

Article

The Impact of Carbon Information Disclosure Quality on Enterprise Value: Evidence from Chinese Listed Companies

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Abstract: In the context of increasing carbon emissions and strengthening regulatory measures, an increasing number of stakeholders are paying more attention to corporate carbon information. To further explore the relationship between the quality of carbon information disclosure and enterprise value, this study uses a sample of companies listed on the Shanghai and Shenzhen stock exchanges from 2013 to 2021. The aim is to investigate the link between the quality of carbon information disclosure and enterprise value, while also analyzing the role of green innovation in this relationship. The empirical results show that the quality of carbon information disclosure can significantly enhance enterprise value, with green innovation playing a mediating role in this effect. After robustness checks, including replacing the measurement variables and addressing endogeneity issues, the conclusions remain valid. Further analysis reveals that the effect of carbon information disclosure quality on enhancing enterprise value is more pronounced in non-high-pollution industries, non-state-owned enterprises, and firms located in eastern regions. This study provides valuable insights for future policy optimization related to carbon information disclosure and the promotion of low-carbon development in enterprises.

Keywords: carbon information disclosure quality; enterprise value; green innovation



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1. Introduction

In recent years, with the rapid industrialization process globally, large amounts of waste gases and industrial emissions from the burning of fossil fuels have been released into the atmosphere, leading to increasingly severe air pollution. Climate change has had profound impacts on the natural environment (including agriculture and ecosystems) as well as on the development of human society [1]. Currently, as global awareness of the harmful effects of environmental pollution continues to rise, environmental protection has gradually become a core development concept adopted by various countries. The Chinese government attaches great importance to ecological environmental protection, considering the construction of ecological civilization as a fundamental national policy, and consistently upholds coordinated development across multiple dimensions, including ecological environment, economic growth, and social equity. In 2011, China launched carbon pilot projects in seven provinces and municipalities, and in 2013, the carbon trading market was officially established. In 2016, the government issued guidelines for building a green financial system, requiring companies to strengthen carbon information disclosure. In 2020, the government further set forth the targets of “carbon neutrality” and “carbon peaking”. In 2021, China launched the comprehensive implementation of a unified carbon emissions trading system. Additionally, the Chinese State Council issued the White Paper

on “Green Development in the New Era of China” in 2023, which explicitly calls for accelerating the construction of ecological civilization and promoting the comprehensive green transformation of the economy and society [2,3].

In this context, the notions of ecological civilization and green development have garnered broad consensus. Only by ensuring that enterprises develop in harmony with nature, society, and people can they achieve long-term, sustainable green development [4]. As key players in the market economy, enterprises consume substantial amounts of energy in their production and operational processes, particularly those relying on fossil fuels. Therefore, enterprises need to reduce carbon emissions through green innovation activities, such as optimizing product design and improving energy efficiency, while achieving environmental protection alongside economic benefits. Green innovation encompasses the integration of environmentally conscious and sustainable principles, technologies, and practices across product, service, production processes, and management. Situated within the broader framework of economic, social, and environmental sustainability, its goal is to foster a harmonious balance that advances both corporate sustainability and environmental protection [5]. In this regard, the government needs to implement environmental regulatory policies, such as carbon information disclosure, to guide enterprises in intensifying their green innovation efforts, thus promoting corporate sustainable development and enhancing enterprise value [6].

The existing literature presents varying interpretations regarding the relationship between the quality of carbon information disclosure and enterprise value. Some researchers suggest a positive correlation between the two. Studies have shown that higher levels of carbon information disclosure are associated with increased enterprise value, with the positive correlation being more pronounced in developing countries where carbon disclosure is voluntary [7]. Conversely, other researchers analyzing Chinese listed companies in high-pollution industries found a negative correlation between carbon disclosure levels and enterprise value. This may stem from the tendency of companies with suboptimal carbon reduction performance to disclose carbon information as a means of addressing stakeholder concerns and preserving organizational legitimacy [8]. Moreover, Deqing Wang et al. (2023), using data from listed companies, discovered a U-shaped relationship between carbon information disclosure and enterprise value. Initially carbon information disclosure has a negative impact on enterprise value. With the passage of time, carbon information disclosure gradually promotes the improvement of enterprise value [9]. These findings reveal notable disparities in the effect of carbon information disclosure quality on enterprise value, emphasizing the necessity for further investigation into the dynamics of this relationship. The differences in the above research findings may be influenced by industry variations. In high-pollution industries, where enterprises have high carbon emissions, disclosing carbon information may expose deficiencies in their environmental management, leading to increased external regulatory pressure and unfavorable public opinion, which in turn can affect the enterprise’s value.

As global carbon trading continues to grow, the importance of research related to carbon information disclosure has also increased [10,11]. As central actors in both economic and social spheres, enterprises not only represent the foremost contributors to carbon emissions but also serve as the principal agents responsible for achieving carbon reduction targets, a dynamic that has garnered significant academic focus. Carbon information disclosure can directly promote green technology innovation through the spillover effects of reputation. Additionally, it can indirectly stimulate green technological innovation by alleviating financing constraints, increasing public attention, and reducing agency costs [12,13].

Existing research presents conflicting empirical results regarding the relationship between green innovation and enterprise value. Some scholars argue that green technological innovation, through new patents and technologies, helps companies improve production efficiency, reduce costs, and establish product differentiation advantages. This contributes to enhancing core competitiveness and achieving sustainable development, thereby increasing enterprise value [14]. However, other scholars highlight that green technological innovation requires substantial R&D investment and has long development cycles and uncertain returns. As a result, it may weaken enterprise value by diverting resources and increasing risk [15,16].

As the economy accelerates its transition towards a green and low-carbon direction, companies are placing increasing emphasis on green innovation to maintain their competitive advantage in the fierce market competition, while also complying with government environmental regulations. Green innovation not only brings technological advantages to companies but also effectively enhances enterprise value. However, green innovation is often a high-cost, high-risk, and long-term endeavor. In an environment characterized by information asymmetry, company managers may be inclined to make low-risk investment decisions. This leads some companies to fail in truly implementing low-carbon and environmentally friendly principles, instead focusing their efforts on exaggerated advertising and image embellishment, resulting in the phenomenon of “greenwashing”. Such behavior undoubtedly reduces the effectiveness of resource allocation in capital markets, which is detrimental to the sustainable environmental development of enterprises [17,18]. The phenomenon of “greenwashing” manifests in two main dimensions: on one hand, companies exaggerate the environmental benefits of their products or services to mislead consumers, creating a positive impression of the product or service; on the other hand, companies exaggerate their environmental commitments to mislead investors and other stakeholders. Some scholars have found that “greenwashing” behavior in corporate sustainability reports significantly reduces the creation of “shared value”. Moreover, the effectiveness of internal controls and the pressure from external media supervision are positively correlated with the reduction in the negative impact of “greenwashing” on “shared value” creation [19]. In addition, Antonio J. Mateo-Márquez et al. incorporated international climate-related regulations into their analysis of corporate “greenwashing” behavior. They proposed that the number of climate change-related regulations negatively affects the tendency of companies to engage in “greenwashing”, meaning that companies in countries or regions with stricter climate regulations are less likely to participate in such behavior [20].

Corporate carbon information disclosure demonstrates the company’s proactive response to national policies and its commitment to social responsibility, which helps establish brand reputation, attract more external resources, and garner increased attention from external stakeholders. This, in turn, raises the external pressure on the company. The increase in both external resources and external pressure is conducive to promoting green innovation, thereby advancing the company’s sustainable development [21,22]. It can be argued that, in pursuing social value, the company also achieves its economic value, thus maximizing enterprise value. Therefore, companies should actively engage in carbon information disclosure, enabling stakeholders to better understand the company’s situation and make informed decisions.

However, due to the delayed market response to corporate carbon information disclosure and the relatively high disclosure costs, companies find it difficult to predict the exact impact of carbon information disclosure on enterprise value. As a result, the willingness of companies to voluntarily disclose carbon information is low [23]. Within this context, the present study centers on the quality of carbon information disclosure, drawing upon

the existing literature to investigate in depth whether proactive carbon disclosure can substantively enhance enterprise value.

In the context of existing research, this study provides a distinct set of insights. First, it expands the scope of investigation into the quality of carbon information disclosure, an area where most prior studies have predominantly focused on the impact on corporate financial performance. By utilizing Tobin's Q as a measure of firm value, this study delves into the relationship between the quality of carbon information disclosure and enterprise value. Second, it explores the mediating role of green innovation in the linkage between carbon information disclosure and enterprise value, offering partial pathways through which carbon disclosure affects firm value. Further analysis reveals that the positive impact of carbon information disclosure quality on enterprise value is more pronounced in non-high-pollution industries, non-state-owned enterprises, and firms located in the eastern regions of China. These findings contribute to the ongoing refinement of carbon information disclosure policies in China, providing valuable guidance to enterprises seeking to navigate low-carbon transitions and achieve sustainable development.

The structure of this paper is organized as follows: Section 1 introduces the study and reviews the relevant literature; Section 2 presents the formulation of the theoretical hypotheses; Section 3 outlines the research design, followed by an analysis of the empirical results; Section 4 offers further discussion and analysis; Section 5 discusses the research findings and limitations; and Section 6 provides recommendations derived from the empirical findings.

2. Theoretical Analysis and Research Hypotheses

2.1. *The Impact of Carbon Information Disclosure Quality on Enterprise Value*

According to signaling theory, in situations of information asymmetry, companies with information advantages disclose internal information to external stakeholders to demonstrate their proactive social responsibility, thus avoiding adverse selection issues [24]. Therefore, by proactively disclosing carbon information, companies can reduce information asymmetry between themselves and external stakeholders, lowering the costs of information collection, transaction costs, and decision-making costs. This allows stakeholders to better assess the company's operations and growth prospects. On the other hand, stakeholders may question companies with poor carbon information disclosure quality, perceiving them as concealing negative information, which could lead to the undervaluation of the company [25].

From a legitimacy perspective, for an organization to sustain long-term development, its actions must align with publicly accepted values and ethical standards [26]. Listed companies that actively disclose carbon information demonstrate their commitment to social and environmental responsibilities, which helps enhance their organizational legitimacy and build a positive corporate image. Furthermore, proactive carbon disclosure can encourage companies to adopt green technology innovations, energy-saving measures, and pollution reduction strategies, which can lower greenhouse gas emissions, reduce political risks, and cut costs related to environmental restoration. This also helps mitigate litigation and penalties arising from environmental issues [16,27]. Additionally, by actively disclosing carbon information, companies can enhance their reputation and influence. In today's highly competitive business environment, a strong corporate reputation can bring more business opportunities and capital premiums, boosting investor confidence, attracting more investment, and ultimately increasing enterprise value [28,29]. Accordingly, this paper posits the following hypothesis:

Hypothesis 1 (H1). *The quality of corporate carbon information disclosure is positively correlated with enterprise value.*

2.2. The Mediating Effect of Green Innovation

Corporate green innovation, similarly to general technological innovation, carries uncertain returns and involves a systematic set of factors, including the market, technology, economics, and strategy. To maintain product advantages and competitiveness, companies are typically reluctant to fully disclose information to investors. This creates an information barrier between the company and its external stakeholders, making it difficult for investors to accurately gauge the company's financial investments in green innovation [30,31]. However, Porter's hypothesis emphasizes that environmental protection policies primarily affect the economy by incentivizing companies to innovate technologies or adopt innovative techniques. While this may increase short-term operational costs, in the long run, it can enhance the company's core competitiveness and production efficiency, thereby offsetting the costs associated with environmental protection and improving profitability, which ultimately boosts enterprise value.

Additionally, according to signaling theory, companies that actively disclose carbon information send a signal to the outside world about their achievements in low-carbon strategies, energy conservation, and emission reductions. This alignment with the "dual carbon" policy strengthens the company's legitimacy, builds a positive corporate image, facilitates fund-raising efforts, and attracts innovative talent, all of which provide the foundation for green technological innovation and enhance enterprise value [32,33].

Finally, from a reputation mechanism perspective, when media reports highlight environmental issues within a company, it may lead to a public trust crisis. To maintain a positive green image or when under external pressure, listed companies may adopt immediate corrective actions. However, short-term measures do not fundamentally resolve environmental issues. In such cases, companies are likely to opt for green technological innovation to seek long-term value benefits and signal to the external world their proactive social responsibility, thereby repairing their corporate reputation [34,35].

Clearly, actively disclosing carbon information not only alleviates information asymmetry but also strengthens corporate legitimacy and maintains reputation, thus driving companies toward green innovation. As governments and consumers increasingly focus on environmental issues, there is growing concern about corporate legitimacy and the environmental attributes of products, as well as a greater willingness to accept the added environmental value of company products. Through green innovation, companies can optimize production processes and equipment, reduce environmental pollution, mitigate potential penalties, and lower non-compliance costs, thereby improving overall performance and enterprise value [36]. Accordingly, this paper posits the following hypothesis:

Hypothesis 2 (H2). *Corporate green innovation mediates the relationship between carbon information disclosure quality and enterprise value.*

3. Materials and Methods

3.1. Sample Selection

The General Office of the National Development and Reform Commission officially issued the "Notice on the Implementation of Carbon Emission Trading Pilot Programs" in October 2011, approving seven provinces and cities, including Shanghai, Beijing, and Guangdong, to carry out carbon emission trading pilot programs. Starting in 2013, carbon exchanges gradually began to be established, and in 2021, a unified carbon emission trading market was fully launched. This paper selects Shanghai and Shenzhen listed companies from 2013 to 2021 as the initial sample and processes the data using STATA 16 software with the following steps: (1) performing a 1% trimming on continuous variables; (2) excluding

companies in the financial industry; (3) excluding ST and *ST companies; and (4) excluding companies with significant missing data. The final dataset consists of 6960 observations.

The data on carbon information disclosure quality are primarily obtained from securities exchanges, official company websites, annual reports, and pertinent sustainability reports. The patent data of green innovation comes from CNRDS database and other data are obtained from China CSMAR database.

3.2. Variable Definition

3.2.1. Dependent Variable

Following the approach of Yijun Zhang, this paper uses Tobin's Q as a measure of enterprise value. Tobin's Q is measured by dividing the sum of net debt market value and equity market value by the book value of total assets at the end of the period. It takes into account both the company's operating performance and the external market's stock price fluctuations, providing a relatively accurate assessment of enterprise value [37].

3.2.2. Independent Variable

This paper primarily references the study by Hong Chen et al. (2019) and relevant practices in China, using the entropy weight method to assess the quality of carbon information disclosure [38]. The sample is selected from Shanghai and Shenzhen listed companies in China between 2013 and 2021. The data sources include stock exchanges, the official websites of the companies, annual reports, and sustainability-related reports, with companies having severe data deficiencies being excluded. In order to reduce the subjective bias in constructing the indicator system, this paper employs the entropy weight method to calculate the weights of each indicator. The detailed construction process is as follows:

Step 1: Establishing the Carbon Information Disclosure Evaluation Indicator System.

Based on the carbon information disclosure management frameworks set by major authoritative international organizations and the "General Guidelines for the Accounting and Reporting of Greenhouse Gas Emissions from Industrial Enterprises" issued in China in 2015, the following primary indicators are identified: carbon reduction strategy and goals, carbon reduction actions and performance, carbon reduction management and incentives, and carbon emission accounting and trading. The secondary indicators include nine items such as carbon reduction goals, carbon reduction concepts and strategies, low-carbon policy responses, etc. The tertiary indicators consist of 18 items, including environmental protection goals, social responsibility reports, environmental reports, etc. The specific indicator system is shown in Table 1.

Table 1. Carbon information disclosure quality evaluation indicator system.

Primary Indicators	Secondary Indicators	Tertiary Indicators
Carbon reduction strategy and targets	Carbon reduction targets	Environmental protection goals
	Carbon reduction philosophy and strategy	Social responsibility report
		Environmental report
	Low-carbon policy response	Whether it follows the GRI Sustainability Reporting Standards
Carbon reduction actions and performance	Carbon reduction actions	Special environmental protection actions
		Compliance with pollutant emission standards
		Environmental violations or incidents
	Carbon reduction performance	Environmental protection investment
		Implementation of clean production
		Whether certified under ISO9001
		Whether certified under ISO14001

Table 1. Cont.

Primary Indicators	Secondary Indicators	Tertiary Indicators
Carbon reduction management and incentives	Carbon reduction management institutions	Environmental management system
		Environmental education and training
	Carbon reduction incentive mechanisms	Environmental honors or awards
Carbon emission accounting and trading	Carbon emission accounting methods	Annual report of listed companies
		Whether verified by a third party
		COD emissions
		CO ₂ emissions

Step 2: Identifying and Classifying Relevant Keywords Pertaining to “Carbon Information” from Annual Reports, Corporate Social Responsibility Reports, and Environmental Disclosures.

In this phase, relevant keywords associated with “carbon information” are extracted from annual reports, corporate social responsibility disclosures, and environmental reports. These keywords are subsequently categorized and evaluated. Content analysis is employed to assess the indicators across three dimensions: significance, timeliness, and quantifiability. The specific scoring criteria are as follows: (1) for the disclosure of carbon information quality in annual reports, social responsibility reports, and environmental reports, scores of 1, 2, and 3 are awarded respectively, based on the level of prominence in the disclosure; (2) for the temporal relevance of the information (whether it reflects current, past and present, or present and future data), scores of 1, 2, and 3 are assigned; and (3) for the nature of the information (qualitative analysis, quantitative analysis, or monetary information), scores of 1, 2, and 3 are given accordingly.

Step 3: Calculating Indicator Weights.

In the existing methods, the Analytic Hierarchy Process is considered too subjective. Therefore, this paper uses the entropy weight method to calculate the weights of the evaluation indicators, ultimately determining the total Cid score for each company in every year.

3.2.3. Mediating Variable

In existing research, the green innovation capability of enterprises is primarily measured through indicators such as the number of green patent grants, the number of green patent citations, and the number of green patent applications. Green patents refer to patents that involve innovations in areas such as environmental protection, energy conservation, emissions reduction, and sustainable development. By evaluating the number of green patents held by a company, one can assess the company’s investment and performance in environmental technology research and innovation. In this study, following the method of Weixuan Hu et al., the number of invention-based green patent applications is chosen as a representative indicator of green innovation. Additionally, the logarithmic transformation of patent numbers is applied to ensure the data follow a normal distribution, thus allowing for a more accurate assessment of the company’s green innovation capability [39].

3.2.4. Control Variables

Based on the existing literature on enterprise value, this study selects the following variables: debt-to-equity ratio (Lev), firm size (Size), proportion of independent directors (Indep), total asset turnover (ATO), board size (Board), and ownership concentration (Top1). The detailed descriptions of these variables are provided in Table 2 below.

Table 2. Variable definitions.

Variable Type	Variable Name	Variable Symbol	Variable Definition
Explained variable	Enterprise value	Tobin's Q	The sum of the market value of equity and the market value of net debt divided by the ending book value of total assets
Explanatory variable	Quality of carbon information disclosure	Cid	Construct carbon information evaluation index system
Intermediate variable	Green innovation	GTI	The natural logarithm is taken after the number of green patent applications plus one
Control variable	Asset–liability ratio	Lev	Total liabilities divided by total assets
	Company size	Size	The natural logarithm of the firm's total assets as of the year-end
	Turnover of total assets	ATO	Operating income divided by average total assets
	Proportion of independent directors	Indep	The proportion of independent directors among the total number of directors
	Board size	Board	The number of board members is taken as the natural logarithm
	Ownership concentration	Top1	The total number of shares held by the largest shareholder divided by the average number of shares

3.3. Model Design

Based on the above analysis, this paper constructs Regression Model (1) to verify that the quality of carbon information disclosure can enhance enterprise value. To test the mediating effect of green innovation, this paper refers to the mediating effect testing method proposed by Wen Zhonglin et al. [40], and constructs Models (2) and (3):

$$\text{Tobin's } Q_{i,t} = \alpha \sum_0 + \alpha_1 \text{Cid}_{i,t} + \alpha_j \sum_j \text{Controls}_{i,t} + \sum \text{Year} + \sum \text{Ind} + \varepsilon_{i,t} \quad (1)$$

$$\text{GTI}_{i,t} = \beta_0 + \beta_1 \text{Cid}_{i,t} + \beta_j \sum_j \text{Controls}_{i,t} + \sum \text{Year} + \sum \text{Ind} + \varepsilon_{i,t} \quad (2)$$

$$\text{Tobin's } Q_{i,t} = \gamma_0 + \gamma_1 \text{Cid}_{i,t} + \gamma_2 \text{GTI}_{i,t} + \gamma_j \sum_j \text{Controls}_{i,t} + \sum \text{Year} + \sum \text{Ind} + \varepsilon_{i,t} \quad (3)$$

In these models, i and t represent the enterprise and year; Tobin's $Q_{i,t}$ is the dependent variable, representing the enterprise value of firm i in year t ; $\text{Cid}_{i,t}$ is the independent variable, representing the quality of carbon information disclosure of firm i in year t ; $\text{GTI}_{i,t}$ is the mediating variable, representing the level of green innovation of firm i in year t ; $\sum_j \text{Controls}_{i,t}$ represents the control variables of firm i in year t ; $\sum \text{Industry}$ and $\sum \text{Year}$ represent the industry and year fixed effects, respectively; and ε represents the random error term.

3.4. Descriptive Statistics

As shown in Table 3, this paper conducted descriptive statistics on a sample of 6960 observations from Shanghai and Shenzhen listed companies between 2013 and 2021. Among the sample firms, the minimum value of Tobin's Q is 0.802, while the maximum value reaches 16.647, indicating significant differences in enterprise value across the sample. The maximum value of carbon information disclosure quality (Cid) is 0.972, the minimum value is only 0.061, and the mean value is 0.326. This suggests that most firms have incomplete carbon information disclosure, reflecting a relatively low emphasis on the quality of carbon disclosure. There is considerable variation in the carbon information disclosure quality among the sample firms, which may be related to the current non-mandatory carbon information disclosure system. Additionally, there is also substantial variation in the green innovation index (GTI) across the sample firms.

Table 3. Descriptive statistical results.

Variables	N	Mean	SD	Min	Max
Tobin's Q	6960	1.958	1.146	0.802	16.647
Cid	6960	0.326	0.154	0.061	0.972
GTI	6960	1.530	0.912	0.693	6.848
Size	6960	22.392	1.320	19.777	26.430
Lev	6960	0.426	0.188	0.046	0.924
Indep	6960	0.378	0.054	0.286	0.600
ATO	6960	0.636	0.353	0.062	2.891
Top1	6960	0.331	0.144	0.081	0.757
Board	6960	2.110	0.195	1.609	2.708

3.5. Correlation Analysis

This paper employs Pearson correlation analysis to assess the relationships among the variables to determine whether there are interconnections between them, while also mitigating the potential adverse effects of multicollinearity on the research results. The correlations between the variables are shown in Table 4. The quality of corporate carbon information disclosure is significantly positively correlated with enterprise value ($p < 0.01$), temporarily supporting H1. Additionally, the quality of corporate carbon information disclosure is significantly positively correlated with green innovation ($p < 0.01$). However, to obtain more reliable results regarding the impact of carbon information disclosure quality on enterprise value and green innovation, it is necessary to consider control variables and conduct regression analysis.

Table 4. Results of the correlation analysis.

Vars	Tobin's Q	Cid	GTI	Size	Lev	Indep	ATO	Top1	Board
Tobin's Q	1								
Cid	0.181 ***	1							
GTI	0.079 ***	0.150 ***	1						
Size	−0.279 ***	0.300 ***	0.325 ***	1					
Lev	−0.288 ***	0.186 ***	0.207 ***	0.529 ***	1				
Indep	0.017	−0.036 ***	0.033 ***	0.040 ***	0.001	1			
ATO	−0.028 **	0.058 ***	0.042 ***	0.157 ***	0.170 ***	−0.017	1		
Top1	−0.088 ***	0.075 ***	0.023 *	0.133 ***	0.037 ***	0.054 ***	0.121 ***	1	
Board	−0.105 ***	0.107 ***	0.051 ***	0.278 ***	0.153 ***	−0.530 ***	0.053 ***	−0.019	1

***, **, and * indicate significance at the 99%, 95%, and 90% confidence levels, respectively.

3.6. Regression Results Analysis

In column (1) of Table 5, the regression coefficient of carbon information disclosure quality (Cid) is 0.163, and this value is significant at the 1% level. This suggests that, after controlling for other variables, improving the quality of carbon information disclosure effectively promotes the growth of enterprise value, which is consistent with Hypothesis 1. Both firm size and total asset turnover pass the significance test and are significant at the 1% level. Additionally, the study finds a significant negative relationship between firm size (Size) and enterprise value, meaning that the larger the firm, the lower its value. According to the theory of economies of scale, firms have an optimal size. Once the firm exceeds this optimal size, larger firms may experience issues such as excessively large organizational structures and complicated decision-making processes, leading to reduced efficiency and ultimately lowering their enterprise value.

Columns (2) and (3) of Table 5 display the regression results for Models (2) and (3), respectively. In Model (2), the regression coefficient of corporate carbon information disclosure quality (Cid) is $\beta_1 = 0.068$, and this result is significant at the 5% level. This indicates that the quality of carbon information disclosure can effectively enhance the firm's green innovation capability. In Model (3), the coefficient of carbon information disclosure quality (Cid) is $\gamma_1 = 0.151$, and the coefficient of green innovation (GTI) is $\gamma_2 = 0.035$,

with the former being significant at the 1% level and the latter significant at the 5% level. Additionally, in this model, both the α_1 coefficient and the interaction term $\beta_1 \times \gamma_2$ are positive, which provides evidence that green innovation plays a partial mediating role between carbon information disclosure quality and enterprise value, thus supporting Hypothesis 2 (H2). As discussed in the theoretical analysis earlier, carbon information disclosure can promote green innovation by improving organizational legitimacy, reducing information asymmetry, and maintaining corporate reputation, which in turn helps to reduce pollution emissions, lower regulatory costs, enhance firm performance, and increase enterprise value, ultimately contributing to sustainable corporate development.

Table 5. Regression results.

	(1)	(2)	(3)
Vars	Tobin's Q	GTI	Tobin's Q
Cid	0.163 *** (3.774)	0.068 ** (2.014)	0.151 *** (3.683)
GTI			0.035 ** (1.982)
Size	−0.111 *** (−2.898)	0.171 *** (5.741)	−0.117 *** (−3.046)
Lev	−0.028 (−0.195)	−0.081 (−0.738)	−0.025 (−0.174)
Indep	0.721 * (1.781)	0.021 (0.067)	0.721 * (1.779)
ATO	0.495 *** (7.117)	0.044 (0.810)	0.493 *** (7.096)
Top1	−0.344 (−1.310)	0.356 * (1.748)	−0.356 (−1.358)
Board	0.065 (0.472)	−0.216 ** (−2.015)	0.073 (0.527)
_cons	4.183 *** (3.474)	−2.000 ** (−2.138)	4.254 *** (3.532)
Year	Yes	Yes	Yes
Ind	Yes	Yes	Yes
Observations	6960	6960	6960
R-squared	0.203	0.142	0.201

Note: Values in parentheses represent T-values; ***, **, and * indicate significance at the 99%, 95%, and 90% confidence levels, respectively.

3.7. Robustness Check

3.7.1. Replacement of the Dependent Variable

To ensure that the research results are not constrained by the measurement of the dependent variable, this paper performs a robustness check using a variable replacement method to validate the reliability of the results. Specifically, the study uses Return on Assets (ROA) as an alternative indicator to measure firm value. Compared to the traditional Tobin's Q indicator, ROA focuses more on a firm's profitability derived from its actual operating activities using its assets. It is calculated as net profit divided by the average total assets, offering a more direct reflection of a firm's efficiency in resource allocation and management. The robustness test results, shown in Column (1) of Table 5, indicate that the regression coefficient of carbon information disclosure quality (Cid) is significantly positive and significant at the 5% level, suggesting that higher-quality carbon information disclosure can significantly enhance a firm's financial performance and profitability.

3.7.2. Instrumental Variable Method

This study also addresses the potential endogeneity issue in the model, which typically arises from the correlation between the explanatory variables and the error term. This correlation could lead to bias in the regression analysis results, thereby affecting the robustness of the conclusions. To address this, the study uses the average carbon information disclosure

quality of firms in the same industry and the same year (IMCid) as an instrumental variable to ensure the reliability of the results. The results are shown in Columns (2) and (3) of Table 6. In the first stage, the F-statistic is 82.84, which is well above the threshold of 10, thus ruling out the hypothesis of “weak instruments” and confirming that the selected instrumental variable is appropriate. The first-stage test results using the instrumental variable method are shown in Column (2), with an estimated coefficient of 0.768, which is significant at the 1% level. Column (3) presents the second-stage results of the instrumental variable method, which indicate that the positive impact of carbon information disclosure quality on firm value remains significant, further validating the conclusions of this study.

Table 6. The robustness test.

	(1)	(2)	(3)	(4)
	ROA	Cid	Tobin's Q	Tobin's Q
Cid	0.005 ** (2.259)		0.051 *** (3.111)	
IMCid		0.768 *** (6.456)		
L.Cid				0.126 ** (2.170)
Size	0.023 *** (11.017)	0.075 *** (18.187)	−0.138 *** (−3.816)	−0.016 (−0.268)
Lev	−0.195 *** (−25.251)	0.129 *** (4.672)	−1.090 *** (−10.815)	0.035 (0.173)
Indep	0.000 (1.057)	−0.002 ** (−2.166)	0.003 (1.014)	0.004 (0.718)
ATO	0.126 *** (33.264)	0.013 (0.993)	0.120 *** (3.150)	0.641 *** (6.551)
Top1	0.063 *** (4.385)	0.127 *** (4.210)	−0.342 *** (−3.219)	−0.656 * (−1.778)
Board	−0.007 (−0.980)	0.093 *** (3.414)	−0.156 * (−1.702)	0.100 (0.547)
_cons	−0.288 *** (−4.385)	−1.799 *** (−14.754)	5.692 *** (6.848)	2.131 (1.530)
Year	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes
N	6960	6960	6960	3677
r2	0.327	0.434	0.211	0.234

Note: Values in parentheses represent T-values. ***, **, and * indicate significance at the 99%, 95%, and 90% confidence levels, respectively.

3.7.3. Lagged One Period

In the baseline regression model, this study initially examined the effect of carbon information disclosure quality and conducted robustness tests using variable substitution and the instrumental variable method. The results suggest that carbon information disclosure quality promotes the improvement of firm value, which contributes to the sustainable development of enterprises. In practice, firms with higher value are often more proactive in disclosing carbon information, thereby improving the quality of carbon information disclosure. As a result, there may be a causal relationship in the empirical analysis of how carbon information disclosure quality enhances firm value. To address this potential endogeneity issue, this study adopts the method of lagging the explanatory variable by one period. The regression results are presented in Column (4) of Table 6. It can be observed that the lagged explanatory variable has a regression coefficient of 0.126, which is significant at the 5% level, indicating that carbon information disclosure quality can indeed improve firm value.

4. Further Analysis

4.1. Impact of Corporate Pollution Type

Enterprises in different industries use different resources, energy structures, and supply chain configurations in their production processes, which results in variations in their carbon emissions. For example, energy-intensive industries such as the chemical industry typically have higher carbon emissions, while industries like services and information technology tend to have relatively lower emissions. These differences may lead to variations in the level of attention that firms pay to carbon information disclosure, as well as differences in the quality and extent of the disclosure. Additionally, the regulatory requirements for environmental protection and carbon reduction, as well as the level of societal attention, differ across industries. Some industries may face greater environmental pressures and stricter regulations, leading to a stronger emphasis on carbon information disclosure. Moreover, the attention of stakeholders and investors to carbon emission levels and environmental performance may also influence the level of carbon information disclosure by firms.

Considering various factors, this paper divides the sample firms into high-pollution industries and non-high-pollution industries. Regressions were performed separately for each group, and the results are presented in columns (1) and (2) of Table 7. It was found that in the non-high-pollution industries, the coefficient for carbon information disclosure quality (Cid) is 0.189 and is significant at the 1% level. However, in the high-polluting industries, the effect of carbon information disclosure quality on firm value is not significant. This may be because high-polluting industries are inherently high in emissions and energy consumption, and improving the quality of carbon information disclosure often requires additional resources such as capital and technology, which could divert resources from other business activities and negatively affect firm value. Additionally, stakeholders generally believe that high-polluting industries should make more efforts in carbon reduction. When the quality of carbon information disclosure is similar, non-high-pollution industries are more likely to gain favor from stakeholders.

Table 7. The heterogeneity test.

	(1) Non-Heavy Pollution	(2) Heavy Pollution	(3) State-Owned	(4) Non-State- Owned	(5) Eastern Region	(6) Central Region	(7) Western Region
Vars	Tobin's Q	Tobin's Q	Tobin's Q	Tobin's Q	Tobin's Q	Tobin's Q	Tobin's Q
Cid	0.189 *** (3.402)	0.059 (0.889)	0.133 (1.190)	0.156 *** (3.313)	0.209 *** (4.137)	−0.068 (−0.623)	0.006 (0.042)
Size	0.002 (0.046)	−0.329 *** (−5.350)	−0.268 *** (−2.898)	−0.054 (−1.240)	−0.034 (−0.726)	−0.214 ** (−2.476)	−0.364 *** (−3.255)
Lev	0.138 (0.744)	−0.456 ** (−2.056)	−0.173 (−0.519)	0.082 (0.509)	0.015 (0.092)	−0.422 (−1.203)	0.585 (1.369)
Indep	0.004 (0.712)	0.013 ** (2.458)	0.023 *** (2.823)	−0.000 (−0.007)	0.003 (0.512)	0.024 ** (2.509)	0.012 (1.092)
ATO	0.649 *** (6.805)	0.219 ** (2.230)	0.264 ** (2.091)	0.518 *** (5.958)	0.486 *** (5.944)	0.314 * (1.807)	0.805 *** (3.472)
Top1	0.326 (0.798)	−0.576 * (−1.733)	−0.838 * (−1.719)	−0.009 (−0.027)	−0.216 (−0.631)	−0.524 (−0.971)	0.012 (0.017)
Board	−0.081 (−0.452)	0.341 * (1.659)	0.485 * (1.769)	−0.124 (−0.785)	0.071 (0.420)	−0.095 (−0.323)	0.347 (0.841)
_cons	2.140 (1.267)	8.378 *** (4.856)	5.839 ** (2.449)	3.873 ** (2.440)	2.589 * (1.811)	5.604 *** (2.618)	6.254 ** (2.281)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4710	2250	1390	5570	5161	1116	683
r2	0.231	0.186	0.149	0.223	0.220	0.225	0.185

Note: Values in parentheses represent T-values. ***, **, and * indicate significance at the 99%, 95%, and 90% confidence levels, respectively.

4.2. Impact of Ownership Structure

Existing research has demonstrated that under the current market economy system, state-owned enterprises (SOEs) are directly managed and guided by the government, which provides them with more stable sources of funding and policy support. In contrast, non-state-owned enterprises (non-SOEs) operate with greater freedom and are more heavily influenced by market competition. This disparity may lead to SOEs having an advantage in terms of policy compliance and execution in implementing carbon information disclosure. Furthermore, SOEs typically bear more social responsibility and are guided by government priorities, with their business objectives extending beyond economic profit to include contributing to national development strategies and promoting regional economic growth. Non-SOEs, on the other hand, tend to focus more on market share and profitability in their business goals. This could result in SOEs placing more emphasis on corporate social responsibility in carbon information disclosure, while non-SOEs are more focused on economic benefits.

To further analyze whether the effect of carbon information disclosure quality on enterprise value differs between different ownership structures, this paper divides the sample companies into two categories, state-owned and non-state-owned enterprises, and conducts separate regression analyses. The results are presented in columns (3) and (4) of Table 7. The findings show that the coefficient of carbon information disclosure quality (Cid) is 0.133 for the SOEs and 0.156 for the non-SOEs, with both coefficients having a positive impact on firm value. However, the coefficient for the non-SOEs is statistically significant at the 1% level, while that for the SOEs is not significant. This may be because the purposes of carbon information disclosure differ between the two types of enterprises. SOEs are more likely to disclose carbon information in response to national policy calls, playing a role as a model for state enterprises. In contrast, non-SOEs are more motivated by economic goals, actively fulfilling social responsibilities to build a positive corporate image, obtain government subsidies, attract investment, and ultimately enhance firm value.

4.3. Regional Influence

China is a vast country with significant economic disparities across its regions. These differences are the result of a combination of historical, geographical, and resource factors. In order to promote economic development and optimize resource allocation, the State Council has divided China into three major economic zones—Eastern, Central, and Western regions—based on factors such as regional economic development, economic resources, and natural environments. The Eastern Economic Zone is located along China's coastal areas, boasting developed economic infrastructure and abundant human resources. The Central Economic Zone is situated in the central and western parts of China, with vast land resources, abundant water resources, and lower labor costs. The Western Economic Zone encompasses the northwestern and southwestern regions of China, characterized by complex terrain and rich natural resources.

Considering this, this study divides the sample firms into three groups based on their geographical locations—Eastern, Central, and Western regions—and performs regression analysis for each group. The results are shown in columns (5), (6), and (7) of Table 7. The findings indicate that the correlation coefficient for carbon information disclosure quality in the Eastern region is 0.209, which is statistically significant at the 1% level, while the results for the Central and Western regions are not significant. This may be due to the higher level of marketization and developed economic environment in the Eastern region. Firms in the Eastern region typically face higher market competition and regulatory pressure, which incentivizes them to ensure greater transparency regarding environmental issues and corporate social responsibility. Additionally, government and regulatory agencies in the

Eastern region may enforce stricter market oversight, further encouraging firms to disclose carbon information proactively. Moreover, since investors tend to use various types of information to make investment decisions, firms with higher-quality carbon information disclosure in the Eastern region are more likely to receive a positive market response. In the Eastern region, where the marketization level is higher and investors are more focused on environmental and sustainability issues, firms that perform well in environmental information disclosure are generally more favored by investors.

5. Discussion

In the context of fostering harmonious development among enterprises, nature, society, and humanity, coupled with the growing consensus on ecological civilization and the principles of green, sustainable development, an increasing number of stakeholders are placing greater emphasis on corporate carbon disclosure. This study draws on data from companies listed on the Shanghai and Shenzhen stock exchanges between 2013 and 2021 to investigate the relationship between the quality of carbon information disclosure and enterprise value, while also examining the mediating role of green innovation. The empirical findings reveal that high-quality carbon information disclosure significantly enhances enterprise value, with green innovation serving as a partial mediator in this relationship. Further analysis highlights that the positive impact of carbon information disclosure on enterprise value is particularly pronounced in non-high-polluting industries, non-state-owned enterprises, and companies located in eastern regions, aligning with the results of most existing studies [7].

However, some scholars argue that corporate carbon disclosure may increase unnecessary costs and have a detrimental effect on enterprise value [8]. The divergence in research findings could be attributed to industry differences. High-pollution industries typically have higher carbon emissions, and these companies may face significant pressure in carbon emission management. While disclosing carbon information can help demonstrate a company's efforts in environmental governance, it may also reveal deficiencies in areas such as emission reduction technologies or pollution control facilities. This, in turn, could attract negative attention from external regulatory bodies and the public, potentially leading to adverse effects on enterprise value in the short term.

In addition, some scholars suggest that the relationship between the quality of carbon information disclosure and enterprise value may be U-shaped [9]. Specifically, in the early stages of carbon disclosure, companies may need to invest substantial financial resources to disclose environmental governance-related information. These investments could consume corporate funds and potentially have an adverse impact on short-term financial performance and value. However, over time, stakeholders gradually form perceptions and evaluations of a company's carbon information disclosure quality. By providing transparent carbon disclosures, firms can enhance their market reputation and social image, thereby driving the growth of enterprise value. Therefore, the effects of carbon disclosure may exhibit a lag, where the initial investments and disclosure costs take time to translate into market returns. From the broader perspective of corporate development, actively adopting low-carbon environmental principles and improving the quality of carbon information disclosure contributes to the long-term sustainable development of the company.

This study also has some limitations. In the heterogeneity analysis, we only considered differences in ownership structure, industry, and region, without exploring the underlying core factors behind these differences, such as the impact of environmental regulations. Additionally, the relationship between carbon information disclosure quality and enterprise value may be influenced by other pathways. In future research, we will

focus on addressing these limitations and further explore the relationship between carbon information disclosure quality and enterprise value.

6. Conclusions

This study investigates the quality of carbon information disclosure among Chinese listed companies in recent years, exploring its relationship with enterprise value and the mediating role of green innovation. The findings indicate that high-quality carbon information disclosure significantly enhances enterprise value, with green innovation serving as a partial mediator in this process. Further analysis reveals that the positive impact of carbon information disclosure on enterprise value is more pronounced in firms from non-high-pollution industries, non-state-owned enterprises, and those located in the Eastern region. Building on these results, the study offers recommendations for optimizing future carbon information disclosure policies, fostering corporate innovation, and supporting China's low-carbon economic transformation.

- (1) Carbon information disclosure policies should be continuously optimized and improved. Currently, China's carbon information disclosure policies lack mandatory disclosure items and heavily rely on voluntary disclosure, which has led to insufficient motivation among companies to fully disclose carbon information. Therefore, in the context of carbon peak and carbon neutrality, China should introduce more mandatory disclosure requirements for carbon information, alongside appropriate incentive measures to encourage companies to actively disclose carbon information. Additionally, penalties should be imposed on companies that fail to disclose carbon information effectively. This will help increase corporate enthusiasm for carbon information disclosure.
- (2) The government should encourage green investment and innovation through subsidies and other preferential policies, to fully leverage the direct and indirect effects of carbon information disclosure quality on enterprise value. Simultaneously, the government and media should intensify efforts to raise public and investor awareness of corporate low-carbon environmental practices, ensuring that companies with positive carbon information disclosure performance receive favorable responses and greater returns in the capital markets.
- (3) The regulation of carbon information disclosure in high-pollution industries should be strengthened. High-pollution industries are inherently characterized by high emissions and energy consumption, and improving carbon information disclosure often requires more investment in funds, technologies, and other resources, which may compete with other operational needs. This leads to low willingness to disclose carbon information. Therefore, it is essential to improve relevant systems and promote the formation of unified carbon information disclosure standards for high-pollution industries. Furthermore, stronger oversight of high-pollution enterprises is necessary to ensure that they actively disclose carbon information.
- (4) State-owned enterprises should prioritize carbon information disclosure from an economic value perspective. State-owned enterprises should disclose carbon information not only to respond to national policy calls but also to enhance their enterprise value. Managers should prioritize low-carbon environmental issues, set clear strategic goals for carbon information disclosure, optimize efficient carbon management systems, accurately disclose carbon information, and increase green innovation and competitiveness, thereby enhancing enterprise value and achieving sustainable development.

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