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Carbon Emission Trading Pilot and Corporate Greenwashing-Based on Multi-Period PSM-DID Analysis

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Abstract

The report of the Twentieth Party Congress emphasizes the further promotion of the realization of the "dual-carbon" goal and the promotion of a green economy, which requires the handling of the risk of corporate greenwash in the process of green development. In view of this, this paper studies the key role of carbon emissions trading pilot policy in reducing corporate greening from the perspective of actively incentivizing corporate green development. Based on the financial statement data of listed enterprises from 2010 to 2022, the article empirically examines the impact of carbon emissions trading on corporate greenwash, and the results show that carbon emissions trading can significantly inhibit the risk of corporate greenwash, corporate green innovation plays a part of the mediating effect, and the level of marketization plays a moderating effect, and the conclusions pass the robustness test. The heterogeneity test found that this conclusion is more significant for state-owned enterprises and enterprises located in high-pollution industries.

Keywords

Corporate bleaching green, carbon emissions trading, green innovation, marketization level.

1. Introduction

Since the reform and opening up, the rapid industrialization path has helped China's economy achieve rapid development, but also face increasingly serious environmental pollution and ecological degradation problems, such as air pollution, haze and climate change. As early as the beginning of the 21st century, China gradually established the Carbon Emission Trading System (CETS) in order to achieve the goals of sustained economic growth and carbon emission reduction, the essence of which is to introduce the market mechanism into the environmental governance policy. With the development of the industrial economy, the upgrading of the energy structure has become a necessary trend, and the environmental governance strategy has gradually shifted from the reduction of greenhouse gas emissions to the development of a green economy. From the "green mountains are golden mountains" put forward by General Secretary Xi Jinping, to the pollution prevention and control of the "three major battles" in the 19th CPC National Congress report, to the "2035 carbon peak" and To the "2035 Carbon Peak" and "2060 Carbon Neutral" in the Nineteenth Party Congress Report, China's green economy development program is constantly advancing. At the micro level, the degree of corporate environmental responsibility is closely related to the development of green economy. Nowadays, under the double pressure of establishing a good public image and obtaining green loans, more and more enterprises choose to disclose their environmental performance, while green-bleaching behavior is also increasing. Greenwashing enterprises often use language art to disclose their environmental information in ambiguous language, to whitewash their environmental performance and to hinder the development of green economy. Therefore, it is

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of great significance to study how to inhibit greenwash for the development of green economy and strengthening environmental governance in China. In order to solve this problem, this paper takes the relevant financial data of A-share listed enterprises from 2010 to 2022 as the research samples to empirically test the relationship between carbon emission rights trading and the risk of corporate greenwash.

The marginal contributions of this paper are as follows: (1) Currently, there are relatively few studies on the relationship between carbon emission rights trading and corporate greenwash risk. This paper can enrich the research in this field through empirical analysis; (2) it supplements the research on the mediating and moderating effects of corporate green innovation and marketization level, expands the mechanism of carbon emissions trading to inhibit corporate greenwash, enriches the results of the study, and improves the reliability of theoretical analyses; (3) Further research introduces the effects of equity nature and different industries on the risk of corporate greenwash, providing a focus for the study of carbon emissions trading to inhibit corporate greenwash risk.

2. Literature Review

Existing studies have shown that the research on the inhibition of corporate greenwashing behavior is usually carried out from the three aspects of the heterogeneity of environmental regulation, the external monitoring mechanism, and the influence of the market and consumer behavior. Specifically, there are significant differences in the effects of different types of environmental regulations on corporate greenwash: command-and-control and public-participation environmental regulations can effectively inhibit corporate greenwash because command-and-control environmental regulations directly stipulate the environmental protection standards that corporations must comply with, whereas public-participation environmental regulations, through enhanced public participation and monitoring, can encourage corporations to adopt more stringent environmental protection standards when facing public pressure. The market incentive environmental regulation shows a “threshold effect”, i.e., under certain conditions, it may aggravate the greenwashing behavior of enterprises, because the market incentive environmental regulation promotes the adoption of environmental protection measures by giving economic incentives to enterprises, but in some cases, the incentives may cause enterprises to adopt environmental protection measures only superficially. such incentives may lead firms to take some environmental actions only superficially to gain economic benefits, instead of truly reducing environmental pollution (Yeh, Jianmu and Li, Ying, 2020)[1]. In addition, external pressure has a significant inhibitory effect on corporate greenwashing behavior, especially government regulation and media supervision, which constrain corporate behavior by strengthening the enforcement of regulations and increasing the cost of non-compliance, and at the same time prompt corporations to pay more attention to their social responsibility through media exposure and public opinion pressure, which suggests that strengthening external supervision and increasing media exposure are effective means to inhibit corporate greenwashing behavior (Wu Yu, 2021)[2] . Green investors can significantly inhibit corporate greenwash behavior by alleviating information asymmetry and improving the quality of internal control, because green investors pay more attention to the long-term sustainable development of the enterprise, and they promote the enterprise to take real environmental protection actions through investment decisions, rather than just carrying out superficial articles (Chen Lingfang, 2023)[3]. Finally, consumers' environmental awareness and green consumption behavior also play a positive role in suppressing corporate greenwashing, because as consumers are more and more inclined to choose those products and services with good environmental records, companies will pay more attention to their

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environmental performance in order to meet the market demand, thus reducing the occurrence of greenwashing (Huang, 2022)[4].

It can be found that most of the existing literature inhibits greenwash from external monitoring and identification. There are two limitations: on the one hand, most of the research on inhibiting enterprise greenwash focuses on how to identify greenwash with the help of information technology and forcibly control the enterprise greenwash behavior, and fails to consider how to incentivize the enterprise to reduce greenwash from another perspective. On the other hand, as an important participant in market activities, the establishment of carbon emissions trading system incentivizes enterprises to carry out green innovation. Enterprises can effectively improve their environmental performance while carrying out green innovation, and no longer need to bleach green to cover up their environmental performance. However, few studies have analyzed the association between carbon emissions trading rights and corporate greenwashing.

3. Theoretical Basis and Research Assumptions

Carbon emissions trading policy realizes greenhouse gas emission reduction through market mechanism, providing an economic means for enterprises to reduce greenhouse gas emissions, thus promoting their active participation in emission reduction actions (Xingxiang Zhang and Saijie Sun, 2024)[5]. By setting a cap on carbon emissions and allowing the trading of emission rights, this mechanism incentivizes enterprises to reduce carbon emissions through technological innovation and efficiency enhancement, rather than relying solely on greenwash behavior to meet policy requirements. By internalizing the social costs of carbon emissions into corporate costs, the carbon emissions trading policy prompts enterprises to consider the environmental impact of their production activities. This cost internalization mechanism helps to reduce the practice of enterprises avoiding the real cost through greenwashing behavior, which often cannot effectively reduce the actual carbon emission cost of enterprises (Liu Lizhen, 2014)[6]. Carbon emissions trading policy encourages enterprises to achieve emission reduction targets through technological innovation and industrial structure upgrading (Yang Zhian and Zhang Fan, 2024)[7]. This policy orientation motivates enterprises to invest in environmentally friendly technologies and green production methods, rather than relying solely on greenwashing behavior to meet the policy requirements.

Based on this, the following hypotheses are proposed:

H1: The implementation of carbon emissions trading policy can significantly reduce the risk of corporate greenwashing.

Carbon emissions trading can significantly promote corporate green innovation, and there is heterogeneity in the impact of different allowance allocation methods on corporate green innovation (Song Deyong et al., 2021)[8]. And the carbon emissions trading policy promotes the level of corporate green innovation in the pilot region, especially substantive green innovation (Zhang Yang et al., 2024)[9]. In addition, carbon price signal is an important factor to promote enterprise green innovation. The higher the carbon price, the stronger the impact of carbon emissions trading on enterprises' green technological innovation (Lili Wei and Liyuan Ren, 2021)[10]. The improvement of enterprise green innovation, enterprises can essentially reduce the enterprise bleaching green behavior. This is because when enterprises invest resources in green technology research and development, optimize production processes, and improve resource use efficiency, their environmental performance will be substantially improved. This substantial improvement reduces the need for companies to rely on superficial efforts to create a good environmental image, thus reducing the likelihood of companies engaging in greenwash. This process not only helps to achieve the GHG reduction target, but also promotes the economic and social transition to green and low-carbon (Wang Conghu and Luo Fei, 2023) [11].

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Based on this, the following hypothesis is proposed:

H2: Corporate green innovation plays a partial mediating effect, and carbon emissions trading can promote corporate green innovation and further reduce the risk of corporate greenwashing.

The improvement of marketization level helps to improve the transparency and fairness of carbon emissions trading. A perfect system of laws and regulations, a reasonable way of allocating carbon quotas, a gradual development model and a strict verification system are important guarantees for the operation of the carbon emissions trading market (Huang Heping and Xie Yunfei, 2023)[12]. These measures help to ensure the fairness and transparency of carbon emissions trading, and enhance the effect of reducing corporate greenwash behavior. And the improvement of marketization level helps to enhance the motivation and ability of enterprises to reduce emissions. The construction of the internal carbon trading market of enterprises can improve the utilization efficiency of greenhouse gas emission rights, thus reducing the greenhouse gas emissions of enterprises (Wang Jingmin, 2011)[13]. This indicates that in the case of a higher level of marketization, enterprises are more motivated and capable of achieving emission reduction targets through market-based means, thus reducing greenwash behavior.

However, as the level of marketization increases, the problem of information asymmetry in the market has been alleviated, and the information exchange between enterprises and investors has become more transparent and efficient. In this environment, the external monitoring pressure faced by enterprises is weakened, resulting in the effect of carbon emissions trading on reducing enterprises' greenwash behavior becoming less obvious. Moreover, under such a market environment, enterprises may be more inclined to adopt short-term strategies to cope with market competition rather than long-term substantive environmental protection actions, which will also lead to enterprises paying more attention to short-term market performance rather than long-term environmental responsibility, thus affecting the actual effect of carbon emissions trading on reducing greenwash behavior.

Based on this, the following hypothesis is proposed:

H3a: The level of marketization plays a positive moderating effect in the process of the impact of carbon emissions trading on reducing the risk of greenwash;

H3b: The level of marketization plays a negative moderating effect in the process of the influence of carbon emission rights trading in reducing the risk of greenwash.

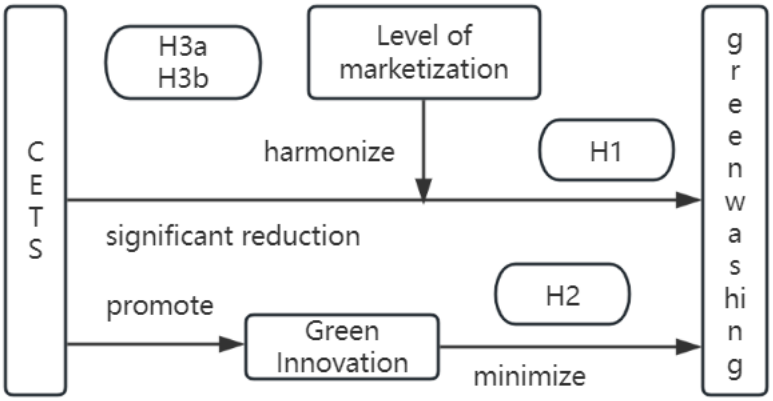

Fig. 1 Hypothetical relationship diagram

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4. Research Design

4.1. Sample Selection and Data Source

This paper selects A-share listed companies in Shanghai and Shenzhen from 2010 to 2022 as the research sample, and does the following to the data: (1) exclude ST and *ST listed companies; (2) delete non-industrial industry companies considering that the main influence of carbon emissions trading pilot is concentrated in the industrial companies; (3) exclude the sample data that cannot be compensated for the missing data in the examined years. After the above screening, a total of 14,725 observations from 3,132 listed companies are obtained. All of these data are obtained from the Cathay Pacific database (CSMAR) and relevant financial data platforms such as Juchao Information Network.

4.2. Variable Setting

4.2.1. Explanatory variables: carbon emissions trading pilot policy (EST)

The explanatory variable ESTi,t is a dummy variable for whether the enterprise is included in the list of carbon emissions trading control enterprises in that year, and takes the value of 1 if the enterprise is included in the list of carbon emissions trading control enterprises in that year, and takes the value of 0 if the enterprise is not included. the list of carbon emissions trading control enterprises is obtained from the information table of the national carbon emissions trading key emission enterprises in the database of GuotaiAn.

4.2.2. Explained variable: corporate greenwash risk (GW)

Referring to Su Dongwei et al. (2023) [14], it is believed that if enterprises disclose environmental information through actionable qualitative descriptions, then this type of disclosure belongs to symbolic disclosure strategy with high ambiguity, and the existence of greenwash risk is more likely. However, if enterprises use specific figures or other quantitative indicators to describe pollution emissions, then this type of disclosure belongs to the substantive disclosure with high transparency, and the incentive for enterprises to drift green is lower. A measure of greenwash risk is thus constructed:

$$GW = \frac{\text{Number of qualitative disclosure items} - \text{number of quantitative disclosure items}}{\text{Number of projects disclosed}} \quad (1)$$

Among them, the number of disclosed items is the number of environmental liability items disclosed by listed companies on their own initiative, the number of qualitatively disclosed items is the number of items disclosed in text form, and the number of quantitatively disclosed items is the number of items disclosed in numerical form. The source of data is the environmental liabilities table with the database of Cathay Pacific, and the items used for measurement include: wastewater emissions, COD emissions, SO2 emissions, CO2 emissions, soot and dust emissions, and industrial solid waste generation.

4.2.3. Mediating variables

Referring to the studies of Xu Jia and Cui Jingbo (2020)[15] and Wang Xin and Wang Ying (2021)[16], the number of green invention patent applications + the number of green utility model applications +1 and take the natural logarithm to measure the green innovation of enterprises (EnvrPat).

4.2.4. Moderating Variables

With reference to previous literature research, the total marketization index from the research results of Fan Gang, Wang Xiaolu and other scholars on the measurement of the relative process of marketization in Chinese provinces is used to measure the level of marketization (Inmarket).

In order to reduce the influence of other factors on enterprise value in the regression process, through combing through a large number of literature, this paper chooses enterprise value,

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enterprise size, gearing ratio, return on assets, enterprise age, per capita GDP of the enterprise's location, and informatization level as the control variables.

Table 1 Variable Definition

Variable Type	Variable Name	Symbol	Variable Meaning
Explained Variables	Greenwash Risks	GW	(Number of qualitative disclosure projects - Number of quantitative disclosure projects)/Number of disclosed projects
Explanatory variables	Carbon Emissions Trading	ESTi,t	Indicates whether enterprise i is a key emission control enterprise in year t.
Mediating variable	Corporate Green Innovation	EnvrPat	Number of green invention patent applications + number of green utility model applications + 1, taking natural logarithms
Moderating variable	Marketability	lnmarket	Total Marketability Index
Control variable	Enterprise Value	TobinQ	(market value of outstanding shares + number of non-outstanding shares × net assets per share + book value of liabilities) / total assets
	Enterprise Size	Size	Natural logarithm of annual total assets
	Gearing Ratio	Lev	Total liabilities / Total assets at the end of the period
	Return on Assets	ROA	Net profit / Average balance of total assets
	Enterprise Age	Age	Natural logarithm of the number of years the enterprise has been established
	GDP per capita of enterprise location	GDP	Per capita GDP level of the enterprise's location
	Informationization Level	XXHSP	Total post and telecommunications business / Gross information product

4.3. Model construction

This paper draws on the model design of Song Deyong et al. (2021) [8] and empirically tests it using the multi-period PSM-DID method. Since whether enterprises are included in the emission control enterprises is based on the policy program of individual pilot provinces, with reference to certain industries and emission standards, enterprises located above a certain emission level will be included in the list, so this process has obvious non-random characteristics. If the double difference method (DID) is used directly, it may cause sample selection bias resulting in inaccurate results. Moreover, the difference between the risk of greenwash between controlled and non-controlled enterprises may also be caused by other unobservable and time-varying factors, and thus may result in endogenous bias due to omitted variables. To mitigate these two problems, the propensity matching method (PSM) is first used to eliminate the sample selectivity problem, and then the double difference method is applied to estimate the impact of carbon emissions trading on firms' greenwash. It is worth noting that in the process of building China's carbon emissions trading system, various pilot regions have been set up and launched carbon trading activities during 2013, 2014, and 2016, respectively. The emission-control enterprises within these pilot regions did not all join the carbon emissions trading system at once, but gradually participated through a phased approach. With the continuous expansion and deepening of the national carbon market, the scale of the carbon emissions trading market in different provinces and municipalities has shown dynamic expansion, and the corresponding list of emission-control enterprises has also experienced

constant updates and adjustments. Some enterprises may withdraw from the trading system due to bankruptcy, reorganization and other factors, while some new enterprises have recently joined because they meet the requirements. In view of this reality, i.e., there is obvious variability in the timing and conditions of the entry of emission-control enterprises in each pilot region, it is not possible to accurately assess the impact of the carbon emissions trading policy by simply applying the traditional double-difference model based on the treatment of the effect at a single point in time. Therefore, a more appropriate approach is to adopt a multi-period PSM-DID research strategy in order to more accurately analyze the long-term impacts of carbon emissions trading policies on the energy-saving and emission reduction effects of various types of emission-control enterprises at different time points. Such an approach can comprehensively judge the actual effect of the policy by combining whether the enterprises participate in carbon trading in different time periods and the changes in their characteristics.

4.3.1. Propensity matching score

Referring to the study of Li Qingyuan et al. (2021) [17] to match the sample data from 2010 to 2022. Firstly, the sample is divided into two groups: one group is the treatment group (T), which is the enterprises within the pilot provinces of carbon emission trading, and the non-control emission enterprises within the pilot provinces of carbon emission trading are deleted in order to avoid the influence of non-control emission enterprises within the trading pilot. One group is the control group (C), which is the enterprises that are not included in the list of emission control enterprises. Let A={T,C} denote all sample enterprises, and calculate the probability of enterprises included in the emission control enterprises:

$$P = \Pr\{A = T\} = \emptyset\{X_{i,t-1}\} \quad (2)$$

where P is the probability of a firm's participation in carbon emissions trading, and Xi, t-1 is a lagged one-period matching variable that contains factors affecting whether a firm is included or not. Considering that the historical emissions of the firms are the main basis for inclusion in the key control ranking list, the return on assets (ROA), the age of the firms (Age) and the number of firms (Total) are selected as the matching covariates. The predicted probability value P(X) of firms' participation in ETSi,t was finally estimated by Logit model. Firms with similar predicted probability values are matched using caliper nearest-neighbor (1:2) matching to obtain the control group of firms Cp.

4.3.2. Multi-period DID model

After the propensity matching score, we get the sample enterprise Ap={T, Cp}, and construct the dummy variable ESTi, t for the enterprise to participate in carbon emissions trading, when i ∈ T and the enterprise is included in the list of key emission control enterprises in the pilot carbon market, ESTi, t takes the value of 1, otherwise it takes the value of 0. Based on this, we construct the multi-period DID regression model:

$$GW_{i,t} = \alpha_0 + \alpha_1 ETS_{i,t} + \sum \alpha_2 Controls_{i,t} + \sum id + \sum Year + \mu \quad (3)$$

where subscript i is the firm, t is the year, the explanatory variable is the firm's risk of greenwash (GW), the explanatory variable is whether or not the firm is included in the key control ranking list in the current year ($ETS_{i,t}$), Controls is the control variable, and μ is the random perturbation term. In addition this paper controls for individual (id) and year (Year) fixed effects.

4.3.3. Mediated effects model

A mediated effects model is constructed from the base model:

$$EnvrPat_{i,t} = \alpha_0 + \alpha_1 ETS_{i,t} + \sum \alpha_2 Controls_{i,t} + \sum id + \sum Year + \mu GW_{i,t} = \alpha_0 + \alpha_1 ETS_{i,t} + \alpha_2 EnvrPat_{i,t} + \sum \alpha_3 Controls_{i,t} + \sum id + \sum Year + \mu \quad (4)$$

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where the mediating variable ($EnvrPat_{i,t}$) is the firm's level of green innovation in the current year, Controls is a control variable, and μ is a random perturbation term with individual and year effects fixed.

4.3.4. Moderating effects model

$$GW_{i,t} = \alpha_0 + \alpha_1 ETS_{i,t} + \alpha_2 Inmarket_{i,t} + \alpha_3 ETS_{i,t} \times Inmarket_{i,t} + \sum \alpha_4 Controls_{i,t} + \sum id + \sum Year + \mu (5)$$

where Inmarket_(i,t) is a moderator variable indicating the local marketization level of the firm, $ETS_{i,t} \times Inmarket_{i,t}$ is the interaction term between the explanatory variables and the moderator variables, Controls is a control variable, and μ is a random perturbation term with individual and year effects fixed.

4.4. Propensity Matching Score Treatment

After matching the sample data with propensity matching scores, in order to ensure the quality of matching, this paper conducted a balance test on the data before and after matching. The results are shown in Table 2, the coefficient values of the covariates in each year after matching are reduced, and all the coefficients are not significant, which indicates that there is no systematic bias in the covariates of the two groups in different years, and the balance test is passed. Afterwards, a kernel density plot is drawn for the matching effect (Fig. 2), the deviation between the treatment group and the control group is large before matching, and most areas of the treatment group and the control group have been overlapped after matching, indicating that the matching is effective. A more ideal matching effect was obtained, i.e., the treatment and control groups reached a better equilibrium in covariate distribution. This indicates that the selection bias has been successfully reduced through the propensity score matching method, which makes the two groups comparable at the covariate level and thus improves the validity and accuracy of the subsequent causal inference analysis.

Table 2 Balance test

Var	U/M	T	C	%bias	%reduct|	t	p	V(T)/V(C)
ROA	Unmatched	0.05858	0.05874	-0.2	-1774.7	-0.06	0.948	0.72*
	Mathed	0.05847	0.05538	4.1		0.8	0.422	0.43*
Age	Unmatched	2.9059	2.8869	5.5	42.5	1.8	0.072	1.19*
	Mathed	2.9086	2.9195	-3.2		-0.75	0.453	1.22*
Total	Unmatched	14112	5795.3	33	99.3	17.93	0	11.55*
	Mathed	10354	10294	0.2		0.09	0.929	0.97

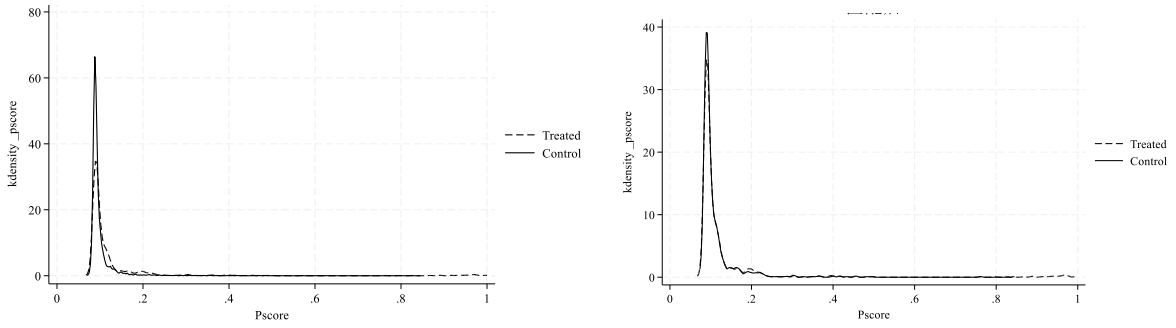

Fig. 2 Kernel density maps before (left) and after (right) matching

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5. Empirical Analysis

5.1. Descriptive statistics

For the matched completed data, descriptive statistics test (Table 3) and the next regression analysis are conducted. The mean value of the explanatory variable corporate greenwash risk (GW) is 0.22, the minimum value is -1, and the maximum value is 1, which indicates that the sample firms present different degrees of potential greenwash risk. The median is 0.33, which is higher than the mean, indicating that more than half of the sample firms' greenwash risk scores lie above the mean, reflecting the fact that most firms in the matched sample set may exhibit greenwash behavior in terms of environmental performance. The median value of the explanatory variable whether the firm is included in the control ranking list (EST) is 0 and the mean value is 0.31, indicating that 31% of the firms in the matched sample are in the state of being included in the control ranking list and more than half of the firms have not been included in the control ranking list.

Table 3 descriptive statistical analysis

Variable	N	Min	Mean	p50	Max	SD
GW	1972.00	-1.00	0.23	0.33	1.00	0.82
EST	1972.00	0.00	0.31	0.00	1.00	0.46
TobinQ	1972.00	0.77	1.88	1.49	12.44	1.23
Size	1972.00	19.41	22.84	22.72	27.62	1.34
Lev	1972.00	0.01	0.45	0.45	1.48	0.20
ROA	1972.00	-1.30	0.06	0.06	0.39	0.09
Age	1972.00	1.10	2.91	2.94	4.16	0.34
GDP	1972.00	13119.00	87262.15	81874.00	190313.00	38920.61
XXHSP	1972.00	0.01	0.06	0.04	0.29	0.05

5.2. Regression analysis

5.2.1. Baseline regression

The regression to test the effect of whether firms are included in emission control on the risk of greenwash is conducted controlling for industry and year fixed effects, and the results are shown in columns (1)(2) in Table 4. Column (1) is the regression without adding control variables, the regression coefficient is -0.117, which is significant at the 10% level; column (2) is the regression after adding control variables, the regression coefficient is -0.148, which is significant at the 5% level, and the adjusted R-square are both 0.487, which indicates that the regression results have a better fit, so the enterprises' inclusion in the list of key emission-control enterprises can significantly reduce the risk of green-bleaching, and the hypothesis 1 is validated. Verified the hypothesis 1 of this paper.

Table 4 Impact of the inclusion of enterprises in controlled emissions on the risk of greenwash

	(1)	(2)
	GW	GW
EST	-0.117*	-0.148**
	(-1.908)	(-2.338)
TobinQ		0.006
		(0.292)
Size		-0.062
		(-1.048)
Lev		0.158

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		(0.692)
ROA		0.586
		(1.582)
Age		0.059
		(0.236)
GDP		0.000
		(1.483)
XXHSP		-0.461
		(-0.365)
_cons	0.248***	1.146
	(8.957)	(0.756)
id	Yes	Yes
Year	Yes	Yes
r2_a	0.487	0.487

Note: *, **, and *** indicate significant correlation at the 10%, 5%, and 1% levels, respectively, with t-values in parentheses, below.

5.2.2. Robustness test

1. Parallel trend test and placebo test

The parallel trend test and placebo test are conducted on the results of the benchmark regression, and it can be seen from Figure 3 that before the implementation of carbon emissions trading policy, there is no significant effect on reducing corporate greenwash, while after the implementation of the policy, it can significantly reduce the risk of corporate greenwash. In the placebo test, the estimated coefficients are distributed around zero and follow a normal distribution, which is in line with the expectation of the placebo test.

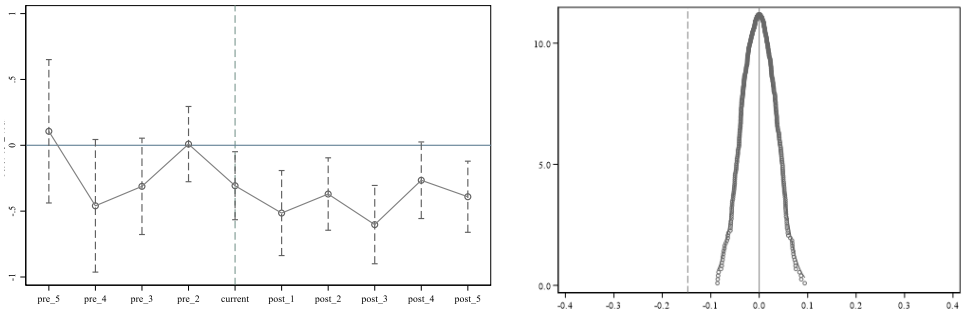

Fig. 3 Parallel trend test (left) vs. placebo test (right)

2. Replacement of explanatory variables

Replacing the original explanatory variable calculation to the number of qualitative disclosure projects/number of disclosed projects (GW1) and re-regressing, the results are shown in column (1) of Table 5, and EST is negatively significant at the 5% level, indicating that the implementation of carbon emissions trading policy can significantly reduce the risk of enterprises' drifting to the green with the replacement of explanatory variables.

3. Change clustering effect

Considering that the production activities of different enterprises will affect each other, in order to make the research conclusions more robust, this paper re-conducts the regression test by changing to the robust standard error of enterprise individual clustering, and the results are shown in column (2) of Table 5. The regression coefficient of the explanatory variables is -0.149, which is significant at the 5% level, indicating that the implementation of the carbon emissions

trading policy can significantly reduce the risk of corporate greenwash, which is consistent with the previous conclusion.

4. Removal of abnormal years

During the sample period, the new crown epidemic that started in 2020 had a great impact on the development of enterprises, in order to reduce the uncertainty of the research results of the abnormal years, this paper removes the three years of data from 2020-2022 and then re-regresses the results as shown in column (3) of Table 5, and the EST coefficient is -0.205, which is still negatively significant at the 5% level, which indicates that the conclusion of the previous paper are robust.

Table 5 robustness check

	(1) GW1	(2) GW	(3) GW
EST	-0.148**	-0.149**	-0.205**
	(-2.398)	(-2.038)	(-2.443)
TobinQ	-0.044*	0.018	0.027
	(-1.828)	(0.793)	(0.979)
Size	-0.112*	-0.026	-0.039
	(-1.884)	(-0.315)	(-0.396)
Lev	0.182	0.140	0.154
	(0.855)	(0.508)	(0.471)
ROA	0.261	0.287	0.270
	(0.796)	(0.676)	(0.399)
Age	-0.341	0.224	0.004
	(-1.193)	(0.724)	(0.011)
GDP	0.000***	0.000	0.000
	(3.021)	(1.108)	(0.661)
XXHSP	-0.497	-0.048	-0.127
	(-0.473)	(-0.038)	(-0.043)
_cons	3.539**	-0.188	0.953
	(2.284)	(-0.088)	(0.376)
id	Yes	Yes	Yes
Year	Yes	Yes	Yes
r2_a	0.343	0.478	0.471

5. Changing the regression method

The baseline model was re-tested using frequency weighting, common support assumption and full sample regression methods respectively, and the results are shown in the following table columns (1), (2) and (3). The coefficients of EST under the three regression methods are -0.094, -0.122, and -0.122 respectively and are significant at 5% and 1% significance levels. This indicates that the inclusion of enterprises in the list of key emission control enterprises can significantly reduce their risk of greenwash after considering the weights of observations, the common support assumption and the full sample, and the adjusted R-square are all high, indicating that the model has good explanatory power.

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Table 6 Replacement of regression methods

	(1) GW	(2) GW	(3) GW
EST	-0.094**	-0.122***	-0.122***
	(-2.057)	(-2.989)	(-3.137)
TobinQ	0.008	-0.015*	-0.015*
	(0.488)	(-1.705)	(-1.706)
Size	-0.077**	-0.084**	-0.080**
	(-1.963)	(-2.724)	(-2.709)
Lev	0.313**	0.121	0.104
	(1.994)	(0.948)	(0.833)
ROA	0.601**	0.224**	0.189*
	(2.333)	(2.250)	(1.983)
Age	-0.071	-0.209	-0.185
	(-0.346)	(-1.456)	(-1.450)
GDP	0.000	0.000	0.000
	(1.122)	(0.430)	(0.749)
XXHSP	-0.412	-0.855*	-0.813*
	(-0.503)	(-1.896)	(-1.933)
_cons	1.930*	2.749***	2.578***
	(1.811)	(3.578)	(3.500)
id	Yes	Yes	Yes
Year	Yes	Yes	Yes
r2_a	0.666	0.466	0.460

6. Replacement of matching methods

The PSM nearest neighbor matching is replaced with radius matching, kernel matching and K nearest neighbor matching, and regressions are carried out respectively, and the results are shown in Table 7, which show that the carbon emissions trading policy under the three matching methods can significantly reduce the risk of drifting green, and the adjusted R-square is greater than 0.4, indicating that the model fit is higher, which further validates the previous conclusions and has robustness.

Table 7 Replacement of PSM Matching Method

	(1) Radius Matching	(2) Kernel Matching	(3) K Nearest Neighbor Matching
EST	-0.120***	-0.122***	-0.128**
	(-2.732)	(-2.775)	(-2.182)
TobinQ	-0.015*	-0.015*	0.008
	(-1.839)	(-1.848)	(0.477)
Size	-0.084***	-0.084***	-0.078*
	(-3.546)	(-3.539)	(-1.841)
Lev	0.127	0.121	0.100
	(1.543)	(1.477)	(0.621)
ROA	0.227**	0.225**	0.255
	(2.007)	(1.990)	(1.160)

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Age	-0.212*	-0.209*	0.014
	(-1.739)	(-1.709)	(0.062)
GDP	0.000	0.000	0.000
	(0.431)	(0.407)	(1.244)
XXHSP	-0.841**	-0.848**	0.335
	(-2.062)	(-2.079)	(0.424)
_cons	2.760***	2.749***	1.726
	(4.634)	(4.620)	(1.505)
id	Yes	Yes	Yes
Year	Yes	Yes	Yes
r2_a	0.466	0.466	0.460

5.3. Mechanism test

5.3.1. Mediating effect test

The mediating effect test of enterprise green innovation is shown in columns (1) and (2) of Table 8. Column (1) shows that the coefficient of China's carbon emission rights trading on enterprise green innovation is 0.201, which is positively significant at 1% level, indicating that carbon emission rights trading can significantly promote enterprise green innovation. And column (2) shows that the coefficient of carbon emission right trading is -0.153 and the coefficient of enterprise green innovation is -0.088, both of which are negatively significant at the 5% level. It shows that carbon emissions trading can further reduce the risk of corporate greening by increasing corporate green innovation, i.e., corporate green innovation plays a part of the mediating effect, which verifies H2.

5.3.2. Moderating effect test

The moderating effect test of marketization level is shown in column (3) of Table 8. The coefficient of carbon emissions trading is -1.12, negatively significant at 5% level, while the coefficient of the interaction term of carbon emissions trading and marketization level is 0.092, positively significant at 5% level. It indicates that the level of marketization will weaken the impact of carbon emissions rights trading to reduce the risk of corporate greenwash and play a negative moderating effect, validating H3b.

Table 8 Mechanism testing

	(1)	(2)	(3)
	EnvrPat	GW	GW
EST	0.201***	-0.153**	-1.120**
	(3.745)	(-2.271)	(-2.484)
EnvrPat		-0.088**	
		(-2.383)	
Inmarket			0.026
			(0.444)
EST* Inmarket			0.092**
			(2.152)
TobinQ	0.008	0.004	0.002
	(0.507)	(0.162)	(0.090)
Size	0.196***	-0.038	-0.044
	(3.334)	(-0.541)	(-0.756)
Lev	-0.066	0.250	0.122

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	(-0.347)	(1.034)	(0.537)
ROA	-0.224	0.509	0.498
	(-0.781)	(1.351)	(1.341)
Age	-0.880***	-0.174	0.029
	(-3.753)	(-0.705)	(0.116)
GDP	-0.000	0.000	0.000
	(-1.412)	(1.634)	(1.398)
XXHSP	2.033**	0.114	-0.827
	(2.152)	(0.089)	(-0.676)
_cons	-1.464	1.224	0.642
	(-1.025)	(0.717)	(0.398)
id	Yes	Yes	Yes
Year	Yes	Yes	Yes
r2_a	0.680	0.504	0.491

5.4. Heterogeneity test

The previous paper verified from the basic regression that carbon emissions trading can significantly reduce the risk of corporate greenwash, and the conclusion passed the robustness test, but it did not discuss the categorization of enterprises. Different nature of enterprise equity and different industries of enterprises will face different policy environment and economic environment. Therefore, according to the nature of enterprise equity is divided into state-owned enterprises and non-state-owned enterprises, and according to the industry is divided into heavy pollution industry and non-heavy pollution industry.

(1) The regression results of heterogeneity of equity nature are shown in columns (1) and (2) of Table 9. Carbon emissions rights trading of state-owned enterprises can significantly reduce the risk of corporate greenwash and is significant at the 5% level. While the inclusion of non-state-owned enterprises in carbon emission rights trading did not affect the risk of corporate greenwash, this is because state-owned enterprises are usually subject to stronger government regulation and social concern, thus paying more attention to environmental responsibility and image building; while non-state-owned enterprises may face different market constraints and cost considerations, resulting in a smaller impact of carbon emission rights trading on their behavior.

(2) The regression results of industry heterogeneity are shown in columns (3) and (4) of Table 9, where the impact coefficient of enterprises located in heavy polluting industries being included in carbon emission rights trading on the risk of corporate greenwash is -0.174, which is negatively significant at the 5% level. In contrast, carbon emission rights trading for firms located in non-heavily polluting industries does not have a significant impact on corporate greenwash. This is because firms in heavy polluting industries face stricter environmental regulations and social supervision, so the carbon emissions trading mechanism exerts a greater constraining effect on their behavior, prompting them to reduce greenwash to improve transparency and compliance. On the other hand, enterprises in non-heavy polluting industries may be subject to less external pressure, so the impact of carbon trading on their behavior is relatively limited.

Table 9 heterogeneity test

	(1) State-owned enterprises	(2) Non-state-owned enterprises	(3) Heavily polluting industries	(4) Non-heavily polluting industries
EST	-0.208**	-0.085	-0.174**	-0.100

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	(-2.270)	(-0.881)	(-2.083)	(-0.947)
TobinQ	0.021	-0.006	0.024	-0.004
	(0.456)	(-0.210)	(0.691)	(-0.139)
Size	0.043	-0.089	-0.116	0.076
	(0.498)	(-0.846)	(-1.531)	(0.694)
Lev	0.206	0.109	0.489*	-0.828*
	(0.554)	(0.308)	(1.721)	(-1.960)
ROA	0.907	1.182**	1.032**	0.267
	(1.444)	(2.217)	(1.995)	(0.406)
Age	-0.033	0.144	0.202	0.148
	(-0.053)	(0.409)	(0.699)	(0.319)
GDP	0.000	0.000	0.000	0.000
	(0.915)	(0.060)	(1.177)	(0.642)
XXHSP	-0.805	-0.847	0.423	-1.913
	(-0.419)	(-0.462)	(0.249)	(-0.965)
_cons	-1.094	1.828	1.641	-1.533
	(-0.425)	(0.674)	(0.853)	(-0.548)
id	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
r2_a	0.458	0.498	0.514	0.440

6. Research Conclusion and Recommendation

This paper takes the relevant financial data of A-share listed enterprises from 2012 to 2022 as the research sample, and utilizes the PSM-DID method to study the impact of carbon emissions trading on the risk of corporate greenwash, and the results show that: firstly, the implementation of the carbon emissions trading policy significantly reduces the risk of corporate greenwash, and this conclusion is confirmed by the parallel trend test, the placebo test, the replacement of the explained variables, changing the clustering effect and the robustness test of the PSM matching approach still holds; second, the impact of carbon emissions trading on corporate greenwash is more significant within state-owned enterprises and enterprises located in heavily polluting industries; third, the implementation of carbon emissions trading policy can further reduce corporate greenwash risk by improving corporate green innovation, and the level of marketization will play a negative moderating effect.

Based on this, this paper puts forward the following suggestions:

The government should further promote and improve the carbon emissions trading market to ensure that more enterprises are included in the system, thus effectively reducing the overall risk of corporate greenwash. Given that state-owned enterprises (SOEs) perform more significantly in reducing the risk of greenwash, the government should encourage and support SOEs to play an exemplary role, and at the same time strengthen the supervision of SOEs to ensure that they continue to improve their environmental performance. For heavily polluting industries, stricter regulatory measures, such as setting higher carbon emission standards, should be adopted to facilitate the green transformation of these industries. To further reduce the risk of greenwash, the government can incentivize enterprises to make green technological innovations through financial subsidies and tax breaks. At the same time, enterprises themselves should increase their R&D investment to improve their green innovation capability.

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