

A study on the impact of corporate low carbon awareness on the quality of carbon information disclosure--Based on the mediating effects of green technology innovation

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Abstract. In the context of carbon peaking and carbon neutrality, it is of practical significance for heavily polluting enterprises to achieve low-carbon transformation. This paper uses 225 Chinese heavy polluting enterprises listed in Shanghai and Shenzhen A-shares from 2015-2019 as a research sample, and uses multiple regression models and mediating effect models to analyze the impact of corporate low-carbon awareness on the quality of carbon information disclosure and to explore the mediating role of green technological innovation. The study found that the quality of carbon information disclosure was higher and the level of green technology innovation was stronger when the companies had stronger low-carbon awareness. The study further found that green technology innovation plays a positive mediating role in the positive relationship between low carbon awareness and carbon information disclosure quality.

Keywords: heavy polluters, low carbon awareness, carbon information disclosure, green technology innovation

1. Introduction

Excessive carbon emissions can lead to global warming, the greenhouse effect and other environmental problems, while global economic development has also suffered a certain degree of stagnation. the "National Carbon Emissions Trading Market Construction Plan" issued in December 2017 marked the official launch of the national carbon emissions trading system, playing a huge role in promoting the construction of a national low-carbon economic system. As a micro-economic entity of, enterprises are an important source of energy consumption and greenhouse gas emissions, and are one of the main actors in solving the current serious environmental problems. Therefore, it is crucial for heavy polluters to make objective and fair disclosure of carbon information (Li Li et al., 2019). In the context of the Chinese government's active response to global climate issues, more and more enterprises' awareness of low-carbon emission reduction has been raised and their carbon reduction behaviours have gradually improved. However, there is still a large gap between the overall awareness and behaviour of enterprises, and there are still inconsistencies between awareness and behaviour (Wang and Wang, 2011). Therefore, it is important to study the impact of heavy polluters' low carbon awareness on carbon information disclosure. The main contributions of this paper are as follows: firstly, the exploration of carbon accounting information disclosure studies at home and abroad are in progress, this paper designs a scale to measure the low carbon awareness and carbon information disclosure of enterprises, which reasonably and accurately measures these two variables and provides a certain theoretical basis for subsequent studies ; secondly, explores the correlation between the low carbon awareness of enterprises and the quality of carbon information disclosure, and provides more sufficient empirical evidence for the study of the influencing factors of carbon information disclosure quality Third, this paper introduces green technology innovation as a mediating variable to study its mediating effect between corporate low carbon awareness and carbon information disclosure.

2. Literature Review

2.1. Low carbon awareness related research

In terms of the relationship between low carbon awareness and carbon disclosure, Qi Xiaoyan (2012) concluded that the importance of environmental protection by company management and the establishment of an environmental protection department were positively related to the level of carbon disclosure by the company. Pan An E and Guo Qiusi (2018) concluded that the stronger the environmental awareness of executives, the higher the level of corporate environmental information disclosure²² Dan E & Shen J (2022) used A-share listed companies from 2009-2017 as a research sample and used voluntary disclosure theory, stakeholder theory and legitimacy theory to construct a research framework and found that leaders' low carbon awareness has a facilitating effect on voluntary corporate carbon information disclosure³⁶.

In addition, studies by many scholars have shown that low carbon awareness has a facilitating effect on low carbon behaviour. For example, Yang D-N and Zhou C-H (2005) found that the more proactive the environmental strategy orientation of corporate management, the more likely it is that companies will voluntarily adopt a standardised environmental management system. An empirical study based on panel data concludes that low carbon awareness has a facilitating effect on firms' soft low carbon behaviour. yang L et al. (2021) conducted a study based on data from Chinese A-share listed companies in the heavy pollution industry and concluded that strengthening environmental management can improve managers' environmental awareness and reduce information asymmetry, thereby regulating the use of idle resources and thus increasing the scale of firms' environmental investments.

At the same time, low-carbon awareness has a contributory effect on corporate performance. For example, Ngo T & Tian Q (2020) used content analysis to quantify social responsibility awareness and examined CSR awareness and its impact on airport performance at major airports in China over the period 2013-2017, and found that increased CSR awareness could improve airport performance. Luo L & Tang Q (2021) argued that companies with a higher awareness of carbon risk awareness of carbon risks can ensure that their resources are properly coordinated and deployed to achieve the desired carbon performance outcomes. Liu J & Wu Y (2022) found that the formalisation of corporate environmental regulations, the level of integration of employee regulations, leadership attention and support, and employee awareness of pollution control and pollution prevention had a significant positive impact on environmental performance.

2.2. Carbon Disclosure Related Research

Carbon information disclosure is the activity of enterprises to disclose their environmental strategies, carbon emission data and emission reduction plans and other related information to the public by specific channels (Jia, Yuhong, 2021). For the related research on carbon information disclosure, the current academic method for evaluating the quality of carbon information disclosure is based on content analysis method, such as Li Huiyun et al. (2016) established carbon information disclosure evaluation index system based on five first-level indicators of timeliness, reliability, comprehensibility, comparability and completeness, and some scholars also adopted index method, such as Wu Xun and Xu Xinge (2015) designed carbon information disclosure quality from three dimensions to design carbon information disclosure quality levels and indicators, forming a carbon information disclosure quality index. Some other scholars use the CDP questionnaire as the basis to evaluate the quality of corporate carbon information disclosure, such as Li Dayuan et al. (2016) use whether they respond to the CDP survey as a measure of the level of corporate carbon information disclosure.

For example, Chen et al. (2013) found that company size, financial risk, and the proportion of fixed assets were significantly and positively related to voluntary carbon disclosure, while sales growth rate and years of listing were significantly and negatively related to voluntary carbon disclosure based on legitimacy theory. Cui Yeguang and Ma Xian (2014) found that company growth

significantly negatively influenced the level of carbon information disclosure, while industry nature and overseas listing significantly positively influenced the level of carbon information disclosure. Wu Xun and Xu Xinge (2014) concluded that firms with a higher percentage of controlling shareholders' shareholding and a larger board of directors were more inclined to disclose carbon information voluntarily. Zhu Heping and Chen Ying (2018) constructed a multiple linear regression model and found that company size and adoption of ISO14000 environmental information monitoring significantly and positively influenced the level of carbon information disclosure, while the nature of industry, financial leverage and the proportion of independent directors significantly and negatively influenced the level of carbon information disclosure. Some scholars have also explored the influence of carbon information disclosure from the perspective of external pressure. For example, Tang Y et al. (2020) found that the higher the regulatory pressure from local governments and the higher the social pressure, the higher the quality of carbon information disclosure, based on a study of Chinese A-share listed companies in 2014. Chen Y et al. (2021) constructed an OLS model to study listed companies in the pharmaceutical industry, and the results showed that the higher the level of economic development and the stricter the government regulation, the higher the level of carbon information disclosure.

2.3. Green Technology Innovation

The implementation of green technology innovation is an important initiative for companies to carry out carbon reduction activities. Green technology is a general term for technologies, patents or products that reduce environmental pollution and reduce the use of raw materials and energy (Chen, Xiaobei and Chen, Xue-ting, 2021). sarkis et al. (2010) found that executives' environmental attitudes were an important influencing factor on the implementation of green innovation in companies. Li Qiaohua et al. (2015) concluded that managers' concern for the environment was the most important driver for firms to adopt green practices and had a significant positive impact on both green product innovation and green process innovation. Bian Mingying et al. (2021) empirically found that managers with strong environmental values were more likely to promote the development of environmental strategies and the implementation of green innovations. The green culture of a company has a guiding and motivating effect and is conducive to green technology innovation in environmental companies, whereas a traditional conservative corporate culture that ignores environmental benefits can act as a barrier to green technology innovation (Lei Shanyu et al., 2014). Managers who are more environmentally conscious will respond proactively to environmental issues. The more environmentally conscious executives are, the more responsible they are to carry out green innovation and the more willing they are to invest corporate resources in green innovation (Cao, Hongjun and Chen, Zewen, 2017). Managers will devote more resources to environmental protection only when they perceive environmental issues as an opportunity for the company (and Su Chao et al., 2016).

In summary, existing studies have focused on the internal influencing factors of carbon information disclosure mainly confined to the objective characteristics of enterprises and corporate governance factors, while less research has been conducted on the influence mechanism of enterprises' low carbon awareness and willingness to disclose on carbon information disclosure. In addition, although the existing literature provides a richer analysis and reference for studying the relationship between low carbon awareness, green technology innovation and carbon information disclosure quality, the relationship between low carbon awareness, green technology innovation and carbon information disclosure is still lacking sufficient research, and it is not difficult to find that the previous studies by scholars are mostly based on the two-two relationship between the three, and the literature that puts the three in one framework for research There is less literature that puts the three in one framework. Therefore, this study uses green technology innovation as a mediating variable to explore the influence mechanism of corporate low carbon awareness on the quality of carbon information disclosure, in an attempt to enrich the existing literature and provide a certain theoretical basis for subsequent research.

3. Theoretical analysis and research hypothesis

3.1. Low carbon awareness and the quality of carbon information disclosure

According to the Theory of Planned Behaviour, there is a significant positive effect of firms' attitudes on their willingness to act, such that firms with higher low-carbon awareness will be more inclined to disclose relevant carbon information to the public. For example, Lin Yinghui et al. (2016) concluded that firms' attitudes towards carbon information disclosure have a positive contribution to their willingness to disclose carbon information. dan E & Shen J (2022) found that for companies in low carbon industries, leaders' low carbon awareness has a positive impact on voluntary carbon information disclosure. At the same time, a stronger awareness of low carbon will motivate companies to invest more resources in environmental protection. According to signaling theory and stakeholder theory, companies are more inclined to actively disclose carbon information at this time, actively showing the public and other stakeholders the efforts and achievements made by the company towards low carbon environmental protection, thus improving the relationship between the company and various stakeholders, reducing information asymmetry, and communicating to the public. This will improve the relationship between the company and its stakeholders, reduce information asymmetry, and convey to the public the company's positive image of responding to the government's call and practising low-carbon environmental protection (Wang, Juncai and Niu, 2013). Based on this, this paper proposes the following hypothesis1.

H1: Controlling for other factors, there is a positive effect of corporate low carbon awareness on the quality of carbon information disclosure.

3.2. Low carbon awareness and green technology innovation

Based on the "attitude-context-behaviour" theory, a strong low-carbon awareness will promote rigid low-carbon behaviour in enterprises (Zhou et al., 2019), thus enhancing the level of green technology innovation in enterprises. Moreover, given that corporate attitudes are often measured by the attitudes of top managers in empirical studies (Lin Yinghui et al., 2016), corporate low-carbon awareness can be reflected as the environmental awareness of executives. According to higher order theory, the strategic choices of corporate executives are an important factor influencing organisational behaviour and organisational performance, so the green values of top managers have an important role in influencing corporate green innovation behaviour (Liyun Xing and Huixin Yu, 2018). The stronger the responsible environmental awareness of executives, the more importance they attach to social and environmental responsibility, and thus the more inclined they are to proactively incorporate green innovation into their corporate development strategies (Zhang et al, 2015). Executive responsible environmental awareness has a significant positive impact on both green product innovation and green process innovation (Chen, Zewen and Chen, Dan, 2019). Based on this, this paper proposes the following hypothesis 2.

H2: Controlling for other factors, there is a positive impact of corporate low carbon awareness on green technology innovation

3.3. Low carbon awareness, green technology innovation and the quality of carbon information disclosure

Based on the above analysis, low carbon awareness has a facilitating effect on corporate green technology innovation, and green technology innovation helps to improve corporate carbon performance, which in turn enhances confidence in corporate carbon disclosure and improves the quality of corporate carbon information disclosure. Li D et al. (2018) concluded that green innovation not only helps companies to improve their financial performance, but also helps companies to improve their environmental performance, both of which enhance confidence in carbon disclosure, thus improving the quality of corporate carbon information disclosure, thus corporate green product innovation and green process innovation are positively related to carbon disclosure. Zhou Zhifang et al. (2019) found that firms' low-carbon innovation behaviour has a positive contribution to their

carbon performance, and based on Li Li and Liu Quanqi's (2019) findings, firms with good carbon performance are more motivated to provide fuller and more detailed carbon information disclosure to stakeholders to safeguard their own interests, in order to prevent adverse selection by corporate stakeholders. Based on this, this paper proposes the following hypothesis 3.

H3: Controlling for other factors, green technology innovation plays a positive mediating role in the positive relationship between low carbon awareness and the quality of carbon information disclosure.

4. Study design

4.1. Sample selection and data sources

Due to the state's emphasis on the issue of low carbon emission reduction by heavily polluting enterprises, as well as the fact that heavily polluting enterprises are the main source of environmental pollution and have greater social responsibility (Li Li, 2015), the samples in this paper are all derived from the heavily polluting industries. The industry classification is based on the Guidelines for Environmental Information Disclosure of Listed Companies and the Management List of Environmental Verification Industry Classification of Listed Companies (Letter from the Ministry of Environmental Protection [2008] No. 373) published by the Ministry of Environmental Protection in 2010. In this paper, 225 heavily polluting enterprises among A-share listed companies in Shanghai and Shenzhen, China from 2015-2019 were selected as the study sample and the following samples were excluded: (1) ST and ST* enterprises were excluded; (2) real estate and financial enterprises were excluded; and (3) obviously erroneous and seriously missing data were excluded. In order to eliminate the influence of extreme values on the results, this paper Winsorize the data at 1% and 99% to reduce the tail at the end.

4.2. Variable definitions

Explained variables

The quality of corporate carbon information disclosure (CDI). The main methods of measuring information disclosure quality are content analysis, institutional rating method, reputation rating method and index method (Huang, Bingyi et al., 2022), but most scholars use content analysis method, this paper draws on Li Xiuyu and Shi Yaya (2016), from the perspective of stakeholders, divided into government regulators, corporate management, corporate investors and creditors, law firms, accounting firms The five dimensions are government regulators, corporate management, corporate investors and creditors, law firms, accounting firms, and other intermediaries, and the public, and six qualitative indicators are designed to objectively describe the quality of carbon information disclosure, and the specific measurement scale is shown in Table 1 below.

Table 1. Corporate Carbon Disclosure Quality Measure Scale

Carbon Emissions Information Stakeholders	Objective description of carbon information	Score
Government regulators	Whether the enterprise's project or product complies with international emission standards	0,1
	Whether the enterprise's project or product complies with the emission standards set by the relevant authorities in China	0,1
Corporate Management	Does the enterprise carry out environmental education and public education and external environmental protection and low carbon activities	0,1
Corporate investors and creditors	Whether the enterprise discloses the amount of capital investment made to achieve energy saving and emission reduction	0,1
Law firms, accounting firms and other intermediary services	Whether the enterprise discloses the number of energy saving and emission reduction projects or technologies	0,1
Public	Whether to disclose carbon emissions or carbon emission reductions	0,1

This is done by scoring the low carbon information disclosed in the company's annual report, social responsibility report and sustainability report, with the criteria in the scale being assigned a value of 1 and 0 otherwise, with a maximum score of 6. The total score is then standardised, i.e. the actual score is divided by the highest score in the sample period to obtain the Carbon Disclosure Index (CDI Index). The index is calculated using the following formula.

$$CDI = \frac{\text{Score of } CDQ_t}{\text{Highest Score of } CDQ \text{ in } 2015-2019} \quad (1)$$

In the statistics, to avoid the subjectivity of manual scoring, five researchers were selected to evaluate the sample carbon information in this study, and the large differences among them were discussed and adjusted to finally calculate the corporate carbon information disclosure index.

Explanatory variables

Corporate low carbon awareness (Aware). This paper draws on the scale measures of Zhou Zhifang et al. (2019) and Jiang Haitao et al. (2017) for low carbon awareness. We consider low-carbon awareness as a reflection of low-carbon publicity and practice advocacy in enterprises at no extra cost. Therefore, this study considers the following four indicators to measure the low carbon awareness of enterprises: whether they publish CSR reports, sustainability reports, annual reports on environmental impact, whether they have a written low carbon management charter, rules and other systematic measures to know the low carbon management work, whether they integrate the concept of low carbon, environmental protection, energy saving and emission reduction into the corporate culture and company mission, and whether they have the awareness of low carbon technological innovation and environmental protection transformation. The specific scale is shown in Table 2. The scale was scored according to the information related to low carbon awareness disclosed in the annual report and social responsibility report, etc. If the criteria were met, it was recorded as 1, otherwise it was 0. The total score was 4. The summary results were standardized according to the standardization method of deviation, and the data were effectively mapped to [0, 1] interval, the specific formula is as follows, and finally get the enterprise low carbon awareness scoring data.

$$\text{Aware} = \frac{\text{Aware}_t - \text{Aware}_{\min}}{\text{Aware}_{\max} - \text{Aware}_{\min}} \quad (2)$$

Table 2. Low carbon awareness measurement scale

Measurement items	Score	Score Description
Whether to publish CSR reports, sustainability reports, annual reports on environmental impact	0,1	One point for publishing either a social responsibility report or a sustainability report or an annual report on environmental impact, otherwise zero points.
Is there a written low carbon management charter, rules and other systematic measures to guide low carbon management	0,1	1 point for low carbon related statutes and rules that are written and published, otherwise 0 points.
Whether the concept of low carbon, environmental protection, energy saving and emission reduction is integrated into the corporate culture and company mission	0,1	1 mark for key words such as low carbon, energy saving and environmental protection in the corporate culture and mission, otherwise 0 marks.
Awareness of low carbon technology innovation or environmental transformation	0,1	1 point for specific low carbon research inputs and results, otherwise 0 points.

Intermediate variables

Green technology innovation (PA_GR). This paper draws on Xia Wenlei et al. (2020) to measure the level of green technology innovation of a company by the number of green patents filed by the company.

Control variables

Based on existing relevant studies, the following control variables are selected in this paper, including firm age (Age), gearing ratio (Lev), profitability level (Roa), operating cash flow (CFO),

board size (Board), and top 10 shareholders' shareholding ratio (Top10). The specific variables are defined as shown in Table 3.

Table 3. Variable definitions

Variable type	Variable name	Symbols	Variable definitions
Explained variables	Quality of corporate carbon disclosure	CDI	The Carbon Disclosure Index, which is $CDI = \frac{\text{Score of } CDQ_t}{\text{Highest Score of } CDQ \text{ in } 2015 - 2019}$
Explanatory variables	Corporate Low Carbon Awareness	Aware	Calculated from the Low Carbon Awareness Scale, i.e. $Aware = \frac{Aware_t - Aware_{min}}{Aware_{max} - Aware_{min}}$
Intermediate variables	Green Technology Innovation	PA_GR	Ln (number of green patents filed by companies) + 1
Control variables	Age of business	Age	The natural logarithm of the year in which the sample was taken minus the year of registration plus one
	Gearing ratio	Lev	Total assets/total liabilities*100%
	Profit Level	Roa	Ratio of net profit to total assets at the end of the year
	Operating cash flow	CFO	Operating cash flow/total assets
	Board size	Board	Natural logarithm of the number of board members
	Shareholding of top ten shareholders	Top10	Number of shares held by top ten shareholders/total number of shares

4.3. Research model

Multiple regression models

To test the hypothesis of this paper, the following multiple regression model was developed.

$$CDI = \alpha_0 + \alpha_1 Aware + \gamma Control + Ind + Year + \varepsilon \quad (3)$$

In this model, CDI denotes the quality of corporate carbon disclosure, Aware denotes the level of corporate low carbon awareness, Control denotes all control variables and ε denotes the residual term, while the model controls for year and industry fixed effects to ensure the robustness of the results.

Intermediary effects model

This paper refers to the mediation effect approach of Wen Zhonglin et al. (2022) and is divided into three stages for validation. The first stage tests the impact of corporate low carbon awareness on the quality of corporate carbon information disclosure; the second stage verifies the impact of corporate low carbon awareness on the level of green technology innovation; and the third stage tests whether there is a mediating effect of green technology innovation. The relationship model of corporate low carbon awareness, green technology innovation and carbon information disclosure quality is shown in Figure 1.

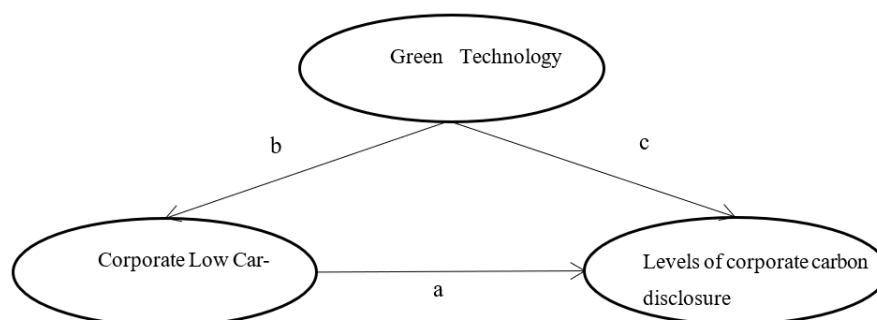


Fig. 1. Relationship model of corporate low carbon awareness, green technology innovation and carbon information disclosure quality (Author's self-painting)

The specific model is as follows.

$$CDI = \alpha_0 + \alpha_1 Aware + \alpha_2 Control + Ind + Year + \varepsilon \quad (4)$$

$$PA_GR = \beta_0 + \beta_1 \text{Aware} + \beta_2 \text{Control} + \text{Ind} + \text{Year} + \varepsilon \quad (5)$$

$$CDI = \lambda_0 + \lambda_1 \text{Aware} + \lambda_2 PA_GR + \lambda_3 \text{Control} + \text{Ind} + \text{Year} + \varepsilon \quad (6)$$

In equation (2), if β_1 is significant, it means that low carbon awareness can significantly affect the level of green technology innovation of enterprises; in equation (3), if λ_2 is significant and λ_1 is insignificant, then green technology innovation plays a full mediating effect, if λ_2 is significant and λ_1 is also significant, then green technology innovation plays a partial mediating effect.

5. Empirical analysis

5.1. Descriptive analysis

The statistical results of each variable are shown in Table 4. Preliminary analysis shows that the mean value of the low carbon awareness level of enterprises is 0.521, indicating that the overall low carbon awareness level of heavy polluting enterprises is high, while it is found that there are some differences in the low carbon awareness level among enterprises, the minimum and maximum values of which are 0 and 1 respectively. the mean value of the enterprise carbon information disclosure quality variable is 0.322, the minimum value is 0 and the maximum value is 0.833, indicating that there are enterprises with high carbon information disclosure quality by individual. However, the overall quality of carbon information disclosure of enterprises in the heavy pollution industry is low, and there is a great difference between enterprises. This reflects that the current system of carbon information disclosure by enterprises in China is not perfect and the level of disclosure is easily influenced by other factors. The mean value of the green technology innovation indicator is 0.424, and the difference between its maximum and minimum value is 3.401, indicating that there is heterogeneity in the level of green technology innovation among different enterprises.

Table 4. Descriptive statistics for each variable

Variable name	Sample size	Average value	Standard deviation	Minimum value	Maximum value
Aware	1118	0.521	0.323	0.000	1.000
CDI	1118	0.322	0.244	0.000	0.833
PA_GR	1118	0.424	0.789	0.000	3.401
Age	1118	20.368	4.723	10.000	35.000
Lev	1118	0.451	0.203	0.071	0.921
Roa	1118	0.037	0.056	-0.164	0.212
CFO	1118	0.067	0.062	-0.108	0.239
Board	1118	2.298	0.188	1.792	2.773
Top10	1118	58.287	14.627	24.790	92.150

5.2. Relevance analysis

This paper conducted Pearson correlation coefficient analysis on the full sample variables and obtained the results as shown in Table 5. It can be seen that the correlation coefficient between corporate low carbon awareness Aware and carbon information disclosure quality CDI is 0.448, which is positively significant at the 1% level, initially verifying this paper's hypothesis H1: Controlling other factors constant, corporate low carbon awareness has a positive influence on carbon information disclosure quality. Meanwhile, the strongest relationship between the variables is 0.520, and the absolute values of the correlation coefficients of the remaining variables are all less than 0.500, indicating that there is no serious problem of multicollinearity among the variables. To ensure the robustness of the results, multiple regression tests are still needed.

Table 5. Pearson correlation coefficient test results for full sample variables

	Aware	CDI	Age	Lev	Roa	CFO	Board	Top10
Aware	1.000							
CDI	0.448***	1.000						
Age	-0.015	0.091***	1.000					
Lev	0.246***	0.218***	0.022	1.000				
Roa	0.034	-0.012	-0.013	-0.437***	1.000			
CFO	0.191***	0.117***	0.072**	-0.150***	0.520***	1.000		
Board	0.221***	0.123***	0.049*	0.166***	0.029	0.089***	1.000	
Top10	0.200***	0.161***	-0.269***	0.080***	0.101***	0.090***	0.094***	1.000

5.3. Multiple regression analysis

Table 6 shows the results of the multivariate regression of the level of low carbon awareness and the quality of carbon information disclosure. Column (3) reports the results after adding the control variables while controlling for industry and year fixed effects, the regression coefficient of carbon disclosure quality (CDI) is 0.299, which is still significant at the 1% level, and the t-values for columns (2) and (3) are 13.156 and 13.070 respectively, indicating that the results are more significant when only the control variables are added. Therefore, having a low carbon awareness will enhance the willingness of companies to disclose carbon information and improve the quality of carbon information disclosure. Ultimately, hypothesis H1 is supported, which indicates that, on the one hand, when enterprises have a stronger awareness of low carbon or managers and employees have a higher awareness of energy saving and emission reduction, their economic activities will be directly affected and they will be more willing to disclose more carbon information spontaneously; on the other hand, as enterprises themselves perform well in low carbon awareness, in order to show the gap with other heavy polluting enterprises, establish an environment-friendly On the other hand, due to the good performance of the enterprises' own low carbon awareness, in order to show the difference with other heavy polluters, establish the image of environmental friendly enterprises, and achieve the purpose of conveying "good" information to the stakeholders, enterprises will be more willing to disclose carbon information and the quality of disclosure will be higher.

Table 6. Multiple regression results

Variables	CDI	CDI	CDI
	(1)	(2)	(3)
Aware	0.339***	0.298***	0.299***
	(17.141)	(13.156)	(13.070)
Age		0.006***	0.006***
		(4.891)	(4.337)
Lev		0.137***	0.131***
		(3.787)	(3.452)
Roa		-0.036	-0.055
		(-0.260)	(-0.381)
CFO		0.184	0.181
		(1.591)	(1.558)
Board		-0.003	0.003
		(-0.086)	(0.079)
Top10		0.002***	0.002***
		(3.455)	(3.453)
_cons	0.145***	-0.124	-0.120
	(13.195)	(-1.480)	(-1.316)
Industry	No	No	Yes
Year	No	No	Yes
N	1118	1118	1118
R ²	0.200	0.228	0.232

5.4. Analysis of the mediating effects of green technology innovation

Table 7 reports the results of the test for the mediating effect of green technology innovation. Column (1) is consistent with the basic multiple regression results, indicating that the higher the level of corporate low carbon awareness, the more it promotes the quality of corporate carbon information disclosure; the regression coefficient of green technology innovation in column (2) is 0.204, which is significant at the 1% level, indicating that companies with higher low carbon awareness have a stronger level of green technology innovation, supporting this paper's research hypothesis H2: Controlling other factors constant, corporate low carbon awareness This supports the hypothesis H2: controlling for other factors, there is a positive effect of corporate low carbon awareness on green technology innovation. Column (3) is designed to test the mediating effect of green technology innovation, which corresponds to the regression coefficients of λ_1 and λ_2 in model (3) of 0.293 and 0.031 respectively, both significant at the 1% level, indicating that green technology innovation has a mediating effect, and plays a partial mediating effect. Therefore, hypothesis H3 is tested: controlling for other factors, green technology innovation plays a positive mediating role in the positive relationship between low carbon awareness and carbon information disclosure quality.

Table 7. Intermediary effect results

Variables	CDI	PA_GR	CDI
	(1)	(2)	(3)
Aware	0.298*** (13.156)	0.204*** (2.937)	0.293*** (12.845)
PA_GR			0.031*** (3.412)
Age	0.006*** (4.891)	0.003 (0.572)	0.006*** (4.301)
Lev	0.137*** (3.787)	0.508*** (4.536)	0.119*** (3.130)
Roa	-0.036 (-0.260)	0.182 (0.412)	-0.054 (-0.374)
CFO	0.184 (1.591)	0.653* (1.719)	0.154 (1.342)
Board	-0.003 (-0.086)	0.214 (1.481)	-0.010 (-0.271)
Top10	0.002*** (3.455)	0.006*** (3.132)	0.001*** (2.973)
_cons	-0.124 (-1.480)	-0.898*** (-2.796)	-0.075 (-0.815)
Industry	No	No	Yes
Year	No	No	Yes
N	1118	1118	1118
R ²	0.228	0.056	0.241

6. Research findings and policy recommendations

6.1. Research findings

With the guidance of national policies, enterprises' awareness of emission reduction is gradually improving and their carbon reduction behaviours are increasing, among which the implementation of green technological innovation is an important initiative for enterprises to carry out carbon reduction activities. Using a multiple regression model, this paper empirically analyses the mechanism of the influence of corporate low-carbon awareness on the quality of carbon information disclosure and investigates the mediating role of green technological innovation, using 225 heavily polluting companies listed on A-shares in Shanghai and Shenzhen, China, from 2015 to 2019 as a research sample, and finds that: first, there is a positive influence of corporate low-carbon awareness on the

quality of carbon information disclosure. The higher the low carbon awareness of enterprises, the higher the quality of carbon information disclosure; Second, there is a positive influence of low carbon awareness of enterprises on green technology innovation, the higher the low carbon awareness of enterprises, the stronger the green technology innovation. Thirdly, green technology innovation plays a positive mediating role in the positive relationship between low carbon awareness and carbon information disclosure quality.

6.2. Policy recommendations

Based on the above analysis, this study proposes corresponding policy recommendations, aiming to enhance enterprises' low-carbon awareness, improve their carbon information disclosure level, enhance green technology innovation and give full play to its positive mediating role in the positive relationship between low-carbon awareness and carbon information disclosure quality.

Improve policies related to carbon information disclosure and increase guidelines to promote green technology innovation

At this stage, China's carbon information disclosure system is not perfect, and the level of disclosure is easily affected by other factors, and the overall quality of carbon information disclosure of enterprises in heavy pollution industries is low. Therefore, the government should gradually improve carbon information disclosure related policies and introduce appropriate implementation rules to standardise, institutionalise and concretise them, so as to continuously promote the construction of "dual carbon" policies towards maturity, and accelerate the construction and improvement of laws and regulations, so as to reduce the decline in the quality of carbon information disclosure brought about by policy uncertainty, improve the low carbon awareness of enterprises and promote the progress of green technological innovation. The government can also further leverage the role of fiscal policy in the development of green technology. The government can also further play a guiding role in the development of green finance by means of fiscal subsidies, for example, to attract more social green capital to enter green industries and provide green capital for the innovation of green technology by enterprises.

Strengthen the performance assessment of carbon management performance indicators within enterprises to enhance their low carbon awareness

The above research shows that when companies have a stronger awareness of low carbon or when managers and employees have a higher awareness of energy saving and emission reduction, their economic activities will be directly affected and they will be more willing to disclose more carbon information spontaneously. Therefore, in order to encourage companies to improve their carbon information disclosure, they can incorporate carbon management performance indicators into their performance appraisal to motivate managers and their employees to fulfill more carbon reduction responsibilities.

Promote the concept of low carbon and environmental protection and enhance investors' awareness of social responsibility

To further promote the concept of low-carbon and environmental protection, establish an environment-friendly corporate image and enhance investors' awareness of social responsibility, investors should be guided to pay more attention to the fulfilment of corporate social responsibility and technological innovation while paying attention to the financial performance of enterprises, especially to information on social responsibility such as carbon emission reduction and the development of green technological innovation of enterprises.

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