interplay of factors that vary by industry, firm size, and other contextual elements.

In conclusion, this study provides a comprehensive understanding of the current state of carbon disclosure, offering insights into its measurement, underlying theories, standards, drivers, and impacts, while also acknowledging the complexities and challenges that firms face in implementing effective carbon disclosure practices.

6.2. Limitations of existing research and future prospects

First, the current diversity in the content and measurement methods of carbon disclosure, coupled with the absence of unified standards, has led to a lack of comparability and transparency across different studies. Future research should focus on establishing a standardized framework for defining and measuring the content of carbon disclosure. By clearly outlining the content and format requirements, such standardization would enhance the comparability and transparency of carbon disclosures, thereby providing a more accurate and reliable data foundation for future studies.

Second, inconsistencies and traceability issues in corporate carbon disclosure remain prevalent. Future research should examine how to ensure the consistency and traceability of carbon information by improving disclosure systems and regulatory mechanisms. Such efforts would encourage firms to disclose carbon information in a more comprehensive and accurate manner, reduce the complexity for information users, and ultimately enhance the effectiveness and usability of carbon disclosure.

Third, existing research on the characteristics of carbon disclosure across different industries remains underdeveloped. Future studies should delve deeper into industry-specific carbon disclosure practices. By comparing and analyzing the status and challenges of carbon disclosure in various sectors, researchers can offer targeted recommendations and policy measures to promote the low-carbon transition and sustainable development across industries.

Finally, the scope of current research on carbon disclosure should be expanded. Future investigations could explore other related fields, such as disclosure practices within carbon trading markets or the disclosure of carbon financial products. By conducting comprehensive and in-depth research on the application of carbon disclosure in these diverse areas, scholars can provide more robust theoretical foundations and practical guidance for building a low-carbon, green, and sustainable economic system.

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Conflict of interest: The authors declare no conflict of interest.

Notes

[1] The CSRD establishes an overall framework for the preparation of corporate sustainability reports, leveraging legal mandates to require enterprises to comply with relevant sustainable development requirements.

[2] The ESRS provides detailed reporting standards to ensure that enterprises can meet the requirements of the CSRD. As a supporting standard document to the CSRD, ESG reports that comply with the CSRD must be prepared in accordance with the ESRS standards.

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