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Carbon information disclosure quality as a driver of firm value: Unpacking the mediating roles of trading volume, reputation, and financing costs

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Abstract

Based on the annual observations of approximately 2,500 high-carbon industry listed companies in China's A-share market from 2020 to 2024, this article examines the impact of carbon information disclosure quality (CID) on enterprise value and its mechanism, and discusses its implications for environmental policies, low-carbon governance, and sustainable development. The study uses transaction volume, corporate reputation, and financing cost as mediating variables, and public attention as a moderating variable, and employs fixed-effect models, mediation tests, and instrumental variable methods for empirical analysis. The results show that the quality of carbon disclosure significantly enhances enterprise value, and the three mediating paths present a parallel transmission structure; public attention positively moderates the impact of disclosure on the mediating variables, but it negatively moderates the relationship between reputation and enterprise value. Heterogeneity analysis indicates that the value effect is more significant in large enterprises, low-carbon industries, and non-carbon trading pilot regions. The paper argues that the value effect of carbon disclosure is a market incentive that can inform carbon disclosure regulation, strengthen environmental accountability, and develop green finance, indirectly influencing enterprises' environmental governance through financing, reputation, and external supervision. However, this paper does not directly test actual carbon emissions or environmental performance improvements. CID measures the quality of disclosure, but does not measure carbon emissions, carbon intensity, or the extent of reduction. High-quality disclosure does not necessarily lead to high environmental performance. Policy-wise, it is necessary to promote hierarchical disclosure, strengthen verification and greenwashing accountability, and develop green finance, thereby converting market incentives into sustainable low-carbon transitions. Future research needs to match carbon emission data for further verification.

Keywords: Carbon information; Disclosure quality; Firm value; Information asymmetry theory; Environmental accountability

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1. Introduction

In recent years, global climate change has become one of the most pressing issues faced by countries worldwide. Climate change is not only a shift in the natural environment

but also concerns socioeconomic development, resource distribution, and ecological balance.[1] Nearly all climate scientists and experts have come to an agreement that, due to the increase in the average temperature of the Earth, extreme climate change events have become frequent. Subsequently, this jeopardizes the ecosystems all over the globe. According to reports from authoritative institutions in the field of climate change, such as the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change, global temperatures have risen by approximately 1.1 °C since the late 19th century. If no urgent and effective mitigation measures are taken, the temperature is expected to increase by more than 3 °C by the end of this century.[2] This warning has brought global climate governance to a critical decision-making moment. Recent studies further indicate that implementing carbon-emission controls and climate-change response measures, particularly at the corporate and industry levels, plays a crucial role in mitigating climate change.[3] Above studies increasingly emphasize the importance of global climate policies. They also indicate that countries and businesses need to become more proactive on climate change.

As the world's largest carbon emitter, China faces enormous environmental pressures and transformation tasks. While promoting rapid economic growth, China faces environmental challenges such as energy-intensive consumption and high carbon emissions.[4] In recent years, the Chinese government's "carbon peak" and "carbon neutrality" goals have provided a Chinese solution to global climate change and an important direction for the country's enterprises in their transformation and sustainable development. China's carbon emission control and green low-carbon transformation are gradually becoming a key part of the global governance system. Against this backdrop, corporate environmental performance and carbon information disclosure quality (CID) have gradually become important indicators for evaluating corporate sustainability, especially as capital markets and policy oversight become increasingly stringent.[5]

Carbon information disclosure quality not only helps companies increase transparency and trust but also promotes internal management transformation. By publicly disclosing carbon emission data and reduction measures, companies have transformed previously difficult-to-observe environmental behaviors into comparable and supervisable information; based on this, investors, creditors, media, the public, and regulators have formed incentives and pressures, which may subsequently drive carbon accounting, Environmental, Social, and Governance (ESG), green innovation, and low-carbon investment.[6] However, disclosure does not equal emission reduction; its governance effect depends on institutional conditions such as third-party verification, carbon pricing, green finance, and greenwashing accountability. In recent years, many Chinese companies have made significant progress in green manufacturing, clean energy usage, and energy-saving reductions. At the same time, this has attracted capital market attention, with the rise of green bonds and green funds providing more green financing support to companies.[7]

However, Chinese companies still face several challenges in CID. First, although the government has introduced relevant regulations, the quality and scope of carbon disclosure by companies vary significantly. Some companies still face issues such as information asymmetry and incomplete data in their disclosures, making it difficult to meet international investors' and regulatory agencies' transparency requirements.[8] Second, because CID standards are not unified, companies often disclose information selectively based on their situation, reducing comparability and transparency and affecting their reputation in international markets.[9] In the future, improving CID transparency and standardization and driving corporate green innovation through scientific carbon management systems will be key for Chinese companies in global green competition. At the same time, CID effectiveness depends not only on active corporate participation but also on joint efforts by government, society, and capital markets to achieve the dual goals of carbon neutrality and sustainable development.[10]

Through a synthesis of the information asymmetry theory, signaling theory, and resource-advantage theory, the CID can affect trading volume (TA), corporate reputation (CR), financing costs (FCs), and eventually promote the formation of value. Furthermore, public attention (PA) has been shown to moderate the impact of negative news on TA, CR, and FCs. Ultimately, drawing on information asymmetry theory, signaling theory, and resource-advantage theory, this study constructs a comprehensive and in-depth analytical framework to explore the internal mechanism by which the quality of carbon disclosure affects enterprise value.

The significance of research on carbon information disclosure goes beyond the creation of enterprise value. Carbon disclosure, by placing the emission performance of enterprises under the supervision of the public and the capital market, constitutes the institutional foundation for making carbon neutrality commitments verifiable. Existing studies have shown that high-quality carbon disclosure can indirectly affect the sustainable development capabilities of enterprises through promoting technological

innovation, alleviating financing constraints, enhancing market recognition, and improving governance systems. However, the empirical part of this paper focuses on the impact of carbon disclosure quality on enterprise value and its market mechanism, and does not directly test the improvement of actual carbon emissions or environmental performance. Therefore, this paper regards carbon disclosure as an institutional bridge connecting micro-enterprise behavior with macro climate governance goals. Its emission-reduction effect still needs further verification by combining carbon emission data.

Asia has the highest concentration of global carbon emissions, accounting for approximately 53%. It also has the fastest economic growth and the largest increase in energy demand globally.[11] Balancing development and emission reduction remains a common challenge for all Asian countries. The CID depends not only on enterprises' compliance behavior at the corporate level but also on whether regional capital markets can effectively connect with the global green financial system. This study examines China as a case and aims to provide an analytical reference for building carbon disclosure systems in other developing economies in Asia.

The implications of carbon disclosure also extend to broader areas of environmental governance, such as water conservation and pollution control. Carbon emissions and resource-environmental problems have a common origin. Improving carbon information transparency reduces information asymmetry and pushes enterprises to improve overall environmental performance. By strengthening market supervision and guiding the flow of green resources, CID builds an institutional bridge between corporate behavior and improved environmental quality.

This paper makes three main contributions. First, against the backdrop of the rapid strengthening of China's carbon information disclosure system after the announcement of the carbon peaking and carbon neutrality goals, it provides systematic evidence on the relationship between CID and firm value (FV) in an emerging market. This complements prior research that has focused largely on developed economies. Second, it identifies three relatively independent mediating channels—TA, CR, and FC—and shows that the value effect of carbon disclosure operates mainly through parallel market transmission rather than a single causal chain. This helps clarify how carbon information is incorporated into market pricing. Third, it incorporates PA into the analytical framework and reveals both complementarity and tension between formal disclosure rules and informal external oversight, offering evidence on the governance boundaries of carbon information disclosure. Importantly, the paper empirically examines the market value effect of CID, not actual carbon emissions or improvements in environmental performance. CID measures disclosure quality; it does not directly measure carbon emissions, carbon intensity, or emission reductions. The discussion of low-carbon governance here therefore concerns institutional implications and mechanisms; it does not establish a causal claim that disclosure leads to emission reductions.

The subsequent sections of this paper are as follows: Section 2 comprehensively reviews the existing literature and proposes a hypothesis model based on this to explore the potential relationship between the variables; Section 3 introduces the research methods in detail, including data collection sources and measurement methods of variables, to ensure scientific and accurate research; in Section 4, detailed results of data analysis are presented to verify the validity of the hypothetical model. Finally, Section 5 summarizes the research findings and, based on the insights of the data analysis, proposes targeted strategies to guide practice and advance the development of related fields.

2. Literature review and hypotheses development

2.1. Carbon information disclosure quality and firm value

From the perspective of resource advantage theory, CID is not only an information transmission behavior but also an important way for firms to transform their environmental management capabilities into competitive advantages.[12] In order to obtain long-term competitive advantages in the market, a firm must fulfill its social and environmental responsibility on a continuous basis. Accordingly, CID is an important way to show one's ability to fulfill the same. By disclosing social and environmental responsibility information, firms can build a good reputation and thus obtain additional benefits such as preferential policies or tax incentives.[13] Zhou *et al.*[14] proposed that firms' disclosure of environmental information can affect consumer demand and is closely related to product market dynamics.

By disclosing carbon information, firms can showcase their achievements in green product research and development and technological innovation, thereby gaining a competitive edge over peers.[15] This advantage is acquired through two channels. First, the firm passes on the environmental and social impacts of its products to the consumer. This makes its products superior to the firm's competitors in environmental terms. Second, the firm passes on information about advanced and environmental technologies used for production. This makes the firm superior to its competitors. Resource advantages bring

competitive dividends to firms, including expanding market share and reducing costs through technological innovation, thereby increasing profit margins.[16] Based on the above analysis, this study hypothesizes that under the ESG value management framework, the quality of CID has a positive impact on corporate value creation.

In view of the above analysis, this study proposes the following hypothesis:

H1: CID is significantly positively associated with FV.

2.2. Carbon information disclosure quality and trading volume

High-quality CID can effectively break down these informational barriers. By enhancing the availability, completeness, and comparability of data, such disclosures significantly reduce uncertainties regarding corporate environmental performance and mitigate the risks of adverse selection and moral hazard.[17] As a result, investor confidence and decision-making efficiency are strengthened. On one hand, investors can more accurately evaluate a company's potential carbon compliance costs, climate policy pressures, and green transition capabilities. On the other hand, a more transparent informational environment improves market pricing efficiency and attracts rational capital to engage in trading, thereby promoting stock market liquidity and TA.[18]

Signaling theory further elucidates the strategic value of corporate carbon disclosure. For investors who are at an informational disadvantage, external corporate behaviors such as voluntary disclosure serve as important signals for identifying internal firm attributes.[19] CID is thus a key signaling mechanism through which companies communicate their sense of environmental responsibility, strategic foresight, and regulatory compliance capabilities. Particularly in institutional environments where mandatory disclosure requirements are still evolving, companies that voluntarily and systematically disclose their current carbon emissions, governance strategies, and future commitments send a positive signal to the market regarding their sustainability and long-term development prospects.[20]

The quality of CID plays a vital role in enhancing corporate TA. On the one hand, it helps to alleviate market failures caused by information asymmetry, thereby strengthening investor trust and recognition. On the other hand, by signaling positive developmental intentions to the market, high-quality disclosures enhance a firm's capital appeal and visibility. Especially against the macro backdrop of China's "dual-carbon" strategy and the growing penetration of ESG concepts, CID has evolved beyond a compliance obligation into a strategic tool that significantly affects market performance.[21] The increase in transaction volume not only reflects market reactions, but also provides external incentives for environmental governance of enterprises. More investors' attention to carbon information may prompt enterprises to maintain their environmental commitments and increase investment in carbon management. However, the hypothesis test in this paper still focuses on FV, and the environmental governance effect will be further discussed in the conclusion section.

In view of the above analysis, this study proposes the following hypothesis:

H2a: CID is significantly positively associated with TA.

Trading volume, being the direct reflection of investor reaction to CID, plays an intermediary role through which the quality of carbon disclosure translates into corporate value. Dastranj[22] argued that voluntary disclosures can effectively alleviate information asymmetry and enhance investor trust, thereby improving stock liquidity and promoting healthy market development. Over the years, the carbon neutrality policy and the rise of green finance have caused the CID to become the core concern of investors. High-quality carbon disclosures provide investors with detailed and transparent environmental performance data, enabling them to more accurately assess firms' sustainability capabilities and potential risks.[23] This increased transparency not only reduces the risk perceived by investors, but also enhances the level of participation in the market as reflected in greater TA, improved capital inflow, and less volatility of stock price, thereby pushing up market as well as corporate value.

Inadequate or low-quality carbon disclosure often triggers negative market reactions, such as decreased TA and increased stock price volatility, which undermine investor confidence, disrupt resource allocation efficiency, and ultimately constrain FV growth.[24] Therefore, improving carbon disclosure quality not only conveys positive signals of corporate transparency and strategic commitment but also stimulates more favorable market trading responses, stabilizes stock prices, and fosters a supportive external environment for sustainable corporate development.[25]

In view of the above analysis, this study proposes the following hypothesis:

H2b: TA plays a mediating role between CID and FV.

2.3. Carbon information disclosure quality and corporate reputation

High-quality CID can significantly enhance a company's transparency, gain public recognition, and signal the firm's active fulfillment of environmental responsibilities, thereby

strengthening its CR.[17] CR is the public's comprehensive perception of a firm's behavior and performance across economic, social, and environmental dimensions, reflecting the long-term interaction and trust accumulation between the firm and its stakeholders. With growing global attention to environmental issues, corporate social responsibility (CSR), especially environmental responsibility, has become a critical factor influencing CR and market performance.[26] In the process of corporate survival and development, external resources and environmental factors play a pivotal role, and firms need to establish strong social networks to acquire and control key resources. Fulfilling environmental responsibilities is not only a manifestation of CSR but also an effective exchange mechanism for firms to obtain external resources and support. High-quality carbon disclosure transparently communicates a firm's environmental efforts, effectively mitigating information asymmetry caused by environmental changes, thereby enhancing public and investor trust and strengthening the firm's resource advantages and reputation.

Furthermore, the active disclosure of environmental information enhances the CR of the firm while reducing the negative influence of information asymmetry. This emphasizes the importance of carbon disclosure for CR. The CID significantly enhances CR by reducing information asymmetry, sending positive signals, and strengthening resource advantages. Reputation building not only affects the FV, but also may enhance the legitimacy motivation for the enterprise to maintain environmental commitments. When carbon disclosure gains recognition from stakeholders, enterprises are more likely to convert the pressure of reputation into carbon management actions. However, whether reputation truly drives emission reduction still depends on the verification and accountability mechanisms.

In view of the above analysis, this study proposes the following hypothesis:

H3a: The quality of CID is significantly positively associated with CR.

Carbon information disclosure quality is an important means for firms to show stakeholders their environmental responsibilities and contributions. By adequately disclosing specific measures regarding its carbon reduction and green development actions, managers succeed in getting the attention of stakeholders and in enhancing stakeholders' perception of the firm's reputation. Proactively fulfilling environmental and social responsibilities not only aligns with societal values and ethical norms but also demonstrates the firm's strong commitment to sustainable development, fundamentally reducing the cognitive barriers caused by information asymmetry and strengthening the firm's credibility and image among stakeholders.[27]

High-quality carbon disclosure upgrades CR by reducing information asymmetry, transmitting positive signals, and enhancing the advantage of intangible resources. CR, as an indispensable intangible asset, is a quintessential element helping the acquisition of firm resources, the management of risk, the market recognition of obligations and rights, as well as the central drive that mediates the promotion of corporate value, which is referred to as stakeholder engagement.

In view of the above analysis, this study proposes the following hypothesis:

H3b: CR plays a mediating role between CID and FV.

2.4. Carbon information disclosure quality and financing costs

Financing cost is the cost incurred by a firm for the funds raised through the issuance of stock, which is the minimum rate of return expected by investors. Due to information asymmetry in the trading market, investors in an inferior information position cannot fully understand the company's true situation, leading to increased investment risks.[16] Investors may diminish their investment or raise the return they require to protect their interests, thereby raising the company's cost of capital. A company that hides such information increases risk to its investors. When their interests are not well protected, investors demand higher returns for bearing the "excess risk." Consequently, the cost of equity capital for the firm will rise. Carbon information disclosed by companies can serve as a critical reference for investors to assess sustainable development risks and opportunities, improving the accuracy of investment predictions and reducing investment risks, ultimately saving FCs for the company.[28]

Improving CID helps reduce adverse selection caused by information asymmetry, which can lead to a decline in market allocation efficiency and increased transaction costs. To compensate for the expensive transaction costs, investors demand higher returns for each transaction, which widens the bid-ask spread and quickly drives up capital costs. Enhancing the transparency of corporate environmental information allows external investors to gain a more comprehensive understanding of the company's environmental responsibility fulfillment and potential environmental risks, thereby reducing investment uncertainty.[29] This reduces the need for price protection among investors, lowering transaction costs. Research has shown that there is a significant negative correlation between a company's environmental information disclosure level and its bid-ask spread. The

decline in FCs has provided the financial conditions for enterprises to invest in a low-carbon manner. If green finance incorporates the quality of carbon disclosure into pricing, high-quality disclosure by enterprises may obtain lower-cost funds and use them for emission reduction projects. However, whether the funds actually flow to emission reduction depends on the investment decisions of enterprises and the carbon price signal.

In view of the above analysis, this study proposes the following hypothesis:

H4a: CID is significantly negatively associated with FCs.

The value that is created by a firm signifies the returns on investment minus the cost of finance. Increased investment uncertainty increases investment risk, which tends to induce investors to accept higher returns. Raises FCs and compresses the space for value creation.[30] Based on information asymmetry theory, because internal managers possess far more information than external investors, especially regarding highly specialized non-financial information such as carbon emissions and environmental governance, information asymmetry exacerbates investors' uncertainty about the firm's future cash flows and risks, increasing their agency costs and risk premiums, ultimately resulting in higher FC. CID affects FCs; improving the quality of CID helps reduce the uncertainty of future returns perceived by investors and lowers investment risks.[31] By increasing the amount of information in the market, improving CID reduces investors' agency costs, thereby lowering the investment returns they require. A decrease in FCs implies a larger investment return space for the company, which is conducive to enhancing corporate value creation. When a company raises substantial funds at a lower cost, the liquidity of funds is higher, and resource allocation efficiency is improved, which is more beneficial to value creation.[32] Moreover, studies reveal that the disclosure of a business's information can create value by impacting fluctuations in stock prices, FCs, and market risk. According to the findings, enhancing the quality of CID can reduce corporate FCs and promote value creation. In view of the above analysis, this study proposes the following hypothesis:

H4b: FCs play a mediating role between CID and FV.

2.5. The moderating effect of public attention

First, according to signaling theory, the media and PA serve as critical channels for information diffusion, effectively amplifying the impact of CID and enhancing the breadth and depth of information dissemination. Recent studies have found that high levels of PA not only promote the faster and more comprehensive transmission of carbon information to investors and the market but also deepen market participants' understanding and concern for corporate environmental performance.[33] Through continuous monitoring and discussion of corporate carbon disclosures across news reports, social media, and other channels, the public encourages market participants to pay closer attention to and value the authenticity and completeness of carbon information, thereby promoting investors to make rational decisions based on fully transparent information and significantly increasing stock TA.[34]

Second, based on information asymmetry theory, companies possess richer and more professional internal information regarding carbon emissions and environmental governance compared to external investors. This information asymmetry limits investors' ability to accurately assess the company's true environmental performance.[35] The rise in PA strengthens external supervision mechanisms; through widespread scrutiny and evaluation of CID, it helps reduce uncertainties caused by information asymmetry, lowering investors' cognitive risks and agency costs.[36] Specifically, when PA is high, companies are more motivated to improve the transparency and quality of CID, which in turn enhances investors' confidence in the company's environmental performance and promotes active trading and capital flow in the market.

Finally, integrating resource advantage theory, PA not only enhances a company's reputation and social recognition in capital markets but also becomes an important intangible resource in building core competitive advantages. A high level of PA can attract more investors' and partners' interest, strengthen the company's financing capabilities and market influence, and stimulate TA and capital allocation efficiency.[37] Meanwhile, the external pressure and incentives brought by PA encourage companies to continuously improve CID, forming a virtuous cycle that further promotes green transformation and sustainable development.

In view of the above analysis, this study proposes the following hypothesis:

H5a: PA has a significant positive moderating effect on CID and TA.

Based on information asymmetry theory and signaling theory, PA, as a critical external supervisory force, can significantly reduce the cognitive gap between the market and stakeholders regarding a company's environmental information. Specifically, carbon emissions and environmental governance information are often highly specialized and complex, making it difficult for external investors and the public to fully and accurately understand

the company's true environmental performance and creating information asymmetry.[24] This asymmetry not only increases investors' perceived risk but also raises agency and capital costs, limiting the company's value creation and market performance. In this context, the enhancement of PA occurs through multiple channels such as media reports, social discourse, and public supervision:

The value created by a company essentially represents the difference between investment returns and FCs. When investment uncertainty increases, it imposes stricter scrutiny on the transparency and authenticity of CID, compelling companies to improve disclosure quality and actively provide accurate and detailed carbon performance data.[38] This process helps the market mitigate the negative effects of information asymmetry, increases investors' confidence in the company's environmental governance capabilities, and promotes CR and healthy capital market interaction.

More specifically, PA intensifies pressure and responsibility on companies to disclose information. When various parties such as media, environmental organizations, and investors focus intensively on a company's environmental performance, any falsification or insufficiency in disclosures can easily trigger negative public opinion and social trust crises, thereby damaging CR and market position.[39] Therefore, to protect their reputation, companies are motivated to comply with higher standards of disclosure and to proactively provide comprehensive and credible carbon information. This increase in transparency helps strengthen stakeholders' recognition and trust in the company, creating a virtuous cycle. In other words, PA is not only a "monitor" of disclosure quality but also a "driver" of improvements in corporate environmental governance.

From a signaling theory perspective, companies convey positive signals to the market through high-quality CID, demonstrating strong environmental governance capabilities and a commitment to social responsibility. These signals reduce market uncertainty about environmental risks and boost investor and consumer confidence. PA amplifies this signaling effect: when public focus on carbon disclosure is high, the environmental responsibility signals sent by the company are more widely recognized and accepted, resulting in enhanced market evaluation and elevated CR. At the same time, public scrutiny strengthens the credibility of these signals and reduces the distortion caused by information asymmetry, thereby consolidating the trust relationship between companies and their stakeholders.

In view of the above analysis, this study proposes the following hypothesis:

H5b: PA has a significant positive moderating effect on CID and CR.

According to information asymmetry theory, FCs largely depend on investors' recognition of and trust in corporate information. As a key driver of information transparency, PA can push firms to improve the quality of carbon disclosure, thereby alleviating information asymmetry and reducing investors' perceived risks and agency costs.[40]

Moreover, signaling theory posits that external supervision from the media and the public enhances the capital market's understanding of a firm's environmental performance, enabling more accurate risk assessments and lowering the risk premium associated with financing.

Building on this, resource advantage theory further indicates that PA can generate intangible assets such as reputation and transparency, which serve as strategic resources. These resources not only improve investor confidence but also help firms access better financing terms, attract more capital, and enhance their capacity for green innovation and sustainable development.

In view of the above analysis, this study proposes the following hypothesis:

H5c: PA has a significant positive moderating effect on CID and FCs.

Based on information asymmetry theory, signaling theory, and resource advantage theory, this study establishes the theoretical framework. As illustrated in Figure 1, this framework systematically depicts the intrinsic logical mechanism of how CID affects FV through mediating variables such as PA, TA, CR, and FCs. Based on the above hypothesis, the specific hypothetical model is as shown in Figure 2.

2.6. Background of China's carbon disclosure regulations, environmental accountability and green finance system

The rapid establishment of China's carbon disclosure system began in 2020 when the "dual carbon" target was proposed. In December 2021, the Ministry of Ecology and Environment released the "Measures for the Legal Disclosure of Environmental Information by Enterprises," which came into effect on February 8, 2022, and for the first time systematically required key polluting units, bond-issuing enterprises, and listed companies to legally disclose environmental information. In the same year, the China Securities Regulatory Commission revised the annual report format guidelines, incorporating "environment and social responsibility" into the disclosure framework. In May 2022, the State-owned Assets

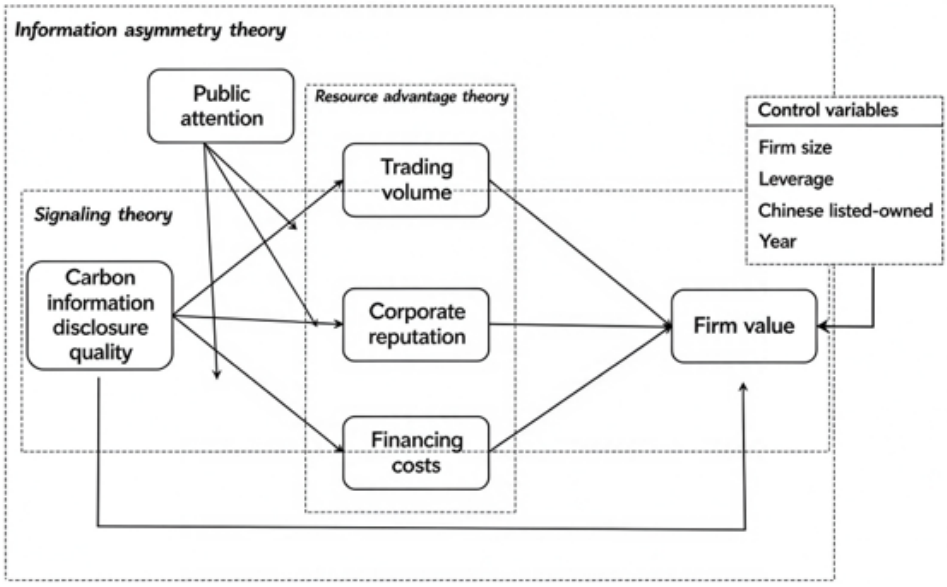


Figure 1. Conceptual framework

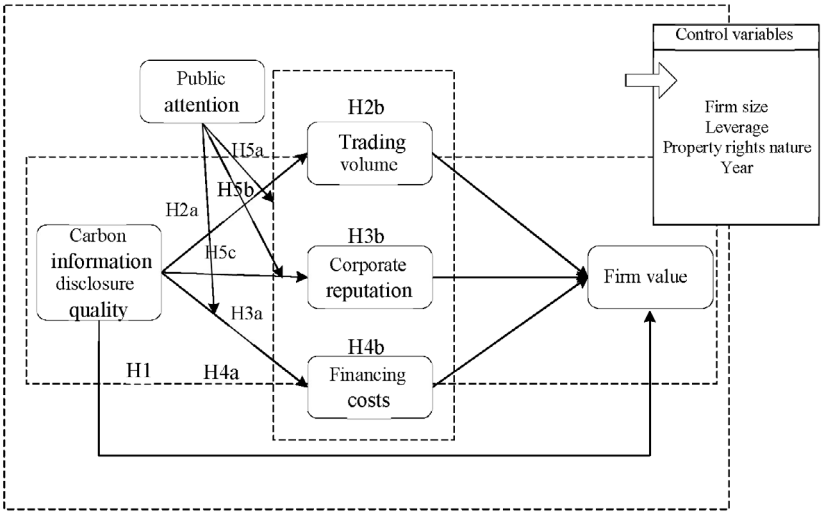


Figure 2. Hypothetical model

Supervision and Administration Commission of the State Council released the "Work Plan for Improving the Quality of Central State-owned Enterprise Controlled Listed Companies," proposing to strive to achieve full coverage of ESG special reports disclosure by central state-owned enterprise (SOE)-controlled listed companies by 2023. In April 2024, the Shanghai, Shenzhen, and North China Stock Exchanges released the "Guidelines for Sustainable Development Reports of Listed Companies," which came into effect on May 1 of the same year, further promoting the transition from voluntary disclosure of environmental information to standardized disclosure. In January 2024, the "Interim Regulations on the Management of Carbon Emission Rights Trading" provided an administrative legal basis for data verification, quota settlement, and legal responsibilities in the carbon market. These institutional arrangements have gradually embedded carbon disclosure into the national climate governance system.

The environmental accountability mechanism is a prerequisite for the effective operation of the carbon disclosure system. Environmental supervision, carbon emission data quality checks, third-party verification,

and credit penalties constitute the accountability system. The "Measures for the Legal Disclosure of Environmental Information by Enterprises" clearly requires that the situation of legally disclosing environmental information be included in the enterprise's credit management, and the administrative penalty information for violating disclosure requirements should be recorded in the credit record. Third-party verification institutions play a key role in the carbon market's MRV system, and their independence directly affects the credibility of the disclosed information. For listed companies, ESG disclosure quality spot checks and regulatory inquiries have also become increasingly regular. Without verification and punishment mechanisms, disclosure may remain at the level of formal compliance, even becoming a reputation management tool.

The green finance mechanism provides market incentives for carbon disclosure. Green loans, green bonds, carbon emission reduction support tools, and ESG investment incorporate enterprise carbon information into pricing and risk management. The central bank has established the carbon emission reduction support tool, guiding funds to be invested in emission reduction areas through low-cost re-lending to financial institutions. Enterprises with higher disclosure quality are more likely to obtain low-cost green funds, while enterprises with low disclosure quality or high carbon risks may face rising FCs and investor avoidance. The carbon pricing function of the national carbon market and pilot carbon markets, based on carbon disclosure data, serves as the operational foundation. The carbon disclosure, green finance, and carbon market thus form a transmission relationship from information to pricing and then to financing. The effectiveness of this relationship depends on the strength of the carbon price signal and the pricing ability of green financial products.

For China to achieve its carbon neutrality goal, the institutional significance of carbon disclosure lies in reducing the identification cost of green capital and supporting the allocation of capital from high-carbon assets to low-carbon assets. It provides a data basis for the carbon market, a risk assessment basis for green finance, and a supervision clue for environmental accountability. However, the disclosure system itself cannot replace emission reduction policies. If there is a lack of effective third-party verification, carbon pricing signals, and greenwashing accountability, disclosure may remain at the level of formal compliance. Therefore, carbon disclosure should be understood as a system arrangement in the carbon neutrality governance system, and its emission reduction effect depends on the synergy with the carbon market, green finance, environmental supervision, and accountability mechanisms.

It should be noted that the empirical part of this paper examines the impact of carbon disclosure quality on enterprise value and its market mechanism and did not directly test actual carbon emissions or environmental performance. The above institutional background provides a framework for understanding the policy implications of the empirical results but does not constitute a causal judgment on the emission reduction effect. Whether CID can truly drive enterprises to undertake low-carbon transformation still requires further verification through future research in combination with carbon emission data.

3. Research methods

3.1. Data collection

The sample construction of this study is grounded in the institutional transformation context of China's low-carbon transition and follows the principles of policy sensitivity, data comparability, and econometric rigor. From 2010 to 2019, carbon information disclosure was mainly based on voluntary guidelines. In 2010, the former Ministry of Environmental Protection issued the "Guidelines for Environmental Information Disclosure of Listed Companies," and in 2017, the China Securities Regulatory Commission revised the annual report format standards, only "encouraging" the disclosure of environmental information. Approximately 62% of A-share listed companies did not separately list carbon emission data in their annual reports. The announcement of the "dual carbon" goal in September 2020 became a watershed. Subsequently, in 2021, the Ministry of Ecology and Environment issued the "Measures for the Legal Disclosure of Enterprise Environmental Information," and for the first time required key polluting units, bond-issuing enterprises, and listed companies to legally disclose environmental information and carbon emission data; the China Securities Regulatory Commission simultaneously upgraded the "environment and social responsibility" section to mandatory disclosure; in 2022, the State-owned Assets Supervision and Administration Commission required central SOE-controlled listed companies to achieve full coverage of ESG reports by 2023. These policies fundamentally changed the carbon information disclosure system environment after 2020, providing an appropriate observation window for this study. Therefore, limiting the sample to 2020 to 2024 helps to enhance the internal validity of the research and ensures that the disclosure behavior has higher comparability within a relatively unified regulatory framework.

In terms of cross-sectional selection, this study focuses on Shanghai and Shenzhen A-share listed companies operating in carbon-sensitive industries, including

manufacturing, new energy, energy and utilities, and environmental protection and green technology. These industries are characterized by high carbon intensity, stronger exposure to climate policy risks, and heightened scrutiny from regulators and capital markets. As major contributors to carbon emissions and key actors in China's industrial transformation, firms within these sectors face both regulatory compulsion and reputational incentives to improve CID. Concentrating on these industries not only improves the explanatory relevance of the empirical model but also mitigates noise arising from structurally low-emission sectors whose disclosure behavior may be less policy-driven. To ensure structural stability and intertemporal comparability, approximately 500 firms are selected for each year from 2020 to 2024. After systematic screening and data cleaning, the final dataset comprises approximately 2500 firm-year observations, forming a balanced panel suitable for dynamic panel estimation and fixed-effects modeling.

The empirical data are constructed through multi-source integration to enhance reliability and measurement precision. Carbon information disclosure data are manually collected from annual reports, ESG reports, and corporate social responsibility disclosures issued by listed companies. The dimensions, scoring criteria, and construction methods of the CID index are detailed in Section 3.2. Firm-level financial indicators, governance variables, and market performance data are obtained from the China Stock Market and Accounting Research Database and the China Research Data Service Platform, both of which are widely recognized as authoritative databases in empirical research on Chinese listed companies. The integration of textual disclosure data and structured financial panel data allows for a multidimensional evaluation of the economic consequences of carbon disclosure practices.

To ensure robustness and methodological rigor, several screening and preprocessing procedures are implemented. Firms in the financial and insurance industries are excluded due to their distinct accounting structures and regulatory environments, which may introduce structural heterogeneity. ST and *ST firms are removed to eliminate potential distortions caused by abnormal financial conditions. Observations with missing key variables are excluded to maintain data integrity. All continuous variables are winsorized at the 1% and 99% levels to mitigate the influence of extreme outliers. The sample screening process can be seen in Table 1. Furthermore, to address potential reverse causality and dynamic endogeneity concerns, core explanatory variables and control variables are lagged by one period in baseline regressions. These procedures collectively enhance causal inference validity and reduce estimation bias.

Table 1. Sample selection

Screening step	Operation description	Change in annual observations	Remaining observations
1	All A-share listed firms in high-carbon industries in the original sample	4,120	4,120
2	Exclude financial and insurance enterprises due to heterogeneous carbon accounting standards	−535	3,585
3	Exclude ST and *ST firms with abnormal going-concern status	−445	3,140
4	Exclude observations with missing values for core variables	−640	2,500

Overall, the final sample captures the post-regulatory enforcement phase of carbon disclosure under China's dual-carbon strategy, emphasizing industries with substantive exposure to climate governance pressures. By focusing on the 2020–2024 period and constructing a balanced panel of approximately 2,500 firm-year observations, this study establishes a policy-relevant and methodologically robust empirical foundation for examining the value implications of CID within an evolving institutional environment.

3.2. Variable measurement and data sources

The CID is the core explanatory variable of this study. The index construction method is fully presented here. In the subsequent chapters, only the results of this index are cited, and the construction details are not repeated. This study uses a third-party comprehensive index to measure the CID. This index is constructed by an authoritative rating agency based on the mainstream international disclosure framework, while considering the specific background of Chinese enterprises. The CID index covers five dimensions: strategic commitment, carbon emission data, governance structure, emission reduction actions, and third-party verification. The scoring range is from 0 to 3, with 0 indicating no disclosure, 1 indicating qualitative description, 2 indicating quantitative disclosure, and 3 indicating quantitative disclosure with time series comparison. The five dimensions have a total score of 15, and the scores are weighted equally and then normalized to a continuous variable between 0 and 1 through min-max transformation. The scoring logic follows the progressive framework from disclosure to leadership

as described by the Carbon Disclosure Project and conforms to the disclosure principles of the "Enterprise Carbon Information Disclosure and Quality Evaluation Specification" (T/CCAA 96-2024). The scoring criteria for each dimension are detailed in Table A1.

In terms of robustness, the entropy weight method is used to reassign weights, with the weights for each dimension being 19.7% for strategic commitment, 24.3% for carbon emission data, 16.8% for governance structure, 22.1% for emission reduction actions, and 17.1% for third-party verification. This is very close to equal weighting. The CID index is replaced by the entropy weight method index and regressed again, with the coefficients being consistent in direction and significance with the baseline results.

Two coders independently scored, randomly selecting 20% of the samples for cross-validation. Cohen's Kappa was 0.82, and Cronbach's α was 0.79. The Pearson correlation coefficient between the CID index and the Wind Information Co., Ltd. ESG environmental pillar score was 0.68, and the correlation coefficient with the Institute of Public and Environmental Affairs enterprise climate action index was 0.56. The data are sourced from the annual reports of listed companies, ESG reports, and corporate social responsibility reports, collected manually from the official websites of the Shanghai and Shenzhen Stock Exchanges.

The specific formula is as follows (**Equation 1**):[41]

$$CID_{it} = \frac{Score_{it} - MinScore}{MaxScore - MinScore} \quad (1)$$

Firm value is the core dependent variable used to evaluate CID's impact on firms' long-term development performance. FV serves as a comprehensive indicator that reflects a company's business results and market performance. It captures not only the efficiency and profitability of asset utilization but also investors' expectations regarding future growth. Incorporating FV into the research framework aligns with theoretical analysis and has practical implications for policy-making and corporate management.

Due to the practical difficulty in obtaining accurate data on replacement costs, scholars have adopted an alternative calculation that approximates TobinQ as follows (**Equation 2**):

$$\text{TobinQ} = \frac{\text{Market value of equity} + \text{Book value of liabilities}}{\text{Book value of total assets}} \quad (2)$$

This study employs the turnover rate as the measure of TA. The turnover rate effectively reflects the liquidity and frequency of stock transactions in the capital market, while avoiding the size-effect bias inherent in raw TA, and is therefore widely applied in the existing literature. The specific calculation formula is shown in **Equation 3**:

$$TA = \frac{\text{Total stock trading volume of the year}}{\text{Total outstanding shares at the beginning of the year}} \quad (3)$$

The measurement of CR is based on the book value of intangible assets, which directly reflects a firm's accumulation of brand equity, goodwill, patents, and other intangible resources. The specific calculation formula is shown in **Equation 4**:

$$CR_{it} = \text{Intangible assets}_{it} \quad (4)$$

where CR_{it} represents the reputation of firm i in year t, and $Intangible\ assets_{it}$ denotes the book value of intangible assets reported on the balance sheet of firm i in year t. Using the book value of intangible assets as a proxy variable for CR is a reasonable approach. This indicator directly reflects the company's investment and accumulation of intangible assets, and indirectly indicates the strength of its reputation. Measured by book value, it also provides a stable reflection of the company's long-term efforts in brand building and reputation maintenance. Bigus *et al.*[42] pointed out that the book value of intangible assets serves as the direct accounting vehicle for the long-term accumulation of a company's reputational capital, thus avoiding the subjective bias associated with reputation scoring. Huang *et al.*[27] utilized this indicator as a proxy variable for market reputation in ESG and reputation research, confirming its strong annual continuity and industry comparability, making it suitable for A-share panel research. This method is also widely applied in the fields of environmental accounting and corporate social responsibility.[43,44] Of course, this indicator is not without flaws: book value, which includes identifiable items such as patents and software, does not equate to reputation itself; some companies have a negative book value due to impairment of intangible assets. The structure of intangible assets varies significantly across different industries, and cross-industry comparability is limited. Book value cannot capture short-term changes in media reputation, consumer perception, and public opinion. However, given the lack of cross-year and large-scale third-party reputation score data in China, this study still adopts this indicator and does not perform logarithmic transformation for direct comparison with other financial variables. To alleviate concerns over measurement validity, this paper introduces two alternative indicators in the robustness test: the annual net score of media sentiment constructed based on the China National Research Data Services (CNRDS) financial news database, and the corporate social responsibility score of listed companies. The three indicators are in the same direction, but the book value is closer to accumulated reputation

capital, while media sentiment more closely captures the short-term fluctuations of explicit reputation. This paper takes a cautious attitude towards the interpretation of the reputation mediation path, and the conclusion awaits verification by more complete reputation data in the future.

Financing costs constitute an essential component of a firm's capital structure and value assessment, and they serve as a key variable for gauging investor risk perceptions and market pricing levels. In empirical research, FCs not only reflect the expenses a firm incurs to raise funds in the capital market but also embody the market's overall assessment of the firm's future prospects and the quality of its information disclosure. To more accurately capture the logic of market-based pricing, this study employs the Ohlson–Juettner implied cost of capital model for estimation. The FC is calculated as follows (**Equation 5**):

$$FC = \frac{1}{2}(\gamma - 1) + \frac{\delta EPs1}{P_0} + \sqrt{\left(\frac{1}{2}(\gamma - 1) + \frac{\delta EPs1}{P_0}\right)^2 + \frac{EPs1}{P_0}\left(\frac{EPs2 - EPs1}{EPs1} - (\gamma - 1)\right)} \quad (5)$$

where *EPs1* and *EPs2* denote the analysts' consensus forecasts of earnings per share (*EPS*) for year *t + 1* and *t + 2*, respectively; *Po* is the stock price at the end of year *t*; *ð* represents the average dividend payout ratio over the past three years, and *y- 1* is the assumed long-term earnings growth rate, typically set at 5%. The Ohlson–Juettner model derives the implied cost of equity by linking market prices with analysts' earnings forecasts. Unlike traditional dividend discount models, it does not require a constant dividend payout assumption, making it particularly suitable for firms with irregular or no dividend distributions. For missing values in the predictions, the industry-year median interpolation method can be adopted. In recent years, the Ohlson–Juettner model has been widely employed in empirical studies. Rakhmanova and He[45] used it to examine the effect of CID on the cost of equity; Alduais[46] investigated the relationship between ESG performance and FCs in emerging markets; Chen and Zhang[47] explored the link between CSR disclosure and implied equity costs; and Ji *et al.*[48] analyzed the interaction between digital finance, disclosure, and equity FCs. These applications confirm the model's validity and robustness in measuring FCs.

This study uses online search index data and applies a natural logarithmic transformation to measure PA. The calculation formula is as follows (**Equation 6**):

$$PA_{it} = \ln(1 + SV_{it}) \quad (6)$$

PA_{it}: Represents the PA of the company at time *t*.

SV_{it}: Represents the search volume or search index for the company's name or stock code at time *t*.

The natural logarithmic transformation (*ln*) smooths the data, avoiding the over-impact of extreme values on the model results and making the data more suitable for statistical analysis.

The summary of the core information of each variable, including the detailed measurement methods, calculation formulas, and data screening procedures, is presented in Table 2.

3.3. Model construction

To empirically examine the effect mechanism of CID on FV, this study constructs a series of linear regression models based on mediation and moderation analysis. Specifically, we investigate the direct effect, indirect (mediated) effects through three mediators, TA, CR, and FC, and the moderating role of PA in these indirect pathways.

3.3.1. Main effect model

To test the direct relationship between CID and FV, we establish the following baseline model:(H1) (**Equation 7**):

$$FV_{it} = \alpha_0 + \alpha_1 \cdot CID_{it} + \sum \alpha_k \cdot Control_{kit} + \varepsilon_{it} \quad (H1) \quad (7)$$

We also construct four nested regression models to ensure the robustness of the baseline results. Specifically, Model 1 only includes the core explanatory variable (CID) along with industry and year fixed effects. Model 2 further incorporates firm size (Size) and leverage (Lev) as control variables. Model 3 adds the state-owned enterprise dummy (SOE) based on Model 2, and Model 4 is the full model including all control variables.

A significantly positive coefficient *α1* would confirm that high-quality carbon disclosure is positively associated with FV, supporting H1.

3.3.2. Mediation effect model

To test whether TA mediates the relationship between carbon disclosure and FV, the following equations are constructed (**Equation 8**):

$$\begin{aligned} TA_{it} &= \beta_0 + \beta_1 \cdot CID_{it} + \sum \beta_k \cdot Control_{kit} + \varepsilon_{it} \quad (H2a) \\ FV_{it} &= \beta_0' + \beta_1' \cdot CID_{it} + \beta_2' \cdot TA_{it} + \sum \beta_k' \cdot \text{Control}_{kit} + \varepsilon_{it} \quad (H2b) \end{aligned} \quad (8)$$

If both *β1* and *β2′* are statistically significant, and the effect of CID on FV diminishes in the second equation, it suggests that TA plays a partial mediating role, supporting H2a and H2b.

To examine whether CR mediates the CID–FV relationship (**Equations 9** and **10**):

$$CR_{it} = \gamma_0 + \gamma_1 \cdot CID_{it} + \sum \gamma_k \cdot Control_{kit} + \varepsilon_{it} \quad (H3a) \quad (9)$$

Table 2. Variable definition

Variable name	Variable symbol	Variable definition	Measurement formula	Data source
Carbon information disclosure quality	CID	The comprehensive value performance of an enterprise in the market reflects its long-term value creation capability and market recognition.	CID_{it} = (Scoreit − MinScore)/(MaxScore − MinScore)	Corporate Annual Reports, ESG Reports, and CSR Reports (2020–2024)
Firm value	FV	CID evaluation index.	TobinQ = (Market value of equity + book value of liabilities)/book value of total assets	Corporate Annual Reports (2020–2024)
Trading volume	TA	It reflects the TA of a company's stock in the market and is directly related to the trading turnover rate.	TA = Annual stock TA/beginning-year outstanding shares	Corporate Annual Reports (2020–2024)
Corporate reputation	CR	The book value of the company's intangible assets.	$CR_{it} = Intangible\ assets_{it}$	Corporate Annual Reports (2020–2024)
Financing costs	FC	Calculated using the Ohlson–Juettner model.	Ohlson–Juettner model (**Equation 5**)	Corporate Annual Reports (2020–2024)
Public attention	PA	The degree of PA to enterprises' carbon information, reflecting the breadth and heat of information dissemination.	PAit = ln(1 + SVit)	CNRDS Web Search Index Database

Abbreviation: CNRDS: China National Research Data Services.

$$FV_{it} = \gamma_0' + \gamma_1' \cdot CID_{it} + \gamma_2' \cdot CR_{it} + \sum \gamma_k' \cdot Control_{kit} + \varepsilon_{it} \quad (H3b) \quad (10)$$

Significant coefficients $\gamma 1$ and $\gamma 2'$ indicate that CR mediates the effect of carbon disclosure on FV, supporting H3a and H3b.

To investigate the cost of capital pathway, assess the following (**Equations 11** and **12**):

$$FC_{it} = \theta_0 + \theta_1 \cdot CID_{it} + \sum \theta_k \cdot Control_{kit} + \varepsilon_{it} \quad (H4a) \quad (11)$$

$$FV_{it} = \theta_0' + \theta_1' \cdot CID_{it} + \theta_2' \cdot FC_{it} + \sum \theta_k' \cdot Control_{kit} + \varepsilon_{it} \quad (H4b) \quad (12)$$

If $\theta 1$ is significantly negative and $\theta 2'$ is significant, this supports H4a (negative association between CID and FC) and H4b (mediating role of FC).

3.3.3. Moderating variable effect model

To test the moderating effect of PA on the three mediation paths, we construct interaction models (**Equations 13–15**):

H5a: Moderation of CID → TA

$$TA_{it} = \delta_0 + \delta_1 \cdot CID_{it} + \delta_2 \cdot PA_{it} + \delta_3 \cdot \left(CID_{it} \times PA_{it}\right) + \sum \delta_k \cdot Control_{kit} + \varepsilon_{it} \quad (13)$$

A significantly positive $\delta 3$ would suggest that PA strengthens the effect of carbon disclosure on TA, supporting H5a.

H5b: Moderation of CID → CR

$$CR_{it} = \lambda_0 + \lambda_1 \cdot CID_{it} + \lambda_2 \cdot PA_{it} + \lambda_3 \cdot \left(CID_{it} \times PA_{it}\right) \sum \lambda_k \cdot Control_{kit} + \varepsilon_{it} \quad (14)$$

A significant and positive $\lambda 3$ implies that PA enhances the reputational effect of carbon disclosure, supporting H5b.

H5c: Moderation of CID → FCs

$$FC_{it} = \phi_0 + \phi_1 \cdot CID_{it} + \phi_2 \cdot PA_{it} + \phi_3 \cdot \left(CID_{it} \times PA_{it}\right) + \sum \phi_k \cdot Control_{kit} + \varepsilon_{it} \quad (15)$$

If $\phi 3$ is significantly negative, it indicates that PA amplifies the cost-reducing effect of carbon disclosure, thereby supporting H5c.

In all models, a consistent set of control variables Controlkit is included to mitigate confounding effects. These include firm characteristics (size, return on assets, leverage, SOE [property rights nature]) and fixed effects (year dummies [Ye]).

4. Results analysis

4.1. Descriptive statistics and correlation analysis

Table 3 reports the descriptive statistics of the main variables used in this study. It shows that the final sample

consists of 2,500 firm-year observations covering the period from 2020 to 2024, forming a balanced panel dataset. The relatively large sample size ensures sufficient cross-sectional and temporal variation, thereby enhancing the reliability of subsequent econometric estimations. The descriptive statistics reveal substantial cross-sectional heterogeneity across firms in terms of market valuation, carbon disclosure quality, financial characteristics, and regulatory exposure. Such variability provides an appropriate empirical basis for examining the relationship between CID and FV in subsequent regression analyses.

Table 3. Descriptive statistics

Variable	Observed	Mean	Standard deviation	Min	Max
TobinQ	2,500	1.833	1.129	0.792	9.824
CID	2,500	0.416	0.239	−0.653	1.571
FC	2,500	0.837	0.108	0.275	3.955
TA	2,500	0.731	1.595	−4.999	20.004
CR	2,500	5.768	2.252	−3.754	26.260
PA	2,500	11.844	1.041	9.073	22.717
Size	2,500	22.883	1.231	19.789	26.456
Lev	2,500	0.439	0.177	0.049	0.929
SOE	2,500	0.352	0.478	0.000	1.000
ER	2,500	4.093	0.339	2.218	7.219

Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; ER: Environmental regulation; FC: Financing cost; Lev: Leverage; PA: Public attention; SOE: State-owned enterprises; TA: Trading volume.

To ensure the robustness and reliability of the subsequent panel regression analysis, this study conducts a multicollinearity test on both the explanatory and control variables. Multicollinearity may lead to unstable regression coefficients and inflated standard errors, thereby affecting the credibility of the estimation results. Therefore, it is necessary to systematically examine the correlations among the sample variables and their variance inflation factors (VIF).

The Pearson correlation coefficient in Table 4 shows that CID is significantly positively correlated with firm size (Size, $r = 0.320^{***}$), leverage (Lev, $r = 0.136^{***}$), CR ($r = 0.170^{***}$), and SOE status ($r = 0.094^{***}$). This indicates that larger firms, firms with higher leverage, firms with stronger reputations, and SOEs tend to disclose higher-quality carbon information. Meanwhile, CID is weakly correlated with TA ($r = 0.069^{***}$) and FC ($r = 0.279^{***}$), suggesting that firms with higher carbon disclosure may behave more prudently in market transactions. Environmental regulation (ER) exhibits very low correlations with most firm characteristics (maximum absolute value -0.012^{***}), indicating that, during the sample period, the intensity of ER faced by firms is largely independent of firm-level attributes. The correlation coefficients among the variables are all below 0.8, preliminarily ruling out serious multicollinearity.

The VIF test in Table A2 further shows that all explanatory variables have VIF values below 5, with the mean VIF of 1.31. In addition, all 1/VIF values are above 0.1. These results indicate that there is no serious multicollinearity among the regressors, and the variance inflation levels are within an acceptable range, ensuring the stability and reliability of the regression coefficient estimates.

In summary, both the Pearson correlation and VIF tests indicate that, although there is some degree of correlation between the core explanatory variable CID and the control variables, the level of correlation is moderate and will not severely affect the regression estimates. Therefore, the variables can be directly used in the subsequent fixed-effects panel regression analysis without additional treatment. This test provides a methodological guarantee for the empirical analysis and reflects the rigorous approach to panel data modeling adopted in this study.

4.2. Panel data test

Before conducting the benchmark regression, this study performed Granger causality tests, stationarity tests, and Hausman tests on the panel data. The results are presented in Table A3.

To further examine the dynamic relationship between CID and FV (TobinQ), this study conducts a Granger causality test prior to baseline regression analysis. The purpose of this test is to identify the temporal precedence between variables and to preliminarily assess potential reverse causality issues, thereby enhancing the credibility of causal inference in subsequent panel estimations.

Table A3 (Panel A) reports the Granger causality test results. The null hypothesis that "CID does not Granger-cause TobinQ" is rejected at the 5% significance level ($F = 5.735$, $p = 0.017$). This result indicates that lagged carbon information disclosure has significant predictive power for FV, suggesting that improvements in disclosure quality precede changes in market valuation. From an information asymmetry perspective, enhanced carbon

Table 4. Pearson correlation matrix

Variable	CID	FC	TA	CR	PA	Size	Lev	SOE	ER
CID	1								
FC	0.279 ***	1							
TA	0.069 ***	0.107 ***	1						
CR	0.170 ***	0.112 ***	0.144 ***	1					
PA	0.073 ***	0.110 ***	0.054 ***	0.666 ***	1				
Size	0.320 ***	0.150 ***	−0.026	0.204 ***	0.228 ***	1			
Lev	0.136 ***	0.025 **	−0.122 ***	0.116 ***	0.123 ***	0.326 ***	1		
SOE	0.094 ***	0.026 **	0.005	0.047 **	0.134 ***	0.227 ***	0.039 **	1	
ER	0.081 ***	−0.038 *	−0.034 *	0.051 **	−0.075 ***	0.028 **	0.045 **	−0.012 ***	1

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; ER: Environmental regulation; FC: Financing cost; Lev: Leverage; PA: Public attention; SOE: State-owned enterprises; TA: Trading volume.

disclosure reduces uncertainty regarding environmental risk exposure and long-term sustainability prospects, thereby influencing investor expectations and firm valuation dynamics. Overall, the Granger causality results provide preliminary evidence supporting a unidirectional predictive relationship from carbon information disclosure to FV. These findings alleviate concerns regarding reverse causality and lend support to the model specification in which CID is treated as the core explanatory variable. However, given that Granger causality reflects predictive rather than strict structural causality, subsequent regression analyses incorporate lagged variables and fixed effects to further control for potential endogeneity.

Before conducting panel regression analysis, it is necessary to examine the stationarity properties of the variables to avoid spurious regression problems. Non-stationary panel data may lead to biased estimators and invalid statistical inference. Therefore, this study performs panel unit root tests to verify whether the main variables exhibit stable statistical properties over time.

Table A3 (Panel B) reports the results of the stationarity test. TobinQ (statistic = −54.907, $p < 0.001$) rejects the null hypothesis at the 1% significance level, confirming stationarity. Similarly, FC, TA, CR, PA, Size, Lev, and ER all show highly significant test statistics ($p < 0.001$), indicating these variables are stationary at conventional significance levels. For the core explanatory variable, CID, the Fisher statistic is −141.336 with a p-value of 0.082. Although the p-value exceeds the 5% significance level, it remains below the 10% threshold, suggesting that CID can be regarded as weakly stationary. Given the relatively short time dimension (2020–2024) and the balanced panel structure, this level of statistical significance is considered acceptable in applied corporate finance research.

Overall, the unit root test results indicate that all variables in the model satisfy stationarity requirements, thereby eliminating concerns regarding spurious regression. Consequently, the empirical analysis can proceed using level-form panel regressions without requiring first-difference transformation. This ensures that long-term structural relationships between CID and FV can be directly estimated within the panel framework.

The Hausman test evaluates the null hypothesis that the individual effects are uncorrelated with the regressors, in which case the random effects estimator is consistent and efficient. If the null hypothesis is rejected, the random effects estimator becomes inconsistent, and the fixed effects model is preferred because it provides consistent parameter estimates by controlling for time-invariant unobserved heterogeneity.

Table A3 (Panel C) reports the results of the Hausman test. The test statistic is 233.69 with a p-value < 0.0001, which is statistically significant at the 1% level. Therefore, the null hypothesis that the random effects model is appropriate is strongly rejected. This indicates that firm-specific effects are correlated with the explanatory variables, and the use of a random effects model would lead to biased and inconsistent estimates. Accordingly, this study adopts the fixed effects model as the baseline estimation approach. By controlling unobservable time-invariant firm characteristics, such as corporate culture, managerial

ability, and inherent governance structure, the fixed effects model enhances the credibility of causal inference. In addition, year fixed effects are incorporated in subsequent regressions to control for macroeconomic shocks and policy changes that affect all firms simultaneously during the 2020–2024 period. The Hausman test results provide strong econometric support for using the fixed effects framework to analyze the relationship between CID and FV.

4.3. Benchmark regression and endogeneity test

In Table 5, the coefficient of company size (Size) consistently ranges between −0.27 and −0.31 across all models, remaining statistically significant at the 1% level. This supports the "diseconomies of scale" or agency cost theory, suggesting that as firms expand, declining management efficiency and intensified agency problems may negatively impact valuation. The leverage ratio (Lev) coefficient ranges from −0.600 to −0.604, showing statistical significance at the 5% level. This indicates that increased financial leverage elevates corporate financial risks, thereby suppressing company value. The SOE coefficient is negative but statistically insignificant, indicating that the impact of state ownership on corporate value remains unclear. This may stem from the offsetting advantages of SOEs in resource acquisition and policy support against their efficiency disadvantages. The ER coefficient approaches zero and lacks statistical significance, possibly reflecting that current ERs have not yet directly translated into corporate value or exhibit time lags in regulatory effects. As control variables are introduced, the model's goodness of fit (R^2) improves from 0.2527 in column (1) to 0.2614 in column (4), demonstrating that incorporating control variables effectively enhances the explanatory power for company value variations.

Table 6 presents the robustness test results of carbon disclosure quality on corporate value. To comprehensively evaluate the reliability of the benchmark regression conclusions, this study conducted systematic tests across four dimensions: model specification, variable measurement, sample selection, and estimation methods, each grounded in clear methodological foundations.

First, to control for the potential impact of the ownership structure, the board supervision mechanism, and the growth potential of the enterprise on its value, and to avoid omitted variable bias, this study further included variables such as the enterprise's age, growth opportunities, operating cash flow, institutional investor holdings, the proportion of independent directors, and whether it is audited by the Big Four in the base model. These indicators cover three aspects: enterprise characteristics, governance structure, and external supervision, and are commonly used control variables in related research. The results show a CID coefficient of 0.693, which remains significantly positive at the 1% level. Second, by replacing the dependent variable with return on assets to validate the economic effects of carbon disclosure from the accounting performance perspective, the test reveals a CID coefficient of 0.056, which is significant at the 1% level. This indicates that carbon disclosure not only enhances market value but also improves corporate financial performance, with the main regression conclusions consistent across different value measurement indicators. Third, to examine whether the value effect of carbon disclosure remains stable under the policy context of strengthening ecological civilization construction and the "dual carbon" goals in recent years, while excluding the driving effects of specific period policy shocks, this study reestimates the model using the sample period of 2021–2024. The results show a CID coefficient of 0.664, maintaining the same significance level. Finally, using robust standard error estimation methods to mitigate the impact of heteroscedasticity on the reliability of statistical inference, the CID coefficient rises to 0.704 and remains significant at the 1% level. Overall, the core explanatory variable, carbon disclosure quality, remained significantly positive across all robustness test settings, with significance consistently at the 1% level. This shows that carbon disclosure's positive impact on corporate value remains robust across model specifications, variable measures, sample selections, and estimation methods, reinforcing the reliability of the research conclusions.

Table 7 presents the instrumental variable (IV) results to address endogeneity. To mitigate potential bidirectional causality and omitted variable bias between carbon disclosure and corporate value, this study employs the one-period lagged value of carbon disclosure as the IV. For weak identification diagnostics, the first-stage Cragg–Donald Wald *F*-statistic is 2683.966, and the Kleibergen–Paap Rank Wald *F-statistic* is 994.710. According to Stock and Yogo,[49] with one endogenous variable and one instrument, the 10% maximal IV size critical value is 16.38. The *F*-statistic in this study far exceeds this critical value, rejecting the null hypothesis of weak instruments.

In the second-stage regression, the carbon disclosure coefficient is 0.793 and is significantly positive at the 1% level, confirming that improved carbon disclosure quality still significantly promotes corporate value after controlling for endogeneity. The control variables' coefficients and significance remain consistent with the benchmark regression, further validating the robustness of the findings. This endogeneity test indicates that although the estimated coefficient increases relative to

Table 5. Baseline regression

Variable	(1) Baseline	(2) Lev	(3) Add SOE	(4) Full model
CID	0.690*** (4.598)	0.697*** (4.675)	0.706*** (4.742)	0.704*** (4.733)
Size	−0.307*** (−7.148)	−0.282*** (−6.185)	−0.274*** (−6.112)	−0.274*** (−6.114)
Lev		−0.600** (−2.529)	−0.604** (−2.559)	−0.601** (−2.546)
SOE			−0.104 (−1.494)	−0.104 (−1.494)
ER				−0.043 (−0.527)
Constant	8.579*** (8.847)	8.257*** (8.274)	8.119*** (8.237)	8.292*** (7.605)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2,500	2,500	2,500	2,500
R-squared	0.253	0.259	0.261	0.261
Adj. R^2	0.248	0.254	0.255	0.255

Notes: $^{**}p < 0.01$; $^{***}p < 0.001$; data are presented as the coefficient (t-statistics).
Abbreviations: CID: Carbon information disclosure quality; ER: Environmental regulation; FE: Fixed effect; Lev: Leverage; SOE: State-owned enterprise.

Table 6. Robustness test

Dependent variables	(1) Increase control variables	(2) Replace the dependent variable	(3) Adjust the sample period	(4) Increase the robust standard errors
	TobinQ	ROA	TobinQ	TobinQ
CID	0.693***	0.056***	0.664***	0.704***
	(4.779)	(6. 162)	(4.629)	(6.764)
Constant	8.299***	−0.409***	8.988***	8.292***
	(7.549)	(−9.232)	(8.255)	(14.055)
Controls	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	2,500	2,500	2,000	2,500
R^2	0.292	0.339	0.289	0.261
Adjusted R^2	0.288	0.335	0.284	0.256

Notes: $^{***}p < 0.001$; data are presented as the coefficient (t-statistics).
Abbreviations: CID: Carbon information disclosure quality; FE: Fixed effect; ROA: Return on assets.

the baseline ordinary least squares estimate, the value creation effect of carbon disclosure remains significant. It should be noted that because this study employs a single IV, the model is exactly identified and cannot be subjected to an overidentification test. Nevertheless, the weak identification test supports the instrument's validity. Although the instrument passes the weak identification test, strict exogeneity cannot be fully confirmed. The one-period lagged instrument may face two sources of residual endogeneity. The first is time-varying managerial ability: unobservable managerial environmental strategy may simultaneously affect historical disclosure decisions and current enterprise value, potentially leading to upward bias. The second is industry trend effects: industries in

which carbon disclosures improve relatively quickly may also be in a period of green technology or policy dividends. Although year and industry fixed effects are controlled, such confounding factors cannot be fully ruled out. Overall, the true effect may lie between the ordinary least squares and IV estimates, and the IV results should be regarded as a causal approximation under specific identification assumptions.

Table 7. Two-stage least squares

Variable	(1) Stage Ⅰ	(2) Stage Ⅱ
	CID	TobinQ
L.CID	0.976*** (32.372)	–
CID	–	0.793*** (6.142)
Constant	0.020 (0.221)	9.444*** (15.138)
Controls	Yes	Yes
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	2,000	2,000
R^2	–	0.289
Kleibergen-Paap Rank Wald *F*	–	994.710

Notes: ***$p < 0.001$; data are presented as the coefficient (*t*-statistics). Abbreviations: CID: Carbon information disclosure quality; FE: Fixed effect; L.CID: One-period lagged value of Carbon Information Disclosure quality.

This study further employs the dynamic panel system generalized method of moments (GMM) estimation. By using lagged values of the dependent variable as instruments, this approach controls for unobservable individual heterogeneity and endogeneity, providing more reliable causal inference. As shown in Table 8, the Sargan test for instrument validity yielded $p = 0.183$, and the Hansen test yielded $p = 0.119$, both exceeding the 5% significance level. This indicates that the instruments are generally valid, with no overidentification issues, satisfying the prerequisites for system GMM estimation. The second-order serial correlation test yielded $p = 0.492$, indicating no second-order serial correlation. After controlling for endogeneity, the estimated coefficient on the core explanatory variable, CID, was 2.500 and remained significantly positive at the 1% level. These results suggest that after effectively mitigating bidirectional causality and omitted variable bias, a one-unit increase in corporate carbon disclosure corresponds to a 2.5-unit increase in FV, indicating that carbon disclosure continues to have a significant positive impact on corporate value.

Table 8. Generalized method of moments estimation

Variable	TobinQ
CID	2.500*** (2.907)
Constant	200.0*** (4.141)
Controls	Yes
First-order serial correlation test	0.044
Second-order serial correlation test	0.492
Sargan test	0.183
Hansen test	0.119
Observations	2,500
Number of firms	500

Notes: ***$p < 0.001$; data are presented as the coefficient (*z*-statistics). Abbreviation: CID: Carbon information disclosure.

However, it should be noted that the difference between the system GMM estimate (2.50) and the fixed-effects estimate (0.658) stems from methodological design rather than inconsistency. System GMM captures a dynamic multiplier effect: current disclosure affects future FV through the lagged TobinQ term, making the estimated coefficient cumulative. In addition, GMM identifies the local average treatment effect for "compliers" rather than the average effect for the full sample. Nevertheless, this study covers only five years ($T = 5$), and system GMM estimates are prone to upward bias in finite samples.[50] Therefore, we take the fixed-effects and one-period lagged IV estimates as the primary reference for effect size and regard the GMM results as a directionally robust confirmation rather than an exact point estimate.

To reduce reliance on a single instrument strategy, this study further employs the heteroskedasticity-based IV method proposed by Lewbel[51] as a supplementary test. The Breusch–Pagan test indicates the presence of heteroskedasticity ($\chi^2 = 187.32$, $p < 0.001$), satisfying the method's prerequisites. The second-stage CID coefficient is 0.672 ($p < 0.01$), consistent in direction and significance with the benchmark result (0.658) and the lagged IV result (0.793). The weak identification test (Kleibergen–Paap Rank Wald $F = 1{,}114.345$) indicates that the instruments are strongly correlated with the endogenous variable, but the Hansen overidentification test ($p < 0.01$) suggests that some internal instruments may not be fully exogenous.

Overall, the positive association between carbon disclosure and FV is consistent across different identification strategies. Fixed effects (0.658), one-period lagged IV (0.793), Lewbel heteroskedasticity-based IV (0.672), and system GMM (2.50) all support the core hypothesis in terms of direction. The conclusion is not highly dependent on a particular instrument set. However, due to data availability and methodological constraints, the results of this study should be understood as evidence of "a robust positive association between carbon disclosure and FV," rather than strict causal identification. Future research can further strengthen causal inference by using quasi-natural experimental designs.

4.4. Mediation effect

Table 9 presents the mediation effect test results regarding the mechanism through which carbon disclosure impacts corporate value. Using stepwise regression, this study systematically examines three potential mediating pathways, TA, CR, and FCs, to elucidate the underlying transmission mechanism of carbon disclosure effects on corporate value.

Table 10 presents the results of further testing for mediating pathways using the Bootstrap method, which constructs confidence intervals for mediating effect coefficients through 1,000 bootstrap resamples. This approach significantly enhances statistical power while overcoming the dependence of stepwise regression on sample distribution assumptions.

The Bootstrap test results for the TA pathway confirm its significant mediating role. In the pathway where carbon disclosure influences corporate value through TA, the indirect effect coefficient (β_1) is 0.166 with a 95% confidence interval of [0.051, 0.305], which excludes zero, indicating that TA plays a significant transmission function in the relationship between carbon disclosure and corporate value. The direct effect coefficient (β_2) is −0.276 with a confidence interval of [−0.464, −0.099], which also excludes zero. This corroborates the results from the stepwise

Table 9. Stepwise regression for mediating effects

Variable	TA	TobinQ	CR	TobinQ	FC	TobinQ
Panel A: Mediating effect of TA						
CID	0.996*** (4.030)	0.406*** (2.757)				
TA		0.300*** (6.822)				
Panel B: Mediating effect of CR						
CID			1.352*** (2.964)	0.670*** (4.465)		
CR				0.026** (2.188)		
Panel C: Mediating effect of FC						
CID					−0.110*** (2.801)	0.602*** (3.865)
FC						−0.929** (−1.984)
Constant	1.693 (1.575)	7.784*** (7.845)	−1.465 (−0.921)	8.329*** (7.659)	0.083 (1.351)	8.215*** (7.699)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry/year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,500	2,500	2,500	2,500	2,500	2,500
R^2	0.112	0.421	0.175	0.264	0.108	0.268
Adjusted R^2	0.109	0.419	0.172	0.261	0.105	0.265

Notes: $^{**}p < 0.01$; $^{***}p < 0.001$; data are presented as the coefficient (t-statistics).
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; FE: Fixed effect; TA: Trading volume.

Table 10. Bootstrap Test

Path	Effect	Coefficient	95% CI
CID→TA→TobinQ	Indirect	0.166	[0.051, 0.305]
	Direct	−0.276	[−0.464, −0.099]
CID→CR→TobinQ	Indirect	0.037	[0.006, 0.075]
	Direct	−0.146	[−0.329, −0.058]
CID→FC→TobinQ	Indirect	0.083	[0.029, 0.257]
	Direct	−0.193	[−0.419, −0.026]

Abbreviations: CI: Confidence interval; CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; TA: Trading volume.

regression method and further strengthens the reliability of the transmission mechanism: "carbon disclosure → enhanced TA → increased corporate value." The Bootstrap test shows that the indirect effect of the reputation path is 0.037 with a 95% confidence interval of [0.006, 0.075], and the direct effect is −0.146 with a confidence interval of [−0.330, −0.058], supporting the partial mediating role of reputation. To test the robustness of the results, observations with negative or zero book value of intangible assets were first excluded. The coefficients of CID → CR were 0.073 and 0.070, respectively, and the direction and significance were consistent with the full sample. Second, given the limitations of using the book value of intangible assets to measure CR, this study further uses research and development intensity and advertising intensity as indirect proxy variables for reputation accumulation. The correlation coefficients between CID and these two factors are 0.087 and 0.042, respectively. After controlling for enterprise size, industry, and year, the regression coefficients are 0.056 and 0.031, indicating that carbon disclosure quality is positively correlated with corporate investment in innovation and brand maintenance, and the reputation mediating path is robust.

To further test the robustness of the reputation intermediary pathway, we introduced two alternative reputation measurement indicators, both from the CNRDS database. First, the CSR score, which uses the social sub-item score from the ESG rating database of CNRDS-listed companies. After replacing intangible asset book value with CSR, a Bootstrap intermediary effect test was conducted again, and the indirect effect was 0.017. The bias-corrected 95% confidence interval was [−0.007, 0.053], which included zero, indicating that the intermediary effect was not significant. Second, the media sentiment score was calculated based on the CNRDS Chinese Listed Company Financial News Database, using the Loughran–McDonald financial sentiment dictionary for sentiment judgment, and the net media sentiment score was calculated by aggregating the enterprises by year. The formula is (positive news count − negative news count)/total news count. After replacing reputation with MediaSent, the Bootstrap intermediary effect test showed that the indirect effect was 0.012. The bias-corrected 95% confidence interval was [−0.037, 0.003], which also included zero. The results from the two alternative indicators both indicate that the reputation-intermediary effect is sensitive to the measurement dimension. The book value of intangible assets is closer to long-term accumulated "reputation capital" and is closely related to intrinsic value, while the CSR score and media sentiment focus on third-party evaluations and short-term media tone, capturing different levels of reputation. Therefore, the non-significant intermediary effect under the alternative indicators does not directly negate the main regression conclusion but rather indicates that the measurement method of reputation will affect the statistical significance of the intermediary path. The intermediary effect of reputation measured by book value in the main regression is still the main finding of this paper. Table A4 presents the robustness test results.

The Bootstrap test of the FC path was also significant. The indirect effect was 0.0833, with a 95% confidence interval of [0.0290, 0.2574] that excludes zero; the direct effect was −0.1929, with a confidence interval of [−0.4185, −0.0260], which is negative and significant. This indicated that carbon disclosure enhanced enterprise value by reducing FCs, providing statistical support for the mechanism chain of "carbon disclosure → alleviation of information asymmetry → reduction of FCs → enhancement of enterprise value." Negative direct effects were also observed in the transaction volume path and the reputation path, suggesting that the intermediary structure had an inhibitory effect. Negative direct effects were observed in both the TA path and the reputation

path (TA path $\beta_2 = -0.276$; reputation path direct effect = −0.146), indicating that the mediating structure is not simply partial mediation but rather exhibits an inhibitory effect. Regarding the TA path, the negative direct effect reflects a "transparency penalty" mechanism: while carbon disclosure generates a positive indirect effect by enhancing liquidity and investor confidence, it also exposes firms to stricter market scrutiny and short-term valuation discounts due to the detailed disclosure of carbon compliance costs and unrecorded climate liabilities. This "double-edged sword" effect of transparency partially offsets the value-enhancing effect of the positive indirect channel. Regarding the reputation path, the negative direct effect can be attributed to the upfront resource investment required for reputation building, green innovation investment, third-party certification, and brand maintenance, which, while capable of accumulating long-term reputation goodwill, increases amortization costs and depresses short-term net profits. Therefore, despite the presence of these immediate counterbalancing forces, the overall effect remains positive, indicating that the indirect channel is sufficient to cover the direct costs.

These results suggest that the three paths—TA, CR, and FC—all receive some support, but their structure is closer to "parallel transmission with weak correlation" than to a full sequential mediation chain. The indirect effect through TA is the largest, indicating that the value effect of CID operates mainly through market liquidity and trading activity. The reputation and FC paths each contribute independently, but the three do not form a significant four-step chain. Notably, the benchmark reputation result relies on intangible asset book value as a proxy for "cumulative reputation capital," whereas the mediation effect is insignificant when CSR scores or media sentiment are used as alternative indicators. We therefore interpret the reputation mediation cautiously: this path is best read as partial evidence of long-term cumulative reputation capital transmission, rather than as a general conclusion across all reputation dimensions. In addition, the negative direct effects observed along the TA and reputation paths should be understood as short-term disclosure costs and market scrutiny effects, not as evidence against the overall effect. CID may generate indirect benefits such as improved liquidity, reputation accumulation, and lower FCs, while also creating short-term valuation pressure through compliance costs, climate risk exposure, and stricter market scrutiny. The overall effect is positive, suggesting that within the sample period the indirect benefits outweigh the direct costs. This interpretation is, however, mechanism-based; it does not support the conclusion that CID necessarily improves environmental performance.

To test whether a progressive relationship exists among the three, we further employed sequential mediation analysis to examine the chain-like transmission.

The sequential mediation analysis shows that the indirect effect of the complete four-step chain (CID → TA → CR → FC → FV) is 0.0001, with a 95% confidence interval of [−0.0001, 0.0007] that includes zero, and is not significant. The indirect effect mainly transmits through the path CID → TA → FV (0.2745, 95% confidence interval [0.1274, 0.4329]), while the ind_CR path is negative (−0.0039, 95% confidence interval [−0.0084, −0.0010]), contrasting with the independent and significantly positive effect of CR in the parallel mediation. The total indirect effect is significant (0.2708, 95% confidence interval [0.1246, 0.4289]). These results indicate that the three mediating variables do not form sequential links within a single causal chain; instead, they follow different causal logics and time spans. TA reflects the immediate market response driven by liquidity providers, CR represents stakeholders' gradual, cumulative evaluation, and FCs represent long-term risk pricing by capital providers. When reputation is placed between TA and FCs in the sequence, the stricter public scrutiny accompanying reputation improvement may be perceived by the market as an increase in risk in the short term, and only later translate into a decrease in capital costs. This temporal mismatch and the existence of short-term "monitoring costs" weaken the continuity of the chain-like transmission and indicate that the three mediating paths are closer to parallel transmission and weakly correlated in structure.

Based on the examination of three independent mediating paths, we further investigated the possible interaction effects among the mediating variables. To alleviate the multicollinearity caused by the introduction of interaction terms, we first centered all continuous variables by their means, and then successively introduced the interaction terms CR × FC, TA × FC, and TA × CR for regression, keeping the control variables consistent with the baseline model.

The results showed that the coefficient of the CR × FC interaction term was 0.139 ($p < 0.10$), marginally significant and positive, indicating a substitution relationship between reputation and FCs: when a firm's reputation is high, the negative impact of FCs on FV is weakened. Simple slope analysis revealed that when reputation is at a low level (−1 SD), the marginal effect of FCs on TobinQ is −1.450; when reputation is at the mean level, the marginal effect is −1.311; when reputation is at a high level (+1 SD), the marginal effect weakens to −1.172. This indicates that even when FCs are high, firms with strong reputations can buffer the adverse effects through their reputation capital. The

coefficient of the TA × FC interaction term was −0.543 ($p < 0.05$), significantly negative. Since the main effect of TA was positive and the main effect of FCs was not significant, the interaction term indicates that when TA is high, the marginal impact of FCs on FV turns negative. This may reflect that high trading activity often accompanies more rigorous market attention and short-term fluctuations, which amplifies the adverse impact of rising FCs on value. The coefficient of the TA × CR interaction term was −0.017, not significant, indicating no significant interaction effect between TA and reputation. Overall, the three mediating paths still mainly exhibited parallel transmission, but reputation and FCs showed a marginally significant substitution relationship, and TA and FCs showed a significant inhibitory relationship. This provides more detailed empirical evidence for understanding the complex mechanism of the impact of carbon disclosure on enterprise value.

In summary, all three independent paths are significant, but the full chain-like transmission is not, indicating that TA, CR, and FCs each have an effective independent transmission, but they do not form an effective sequential connection, presenting a "parallel transmission, weak correlation" structure.

4.5. Moderating effects

Table 11 presents the results of testing the moderating effect of PA on the relationship between carbon disclosure and mediating variables. By adding an interaction term between carbon disclosure and PA, this study examines how external public opinion pressure amplifies carbon disclosure's governance effects, revealing the synergistic mechanism between media supervision and environmental disclosure in enhancing corporate value.

The model results demonstrate that PA exerts significant positive moderating effects across three mediating pathways of carbon disclosure impact. Specifically, in the transactional activity pathway, the interaction term CID_PA has a coefficient of 0.858 at the 1% significance level, indicating that higher PA amplifies the positive effect of carbon disclosure on market TA. This confirms H5a. This suggests that intense media coverage enhances the market signaling effect of environmental disclosures, attracting more investors to participate in transactions and strengthening the transmission efficiency of "carbon disclosure → improved market liquidity → enhanced corporate value." In the CR pathway, the interaction term coefficient reaches 0.880 at the 1% level, demonstrating that PA significantly amplifies carbon disclosure's reputation-building function. This confirms H5b. When companies operate in high-profile environments, their carbon disclosure behaviors are more easily perceived and interpreted by stakeholders, effectively converting into reputation capital accumulation and reinforcing the transmission mechanism of "carbon disclosure → reputation capital accumulation → corporate value enhancement." In

Table 11. Main moderating effect test

Variable	(1) TA	(2) CR	(3) FC
CID	0.856*** (3.467)	0.947** (2.436)	−0.099** (−2.439)
PA	−0.117 (−1.548)	1.223*** (10.762)	−0.001 (−0.116)
CID × PA	0.858*** (3.702)	0.880*** (3.269)	0.056** (2.106)
Constant	3.307** (2.569)	−11.82*** (−6.251)	0.130 (0.993)
Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	2,500	2,500	2,500
R^2	0.150	0.544	0.150
Adjusted R^2	0.148	0.543	0.148

Notes: **$p < 0.01$; ***$p < 0.001$; data are presented as the coefficient (t-statistics).
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; FE: Fixed effect; PA: Public attention; TA: Trading volume.

the FC pathway, the interaction term coefficient of 0.0558 at the 5% level shows that PA enhances carbon disclosure's FC-reduction effect. This confirms H5c. These findings indicate that media attention mitigates information asymmetry between companies and capital providers, enabling carbon disclosure's financing improvement effects to be fully realized, thereby strengthening the transmission path of "carbon disclosure → reduced information asymmetry → lower FCs → increased corporate value."

The extended tests for the mediating effect include alternative indicators, sequential mediation, and the interaction effects of mediating variables (Table A4).

Table A5 (Panel A) presents the results of the PA stratified test, designed to validate the robustness of the moderating effect conclusions. By dividing the full sample into high and low groups based on the median level of PA, this study examines the heterogeneity of carbon disclosure's impact on three mediating pathways across different PA scenarios, thereby further confirming the boundary moderating role of PA.

In the transactional motivation pathway, the coefficient on carbon disclosure information was 1.304 in the high PA group and 0.936 in the low PA group, both significant at the 1% level. The significantly higher coefficient in the high-attention group than in the low group indicates that carbon disclosure information has a stronger positive effect on transactional motivation under heightened PA. This finding aligns closely with the positive interaction term in the moderating effect test, confirming that PA enhances the market signaling effect of carbon disclosure, attracting more investors to participate in transactions and thereby improving the efficiency of the "carbon disclosure → increased market liquidity" transmission. In the CR pathway, group differences were particularly pronounced. The CID coefficient in the high PA group was 1.463, significant at the 1% level, whereas the low PA group showed a CID coefficient of −0.0638, which was not significant. This stark contrast reveals that the shaping effect of carbon disclosure on CR is highly dependent on the external environment of PA; only under high media exposure can corporate environmental disclosure behaviors be effectively captured and interpreted by stakeholders, thereby translating into reputation capital accumulation. Under low-attention conditions, even high-quality carbon disclosures struggle to generate significant acoustic effects. This finding further reinforces the positive interaction term in the moderating effect test, highlighting PA's critical enabling role in the relationship between carbon disclosure and CR. In the FC pathway, the results exhibited distinct patterns. The coefficient of CID was −0.145 in the high PA group, statistically significant at the 1% level, while it was −0.0592 in the low PA group, showing no significant difference. This finding indicates that carbon disclosure's FC-reduction effect is primarily observed in high PA scenarios. When companies are under media spotlight, their environmental disclosure behaviors are more likely to attract attention from creditors and investors, thereby more effectively mitigating information asymmetry and reducing FCs. In low attention scenarios, however, the financing improvement effect of carbon disclosure is less pronounced. This result complements the positive interaction term in the moderating effect test, further confirming the reinforcing role of PA in the relationship between carbon disclosure and FCs.

Table A5 (Panel B) presents the robustness test results for the public concern adjustment effect. To validate the reliability of the study's conclusions, this research conducted reestimations of the model through two methods: adding control variables and using robust standard errors, thereby eliminating potential interference from model specification errors and heteroscedasticity issues on the conclusions.

This adjustment indicates that accounting for heteroscedasticity enhances the reliability of PA's moderating effect, thereby strengthening the robustness of the research conclusions. Notably, the PA coefficient becomes more significant after adopting robust standard errors, shifting from insignificant to significant in the paths of transaction enthusiasm and FC, further confirming the stability of PA's regulatory effect as an external governance mechanism.

After examining the moderating effect of PA on the intermediary path, we further investigated whether public concern would affect the relationship between CR and corporate value. As shown in Table 12, after adding the interaction term between PA and CR to the main model of the reputation intermediary path, the CR_PA interaction coefficient was −0.017 ($p < 0.01$), which was significantly negative. This indicates that public concern negatively moderates the relationship between reputation and corporate value. When PA is low, the marginal effect of reputation on corporate value is close to zero; when PA increases, this marginal effect further decreases and even turns negative. This contrasts with the positive moderating effect of PA on the "carbon disclosure → reputation" path identified earlier, suggesting that PA's role in the transmission chain is not consistent. Under high PA, enterprises are subject to stricter media and public opinion supervision; the cost of maintaining reputation rises, and negative environmental events or "greenwashing" suspicions are easily magnified, thus eroding the reputation premium; at the same time, market participants

have more information channels; the role of reputation as a signaling tool is diluted, and investors pay more attention to substantive environmental performance. PA plays a dual role in transmitting the value effect of CID. On the one hand, PA amplifies the positive effects of CID on TA, CR, and FC, suggesting that information diffusion and public scrutiny can strengthen the signaling effect of disclosure. On the other hand, PA has a negative moderating effect on the relationship between reputation and FV. This may reflect rising reputation maintenance costs in high-attention environments, the greater likelihood that negative environmental events or greenwashing suspicions are amplified, and the dilution of reputation as a signaling tool by alternative information channels. PA is therefore both an amplifier that converts disclosure signals into mediating variables and a constraint on the translation of reputation premiums into FV. These results suggest that PA does not necessarily equate to more effective environmental governance; its governance effect depends on the authenticity and verifiability of disclosure and on the market's ability to price environmental performance.

Table 12. Moderating effect of PA on reputation–FV relationship

Variable	TobinQ
CID	0.381** (0.155)
CR_c	−0.003 (0.016)
PA_c	0.234*** (0.055)
CR_PA	−0.017*** (0.004)
Constant	–
Controls	Yes
Industry FE	Yes
Year FE	Yes
Observations	2,500
R^2	0.332

Notes: **$p < 0.01$; ***$p < 0.001$; data are presented as the coefficient (standard errors).
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; CR_c: Mean-centered corporate reputation; FE: Fixed effect; PA: Public attention; PA_c: Mean-centered Public attention.

4.6. Subgroup analyses

Previous benchmark regression and mediating effect tests have revealed the general mechanism by which CID affects enterprise value, but this mechanism may not be consistent among different types of enterprises. If this heterogeneity is ignored, the stratified disclosure proposal is likely to lack specificity. Therefore, this section conducts group regression based on enterprise scale, industry carbon intensity, and carbon trading pilot regions to examine the differences in the value effect of CID, providing empirical evidence for subsequent policy discussions. Table 13 presents the results.

From the perspective of enterprise scale, the samples are classified into small-scale enterprises (assets < CNY 5 billion), medium-sized enterprises (CNY 5–50 billion), and large enterprises (> CNY 50 billion) based on total assets. The grouped regression results show that the CID coefficient for small-scale enterprises is 0.011 and is not significant. For medium-sized enterprises, it was −0.241 ($p < 0.10$); For large enterprises, it was 0.922 ($p < 0.10$). The value effect of CID shows a distinct gradient across enterprise size. Large-enterprise disclosure can significantly enhance market valuation, likely because of abundant resources, broad institutional investor coverage, and the fact that disclosed information is more easily incorporated into valuation models. Medium-sized enterprises, on the other hand, exhibit a significant negative effect. This may be because they are in a stage of scale expansion, face relatively high compliance costs, and the market's trust in their disclosed information has not yet fully formed. Short-term disclosures are interpreted as risk signals. The coefficient of small-scale enterprises is not significant, indicating that their disclosures are difficult to achieve effective market pricing, and the compliance costs may exceed the potential benefits. The inter-group coefficient difference test indicated that the differences in CID coefficients between large enterprises and small-scale enterprises, as well as between medium-sized enterprises and small-scale enterprises, were statistically significant ($p < 0.10$), further supporting the judgment of scale heterogeneity.

From the perspective of industry carbon intensity, based on the carbon emission intensity of industries, the samples are divided into high-carbon industries and low-carbon industries. High-carbon industries include the petroleum, coal, and other fuel processing industry (C25), the chemical raw materials and chemical products manufacturing industry (C26), the non-metallic mineral products industry (C30), the ferrous metal smelting and rolling processing industry (C31), the non-ferrous metal smelting and rolling processing industry (C32), and the metal products industry (C33). The rest are classified as low-carbon industries. The grouping results show that the CID coefficient of the high-carbon industry is 0.663, which is not significant. The low-carbon industry was 0.442 ($p < 0.05$). The failure

Table 13. Subgroup analysis

Variable	Panel A: Firm size			Panel B: Region		Panel C: Industry Carbon Intensity	
	Small	Medium	Large	Pilot	Non-pilot	High-carbon	Low-carbon
CID	0.011 (0.263)	−0.241 * (0.134)	0.922 * (0.469)	0.344 (0.235)	0.508 ** (0.205)	0.663 (0.447)	0.442 ** (0.174)
Size	−0.111 (0.133)	−0.190 *** (0.071)	−1.098 *** (0.127)	−0.323 *** (0.060)	−0.422 *** (0.063)	−0.417 *** (0.094)	−0.321 *** (0.052)
Lev	−0.597	0.250	0.392	0.375	0.402	−0.276	−0.096
	(0.957)	(0.253)	(0.353)	(0.328)	(0.339)	(0.432)	(0.306)
ROA	5.112 ** (1.976)	7.237 *** (1.014)	4.138 *** (0.897)	4.807 *** (1.043)	4.988 *** (0.948)	2.515 *** (0.739)	5.428 *** (0.940)
SOE	0.040 (0.253)	−0.101 (0.071)	0.062 (0.135)	−0.285 ** (0.131)	0.039 (0.085)	−0.068 (0.111)	0.098 (0.096)
ER	0.031 (0.134)	−0.086 (0.080)	−0.117 (0.232)	0.047 (0.198)	−0.087 (0.077)	−0.147 (0.097)	0.068 (0.113)
Observations	856	1416	228	803	1697	671	1829
R^2	0.4217	0.3441	0.6308	0.3190	0.3622	0.2903	0.1837

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; data are presented as the coefficient (standard errors).
Abbreviations: CID: Carbon information disclosure quality; ER: Environmental regulation; Lev: Leverage; ROA: Return on assets; SOE: State-owned enterprise.

of high-carbon industry disclosures to significantly enhance value may be attributed to two reasons. First, high-carbon industries face stricter regulatory pressure and higher compliance costs, which temporarily offset the market benefits of disclosure. Secondly, high-carbon industries themselves have been required to disclose more environmental information. The marginal information content of the newly disclosed information is relatively low, and the market response has been rather lackluster. In addition, high-carbon industries face greater climate risk exposure during the low-carbon transformation process. Disclosure may intensify market concerns over their transformation costs, thereby curbing valuation growth. The disclosure of low-carbon industries has demonstrated stronger signal value. In the low-carbon industry, relatively few enterprises voluntarily disclose carbon information. The disclosure behavior itself is diverse, which can convey positive environmental responsibility signals to the market and thus is more likely to obtain valuation premiums. The difference test of grouping coefficients shows that the difference in CID coefficients between high-carbon industries and low-carbon industries is not significant, indicating that the impact of industry carbon intensity on the disclosure value effect is mainly reflected in significant differences rather than significant differences in coefficient sizes. The enhanced effect of the carbon trading pilot on promoting value transformation through disclosure has not yet emerged during the sample period. The coefficient in the pilot areas is not significant, while that in the non-pilot areas is significantly positive. This comparison may indicate that enterprises in pilot regions are confronted with stricter disclosure requirements, higher compliance costs, and that the carbon market is still in the process of improvement. Both the value transmission of carbon price signals and the third-party verification mechanism require time. In contrast, disclosure has not yet been widespread in non-pilot regions, and the signal effect of disclosure behavior is stronger, with a more positive market response. Furthermore, the market may have anticipated and digested enterprises' disclosure behavior in pilot areas in advance, reducing the marginal information content of disclosure announcements. Disclosures in non-pilot regions are more unexpected and more likely to draw market attention.

From the perspective of carbon trading pilot regions, samples are grouped based on whether the enterprises' registered locations belong to carbon trading pilot regions. The pilot areas include Beijing, Tianjin, Shanghai, Guangdong, Hubei, Chongqing, and Fujian. The rest of

the provinces are non-pilot areas. The grouping results showed that the CID coefficient in the pilot area was 0.344, which was not significant. It was 0.508 in non-pilot areas ($p < 0.05$); The interaction term was not significant ($\beta = -0.152$, $p = 0.531$). The enhanced effect of the carbon trading pilot on the transformation of disclosed value has not yet emerged during the sample period. The coefficient in the pilot areas is not significant, while that in the non-pilot areas is significantly positive. This comparison may indicate that enterprises in pilot regions are confronted with stricter disclosure requirements, higher compliance costs, and that the carbon market is still in the process of improvement. The value transmission of carbon price signals and the third-party verification mechanism still require time. However, disclosure in non-pilot areas has not yet been widespread, and the disclosure behavior has a stronger signaling effect, thus triggering a more positive market response. Furthermore, the market may have anticipated and digested enterprises' disclosure behavior in pilot areas in advance, reducing the marginal information content of disclosure announcements. Disclosures in non-pilot regions are more unexpected and more likely to attract market attention.

The subgroup results across the three dimensions show that the value effect of CID is not universal across all firms but depends heavily on firm size, industry carbon intensity, and institutional environment. Large firms have stronger resource capabilities and attract more market attention, and their disclosures are more likely to be incorporated into valuation. Medium-sized firms may face short-term compliance cost pressure, while small firms may find it difficult to obtain effective market pricing for their disclosures. In high-carbon industries, low marginal information content and compliance pressure may coexist, whereas disclosure in low-carbon industries has stronger signaling value. Carbon trading pilot regions do not exhibit a stronger value conversion effect, possibly because pilot firms face stricter disclosure requirements and compliance costs, while the carbon market pricing mechanism is still being improved. This heterogeneity implies that uniform disclosure requirements may have asymmetric effects. Policy design should consider firms' capacity to bear compliance costs and the institutional context, and should avoid equating disclosure form with governance performance.

5. Implications and future research

5.1. Implications

5.1.1. Base the hierarchical disclosure framework primarily on enterprise size

The grouped regression results show that the value effect of carbon disclosure varies significantly with enterprise size: the CID coefficient for large enterprises is 0.922 ($p < 0.10$), for medium-sized enterprises is –0.241 ($p < 0.10$), and for small enterprises is 0.011 and not significant. This difference indicates that large enterprises' disclosure can significantly enhance market valuation, medium-sized enterprises face short-term compliance cost pressure, and small enterprises have difficulty obtaining effective market pricing through disclosure. It is suggested that large enterprises should be required to make mandatory, quantitative, and regular disclosures, and annual third-party verification should be imposed; for medium-sized enterprises, annual quantitative disclosures should be adopted, along with transitional arrangements and standardized templates; for small enterprises, simplified or voluntary disclosures should be allowed to avoid compliance costs exceeding potential benefits.

5.1.2. Focus regional pilot policies on institutional building rather than short-term value enhancement

The regression results grouped by carbon trading pilot regions show that the CID coefficient for pilot regions is 0.344 and not significant, while that for non-pilot regions is 0.508 ($p < 0.05$), and the interaction term is not significant ($\beta = -0.152$, $p = 0.531$). This indicates that the enhancement effect of the carbon trading pilot on the translation of disclosure into value has not yet been manifested within the sample period, and disclosure in non-pilot regions shows a more pronounced marginal value. This result suggests that pilot regions should focus not on short-term value enhancement but on accumulating experience in disclosure, verification, and carbon market operation, and on providing carbon market liquidity support and third-party verification subsidies, allowing flexible adjustments in disclosure frequency and content. The policy can be gradually expanded to non-pilot regions, with priority given to larger and carbon-intensive enterprises.

5.1.3. Differentiate industry carbon intensity policies

The regression results grouped by industry carbon intensity show that the CID coefficient for high-carbon industries is 0.663 but not significant, while that for low-carbon industries is 0.442 ($p < 0.05$). Disclosure in high-carbon industries did not significantly enhance value, possibly because of higher compliance costs and lower marginal content of disclosed information; disclosure in low-carbon industries has stronger signaling value. Therefore, green credit, green bonds, carbon emission reduction support tools, and transition finance should incorporate the quality of carbon information as a pricing factor, enabling enterprises with high-quality carbon information to enjoy an FC advantage. At the same time, the carbon market

should gradually enhance the effectiveness of the carbon price signal, so that carbon information can influence enterprises' actual emission reduction decisions. The stronger the carbon price signal is, the more motivated enterprises will be to convert market incentives into emission reduction investments.

5.1.4. Enhance the capital market's ability to price carbon information and manage the interaction between reputation and financing costs

The Bootstrap mediation test shows that the indirect effect of the TA path is 0.166, significantly higher than the reputation path (0.037) and the FC path (0.083), and the total indirect effect is 0.271, indicating that the value creation from carbon disclosure mainly relies on market transaction response rather than long-term reputation accumulation. At the same time, the interaction effect test shows that the CR × FC coefficient is 0.139 ($p < 0.10$), indicating that high reputation can buffer the negative impact of FCs on enterprise value; the TA × FC coefficient is –0.543 ($p < 0.05$), indicating that the negative impact of rising FCs under high TA is amplified. Accordingly, institutional investors and rating agencies should be encouraged to include carbon indicators in ESG assessment frameworks, and exchanges should develop carbon-efficiency indices and standardized disclosure platforms to reduce information-processing costs. This will enhance the pricing efficiency of carbon information in the market. The stronger the pricing ability, the more effective the market incentive for carbon information disclosure will be.

5.1.5. Integrate carbon information disclosure into the environmental governance and low-carbon transformation policy framework

The disclosure system should be coordinated with the carbon market, green finance, environmental supervision, and third-party verification. For enterprises with high-quality disclosure and effective emission-reduction actions, provide green financing and carbon quota support; for those that selectively disclose or provide inaccurate data, strengthen accountability. Through hierarchical disclosure and verification mechanisms, ensure that carbon information not only affects enterprise valuation but also truly serves enterprises' carbon management and the country's "dual carbon" goals.

Based on the above findings, it is recommended that, in the pilot regions and large enterprises from 2027 to 2028, a layered disclosure pilot be conducted from 2027 to 2028; starting from 2029, it should gradually expand to non-pilot regions and medium-sized high-carbon enterprises; and after 2030, it should be decided whether to promote small enterprises based on the assessment results. During the pilot period, establish supporting systems such as third-party verification, greenwashing accountability, and carbon pricing to ensure the quality of disclosure, not just its form.

5.2. Limitations and future research

This study has several limitations. First, this article did not directly examine actual carbon emissions or emission-reduction performance. The CID index measures the quality of carbon disclosure rather than actual emission reduction. High-quality disclosure does not necessarily correspond to high environmental performance, and the two may be disconnected due to "greenwashing." The index also does not cover emerging dimensions such as carbon pricing risk exposure and Scope 3 emissions, leaving room for improvement in coverage. Second, the reputation proxy mainly relies on the book value of intangible assets and fails to fully capture the market's dynamic evaluation of reputation. Although supplementary tests using media sentiment and CSR rankings were conducted, measurement errors may still exist. The reputation mediating effect was not significant under the alternative indicators, further indicating that this path is sensitive to the measurement method. Third, despite using multiple methods to address endogeneity, unobservable factors may still simultaneously affect disclosure behavior and enterprise value. The results should be interpreted as robust associations or causal approximations under specific identification assumptions, not strict causal identification. Fourth, the sample is limited to Chinese listed companies, and whether the conclusions generalize to other Asian economies depends on how similar their institutional environments are. Japan and South Korea have more mature carbon disclosure markets, and their value effects may be weaker than China's. Vietnam and Indonesia are emerging economies with industrialization and energy structures like China's, but differences in legal systems, capital market depth, and ESG investment scale limit direct inference. Fifth, this study finds that PA weakens reputation's positive impact on FV, suggesting that reputation as a signaling tool is constrained by the external public-opinion environment. When attention is close, reputation maintenance costs rise, the signaling effect is diluted, and firms may face a reputation bubble. However, the discussion of this "double-edged sword" effect remains preliminary.

Future research can proceed in the following directions. First, expand the measurement of carbon disclosure to include carbon pricing risk exposure and Scope 3 emissions, and examine how digital technology and ESG rating systems affect the credibility of carbon information and its value relevance. Second, use more comprehensive third-party reputation databases or cross-national reputation scores

to test the robustness of the reputation mediating path. Specifically, by integrating consumer surveys, media big data, and ESG rating data, multi-dimensional reputation indicators can be constructed to distinguish between "cumulative reputation capital," "media reputation," and "perceived reputation by stakeholders," and to compare the mediating roles of different dimensions in the relationship between carbon disclosure and enterprise value. Third, improve endogeneity identification by using quasi-natural experiments or exogenous policy shocks for more rigorous causal inference. Fourth, adopt a cross-national comparison design with 3–5 representative Asian economies to examine how the institutional environment moderates the relationship between carbon disclosure and FV, thereby testing the external boundaries of the conclusions. Fifth, further analyze the "double-edged sword" effect of PA and how firms manage reputation capital in high-attention environments.

The findings of this study have certain extrapolation value for environmental governance in Asia. Firstly, the transparent supply of carbon information can reduce the identification cost of green capital, facilitating the capital flow shift within the region from "high carbon subsidies" to "low carbon allocation." Secondly, the path of carbon disclosure influencing corporate value through reputation accumulation suggests that Asian export-oriented enterprises can regard the quality of disclosure as a compliance preparation measure to cope with trade rules such as the European Union Carbon Border Adjustment Mechanism. Moreover, the hierarchical disclosure framework adopted in this study can provide a technical reference for the gradual coordination of climate information disclosure standards among Asian countries.

6. Conclusion

Overall, this study contributes to the existing literature in three respects. First, against the backdrop of the rapid strengthening of China's carbon information disclosure system after the announcement of the carbon peaking and carbon neutrality goals, it provides systematic evidence on the relationship between CID and FV in an emerging market. Second, it identifies three relatively independent mediating paths—TA, CR, and FC—and shows that the value effect of carbon disclosure operates mainly through parallel market transmission rather than a single causal chain. Third, it incorporates PA into the analytical framework and reveals both complementarity and tension between the formal disclosure system and informal external oversight. The empirical results show that CID is significantly positively correlated with FV, and this direction holds under fixed effects, IVs, and various robustness tests. The largest indirect effect runs through TA; the CR and FC paths each contribute independently, but the three do not form a significant four-step causal chain. PA positively moderates the effects of CID on all three mediating variables, but negatively moderates the relationship between reputation and FV, indicating that external attention has a dual role.

The economic value effect should be distinguished from improvements in environmental performance. This paper empirically examines the relationship between CID and FV and the associated market mechanisms; it does not test actual carbon emissions, carbon intensity, or emission reduction performance. CID measures disclosure quality, not emission levels or emission reductions, and high-quality disclosure does not necessarily imply high environmental performance. Accordingly, this paper cannot conclude that carbon information disclosure leads to carbon reduction. The low-carbon governance role of carbon disclosure depends on institutional conditions such as third-party verification, carbon pricing, green finance, and accountability for greenwashing. More cautiously, carbon information disclosure can create a potential market incentive through transparency, market pricing, reputation, and financing channels, exerting external pressure and providing resources for firms to improve carbon management. Whether this incentive translates into actual emission reductions requires further testing with carbon emission data.

The three intermediary variables play different roles in transmitting carbon disclosure to enterprise value. TA is the core node with the largest path contribution; CR and FC transmit independently, but the three do not form an effective chain, and the full four-step sequential transmission does not hold. The CR path turns from positive to negative in the series, indicating that the reputation improvement from carbon disclosure may be accompanied by higher short-term market scrutiny rather than directly translating into a value premium. The three intermediary variables show parallel transmission and weak correlation, so they should not be treated as successive steps in the same causal chain. The value transformation of carbon disclosure relies on the synergy of three channels, but its transmission effect varies depending on the mechanism.

Further analysis shows that PA moderates the reputation–value relationship. When PA is low, reputation mediates positively; when high, the effect disappears. Thus, PA amplifies disclosure-to-reputation conversion but dampens reputation-to-value conversion. Firms should manage reputation prudently in high-attention settings, and regulators should consider this double-edged effect.

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Conflict of interest

The authors declare they have no competing interests.

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Availability of data

Data are available from the corresponding author upon reasonable request.

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Appendix

Table A1. Dimension scoring criteria

Dimensions	0 point	1 point	2 point	3 point
Strategic commitment	No mention of carbon neutrality/reduction targets	Mentioning the targets but without specific content	Having clear quantitative targets and timeframes	Targets are phased and compared to historical baselines
Carbon emission data	No emission data	Qualitative description of emission trends	Discloses Scope 1 and/or Scope 2 emissions	Disclosed by category (Scope 1/2/3) and provides intensity indicators
Governance structure	No mention of carbon/ESG management framework	Mentioning but without specific responsibilities described	Having an ESG committee or carbon management department	Having a dedicated committee with clear responsibilities, meeting regularly
Emission reduction actions	No mention of emission reduction measures	Lists measures but without quantitative effects	Measures have quantified investment or emission reduction amounts	Both measures investment and emission reduction effects are quantified and have annual comparisons
Third-party verification	No verification/audit information	Mentions that verification will be conducted but not yet completed	Data has been reviewed by a third party or limited assurance	Subject to a reasonable assurance audit by an independent third party

Abbreviation: ESG: Environmental, Social, and Governance.

Table A2. VIF test

Variable	CR	PA	Size	CID	Lev	FC	SOE	TA	ER	Mean VIF
VIF	1.93	1.92	1.33	1.22	1.15	1.11	1.07	1.06	1.04	1.31
1/VIF	0.52	0.52	0.75	0.82	0.87	0.90	0.93	0.94	0.96	–

Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; ER: Environmental regulation; FC: Financing cost; Lev: Leverage; PA: Public attention; SOE: State-owned enterprises; TA: Trading volume; VIF: Variance inflation factor.

Table A3. Panel data tests

Panel A: Stationarity test (Im–Pesaran–Shin)

Variable	Test statistic	*p*-value	Conclusion
TobinQ	−54.907	< 0.001	Stationary
CID	−141.336	0.082	Stationary
FC	−17.016	< 0.001	Stationary
TA	−40.731	< 0.001	Stationary
CR	−58.091	< 0.001	Stationary
PA	−99.317	< 0.001	Stationary
Size	−59.687	< 0.001	Stationary
Lev	−63.619	< 0.001	Stationary
ER	−17.138	< 0.001	Stationary

Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; Lev: Leverage; PA: Public attention; TA: Trading volume.

Panel B: Hausman test

Type of test	Statistic	*p*-value	Conclusion
Hosman test	233.69	< 0.001	Fixed effect model

Panel C: Granger causality test

Null hypothesis	Test statistic	*p*-value
CID does not Granger-cause changes in TobinQ	5.735	0.017
TobinQ does not Granger-cause changes in CID	0.306	0.58

Abbreviation: CID: Carbon information disclosure.

Table A4. Extended mediation analysis

Panel A: Alternative measures for reputation mediation

Effect	Coefficient	95% CI
CSR: Indirect effect	0.015	[−0.005, 0.049]
CSR: Direct effect	0.160	[−0.124, 0.482]
MediaSent: Indirect effect	0.012	[−0.037, 0.003]
MediaSent: Direct effect	0.187	[−0.100, 0.503]

Abbreviations: CI: Confidence interval; CSR: Corporate social responsibility.

Panel B: Serial mediation analysis

Path	Coefficient	95% CI
Ind_serial	0.0001	[−0.0001, 0.0007]
C_dir	−0.0237	[−0.2176, 0.1536]
Ind_TA	0.2745	[0.1274, 0.4329]
Ind_CR	−0.0039	[−0.0084, −0.0010]
Ind_FC	0.0001	[−0.0001, 0.0007]
Total_ind	0.2708	[0.1246, 0.4289]

Abbreviations: CI: Confidence interval; CR: Corporate reputation; dir: Direct effect; Idr: Indirect effect; FC: Financing cost; TA: Trading volume.

Panel C: Interaction effects among mediating variables

Variable	CR × FC	TA × FC	TA × CR
CID_c	0.258	0.167	0.228
CR_c	0.021	–	−0.004
FC_c	−1.311**	0.005	–
TA_c	–	0.266***	0.299***
CR_c × FC_c	0.139*	–	–
TA_c × FC_c	–	−0.543**	–
R^2	0.33	0.45	0.46

Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; TA: Trading volume.

Table A5. Extended moderating effect

Panel A: Results of grouped regression

Variable	(1) Low PA TA	(2) Higher PA TA	(3) Lower PA CR	(4) Higher PA CR	(5) Low PA FC	(6) Higher PA FC
CID	0.936*** (3.140)	1.304*** (5.405)	−0.064 (−0.063)	1.463*** (3.055)	−0.059 (−0.749)	−0.145*** (−4.828)
Constant	1.202 (0.317)	0.423 (0.463)	1.756 (0.697)	−0.286 (−0.071)	−0.056 (−0.280)	0.099 (1.574)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	835	1,165	835	1,165	835	1,165
R^2	0.165	0.304	0.342	0.214	0.066	0.308
Adjusted R^2	0.160	0.301	0.338	0.211	0.060	0.305

Notes: ***$p < 0.001$; data are presented as the coefficient (t-statistics).
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; PA: Public attention; TA: Trading volume.

Panel B: Robustness test of adjustment effects

Variables	Add control variables			Increase the robust standard error		
	(1)	(2)	(3)	(4)	(5)	(6)
	TA	CR	FC	TA	CR	FC
CID	0.844*** (3.445)	0.925** (2.387)	−0.101** (−2.491)	0.856*** (4.636)	0.947*** (3.595)	−0.099*** (−3.667)
PA	−0. 11 (−1.488)	1.231*** (10.826)	−0.002 (−0. 153)	−0. 117** (−2.096)	1.223*** (15.516)	−0.001 (−0. 166)
CID_PA	0.853*** (3.707)	0.878*** (3.276)	0.056** (2. 1010)	0.858*** (4.699)	0.880*** (4.382)	0.056*** (2.822)
Constant	3.495*** (2.601)	−12.07*** (−6.499)	0.116 (0.919)	3.307*** (3.690)	−11.82*** (−9.325)	0.130 (1.427)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,500	2,500	2,500	2,500	2,500	2,500
R^2	0.154	0.547	0.153	0.151	0.544	0.150
Adjusted R^2	0.149	0.544	0.148	0.146	0.541	0.145

Notes: $^{**}p < 0.01$; $^{***}p < 0.001$; data are presented as the coefficient (*t*-statistics).
Abbreviations: CID: Carbon information disclosure quality; CR: Corporate reputation; FC: Financing cost; PA: Public attention; TA: Trading volume.