

The impact of carbon emission trading policy on green investment of listed companies

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Abstract. In the context of global warming and China's 'dual carbon' goals, the carbon emission trading mechanism has become a crucial tool for reducing emissions. This study uses data from A-share listed companies between 2010 and 2023, employing a difference-in-differences model and an instrumental variable model to investigate the impact of carbon emission trading policies on green investment by listed companies. The findings indicate that these policies significantly enhance green investment by listed companies. Heterogeneity analysis reveals that the positive impact is more pronounced for state-owned enterprises and companies in eastern regions. The instrumental variable model confirms that the policies boost green investment by improving firms' total factor productivity and enhancing their level of green innovation. Based on these findings, the study recommends improving the carbon emission trading market and formulating differentiated green investment incentive policies to guide companies in optimizing resource allocation and strengthening green technology research and development, thereby promoting the sustainable development of a green and low-carbon economy.

Keywords: carbon emission trading, green investment, double difference model, resource allocation, green innovation.

1. Introduction

The global climate system is undergoing profound changes, marked by warming, and carbon emissions have become a core challenge threatening human survival and sustainable development. Since the Industrial Revolution, global carbon emissions have steadily increased, leading to more frequent extreme weather events. In this context, the global economic system is under unprecedented pressure to transition to a low-carbon economy. The carbon emission trading mechanism, as a market-based tool for emission reduction, has become a key policy tool for countries to achieve their 'dual carbon' goals. High-energy-consuming and high-emission enterprises, as the primary sources of carbon emissions, play a crucial role in the effectiveness of their green investment decisions, which directly impacts the progress toward achieving the 'dual carbon' goals.

The introduction of carbon emission trading policies aims to limit corporate carbon emissions, which increases the cost of carbon emissions for companies. This necessitates that companies consider environmental factors when making investment decisions, leading them to increase their investment in environmental technologies and projects to reduce emissions and associated costs. Therefore, studying the investment behavior of companies under the influence of carbon emission trading policies, particularly green investments, can reflect the effectiveness of these policies and provide decision-making support for companies to achieve low-carbon transformation and upgrade and to develop green development strategies. Moreover, given the numerous challenges still faced by the carbon emission trading market, clarifying the mechanisms through which carbon trading policies impact corporate green investments can help refine the design of the trading market, effectively balancing environmental governance requirements with the needs of business development.

From a theoretical perspective, the design of the carbon emission trading system is grounded in Coase's theorem, which posits that by clarifying the property rights of carbon emission rights and establishing market mechanisms, environmental externalities can be internalized, thereby achieving carbon reduction goals at the lowest social cost. With the official launch of pilot carbon emission trading policies and the establishment and development of carbon trading markets, the impact of carbon emission trading on the economy, society, and individual corporate behavior has garnered increasing attention from scholars. Research on carbon emission trading primarily focuses on its

emission reduction effects, such as Cai Jun et al., who found that carbon trading policies reduce carbon emissions and improve carbon emission efficiency by lowering energy consumption, adjusting the energy structure, and limiting production capacity in key industries^[1]. Studies on the impact of these policies on corporate behavior have mainly focused on technological innovation, such as Lan Guan Xiufeng et al., who demonstrated that the carbon emission trading system can effectively promote green technological innovation in enterprises^[2].

Green investment refers to environmental investments that positively impact the maintenance of natural resources, pollution control, environmental protection, and ecological construction^[3]. Scholars primarily focus on the efficiency of green investment, such as Tian Jie et al., who found that enhancing the green investment efficiency of heavily polluting enterprises through digital transformation is a new pathway to achieving green transformation^[4]. Research on the impact of carbon trading on corporate green investment mainly focuses on the effects of carbon prices, as analyzed by Niu Huawei et al., who examined how carbon prices influence green investment and credit risk through the lens of expected returns and default costs^[5].

Based on the internal requirements of building a modern energy system and achieving carbon peak and carbon neutrality, this paper analyzes the impact of carbon emission constraints on enterprises' investment decisions and management based on the actual situation of enterprises in the pilot areas of carbon trading.

In terms of theoretical significance, this study expands the theoretical research on environmental regulation and corporate investment behavior. Most existing studies focus on the emission reduction effects of carbon trading policies. Research on the impact of these policies on specific corporate behaviors primarily centers on technological innovation. However, there is insufficient exploration into whether these policies influence corporate green investments and how they affect such investments through intermediary pathways. This paper examines the mechanisms by which carbon trading policies influence corporate green investments, offering a new perspective on how these policies impact corporate investment behavior.

In practical terms, this initiative supports companies in making low-carbon investment decisions and helps them develop investment strategies that balance emission reduction with economic benefits. Additionally, the research findings can assist policymakers in optimizing the design of carbon trading markets. By combining efficient corporate investments with well-designed market mechanisms, the ultimate goal is to achieve the 'dual carbon' targets.

2. Mechanism analysis and hypothesis formulation

The carbon emission trading policy reshapes the resource endowment structure of enterprises by establishing a market-based mechanism for allocating and trading carbon quotas, thereby influencing their investment decisions. As an environmental regulation tool, the carbon emission trading market can reduce overall carbon emissions by increasing the cost of emissions for high-energy-consuming enterprises. Within the specified carbon emission quota, companies can freely trade any excess or surplus carbon emission quotas^[6] on the carbon exchange. If a company's emissions exceed its quota, it must purchase additional quotas to meet compliance requirements, which increases its operating costs and financial burden.

To address this constraint and maximize profits, companies tend to prioritize green investments as a strategic choice for optimizing resource allocation^[7]. By increasing investment in environmental projects, they can curb high carbon emissions at the source, thereby reducing their own carbon footprint. Moreover, green investments not only help reduce carbon emissions, lowering the cost of purchasing carbon allowances, but also enhance production efficiency through technological upgrades, creating a competitive edge. Furthermore, after reducing carbon emissions through green investments, companies can sell any remaining carbon allowances on the carbon trading market, generating additional revenue and further achieving their profit maximization goals.

According to the resource-based view, a company's competitive advantage stems from its unique combination of resources and capabilities. Carbon quotas, as an economically valuable scarce resource, are crucial for a company's low-carbon transition. Green investment is essentially the allocation and utilization of corporate resources. To further explore how the implementation of carbon emission trading policies impacts green investment in listed companies, this paper examines the pathways and mechanisms through which these policies influence green investment from the perspective of optimizing resource allocation and fostering corporate green innovation.

Total factor productivity (TFP) reflects a company's overall efficiency in converting various resources into output, which is a key indicator of its ability to optimize resource allocation. After the policy is implemented, companies need to increase investment in green technology research and development and equipment upgrades to reduce carbon emission costs. These investments not only directly reduce emissions but also enhance overall production efficiency through technological spillover effects. For example, investing in waste heat recovery and utilization projects can not only lower carbon emissions but also reduce production costs by recycling energy resources, achieving both emission reduction and efficiency improvement. The carbon emission trading policy indirectly boosts TFP by encouraging companies to optimize resource allocation, thereby strengthening the motivation for green investments.

The dynamic capability theory, derived from the resource-based theory, highlights that after the implementation of carbon emission trading policies, green innovation can help companies adapt to environmental changes and create new competitive advantages. This is because, under these policies, companies face increased carbon emission costs, which forces them to increase investment in green technology research and development (R&D) to find ways to reduce emissions. For example, they might independently apply for green invention patents or utility model patents, develop low-carbon production processes, thereby reducing their reliance on external carbon allowances. Consequently, companies will increase their investments in green projects and supporting R&D to support green technology development.

Based on the above analysis, the hypothesis of this paper is proposed:

Hypothesis 1: Carbon emission trading policy has a significant positive effect on green investment of listed companies.

Assumption 2: Carbon emission trading policy can further promote enterprises' green investment by improving their resource allocation ability.

Hypothesis 3: Carbon emission trading policy can promote enterprises to increase green investment by promoting green innovation.

3. Variable setting and model selection

In 2011, the National Development and Reform Commission issued a notice to launch pilot programs for carbon emission trading. Starting in 2013, these pilots were conducted in eight provinces and cities: Shenzhen, Shanghai, Beijing, Guangdong, Tianjin, Hubei, Chongqing, and Fujian. This paper explores the impact of carbon emission trading policies on green investments by listed companies through these pilot programs.

To avoid the potential bidirectional causal relationship between carbon trading and corporate green investment, this study examines the impact of carbon emission trading policies on corporate green investment by constructing a difference-in-differences model to address endogeneity issues. In this study, following Hu Jiangfeng et al., the treatment group consists of listed companies in eight pilot industries—petrochemicals, chemicals, building materials, steel, non-ferrous metals, papermaking, power, and aviation—and located in eight pilot regions: Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, Shenzhen, and Fujian. Other listed companies serve as the control group^[8]. Following Zhao Lingdi et al., capital expenditures for wastewater and exhaust gas treatment, energy conservation, water conservation, electricity conservation, desulfurization, denitrification, nitrogen removal, dust removal, waste disposal, waste heat recovery and utilization, and exhaust gas treatment

are counted from the detailed construction projects. Expenses for pollution discharge fees, environmental protection fees, and vegetation restoration are counted from the detailed management expenses^[9]. The amount of green investment is the total of related amounts from construction projects and management expenses. Model (1) is constructed:

$$EPI_{it} = \beta_1 * DID_{it} + \alpha_k \sum Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In this context, i denotes the i -th enterprise, t represents the t -th period, and the dependent variable is defined as the ratio of green investment to operating revenue for the i -th enterprise in the t -th period. DID_{it} is the core explanatory variable of this study, while $treat_i$ is the treatment variable, indicating the time of policy implementation. When an enterprise is in the treatment group, $treat_i = 1$; otherwise, $treat_i = 0$. Since the pilot program for the carbon trading market was officially launched in 2013, this study selects 2013 as the policy implementation date. When t is 2013 or later, $post_t = 1$; otherwise, $post_t = 0$.

The symbol represents a series of control variables designed to control for other potential confounding factors, thereby enhancing the accuracy of policy effect estimates. These include: asset size (Size), measured by the natural logarithm of total assets; debt-to-asset ratio (Lev), measured by the ratio of total liabilities to total assets; return on assets (ROA), measured by the ratio of net assets to average asset balance; growth rate (Growth), measured by the growth rate of operating revenue; and Tobin's Q (TobinQ), measured by the ratio of market value to total assets. The individual fixed effects term controls for individual heterogeneity, avoiding estimation biases caused by time-invariant omitted variables. The time fixed effects term controls for the common external environment faced by all enterprises during the same period, separating the temporal characteristics of policy effects. The random error term represents the residual variation.

On this basis, in order to further study the impact mechanism of carbon emission trading policy on enterprises' green investment, the following mediation effect models (2)-(4) are constructed:

$$GreenIn_{it} = \beta_2 * DID_{it} + \eta_1 \sum Control_{it} + \gamma_1 + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$TFP_LP_{it} = \beta_3 * DID_{it} + \eta_2 \sum Control_{it} + \gamma_2 + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$TFP_OP_{it} = \beta_4 * DID_{it} + \eta_3 \sum Control_{it} + \gamma_3 + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

The intermediate variable represents the level of green innovation of enterprises, which is defined by taking the natural logarithm of the sum of the number of green inventions and green utility models independently applied in the current year plus 1. It represents the total factor productivity of enterprises measured by LP method and OP method respectively.

This study uses data from A-share listed companies in China from 2010 to 2023 as the research sample. Green investment data is manually compiled from the annual reports of listed companies, green innovation data is sourced from the CNRDS database, and other company-level data are obtained from the CSMAR database. The sample data excludes ST or *ST stocks, and continuous variables are truncated by trimming the first and last 1% of the data.

4. Empirical analysis

4.1. Descriptive statistics

Table 1 presents the descriptive statistics for the independent variable DID , dependent variable EPI , and control variables including firm size (Size), debt-to-asset ratio (Lev), return on assets (ROA), growth (Growth), and Tobin's Q (TobinQ). It provides the sample size, standard deviation, mean, minimum, and maximum values of the sample data.

According to the descriptive statistical results, the mean value of DID is 0.032, indicating that 3.2% of sample enterprises are included in the pilot carbon emission trading policy. Moreover, the difference between the minimum and maximum values of EPI is large, indicating that there are large differences in the level of green investment among different enterprises.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EPI	43575	0.923	9.019	-1.401	739.979
DID	53894	0.032	0.175	0.000	1.000
Size	54190	22.025	1.295	19.171	26.452
Lev	54190	0.426	0.205	0.027	0.990
ROA	54183	0.040	0.066	-0.375	0.255
Growth	54084	0.164	0.393	-0.75	3.808
TobinQ	54187	1.923	1.251	0.789	16.647

4.2. Parallel trend test

The parallel trend test is the premise of applying the double difference method. This paper adopts the event study method to conduct the parallel trend test, and the test results are shown in Figure 1.

According to the results of the parallel trend test shown in Figure 1, the regression coefficients of the interaction term of explanatory variables were not significant in the two years before and during the policy pilot. The lack of significance in the year of the policy pilot may be due to the policy's lag effect. However, after the policy officially began, the regression coefficients became significant in the first year and subsequent years, showing a larger fluctuation compared to the period before and during the official policy pilot. This indicates that the formal implementation of the carbon emission trading policy had a significant positive impact on corporate green investment. The trends in green investment changes among enterprises in the experimental group and the control group align with the parallel trend hypothesis, thus the double difference model used in this study can effectively evaluate the impact of the carbon emission trading policy on corporate green investment.

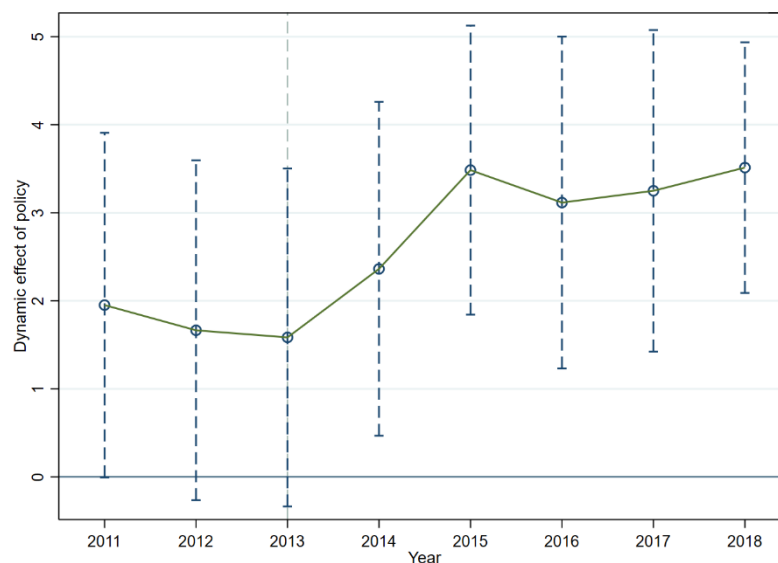


Figure 1 Parallel trend test

4.3. Baseline regression

Table 2 shows the results of the benchmark regression in this paper. Column 1 does not include any control variables, but individual control effect and time fixed effect are included. Columns 2-6 are sequentially accumulated with enterprise size (Size), asset-liability ratio (Lev), return on assets (ROA), growth (Growth) and TobinQ (TobinQ).

As can be seen from column 1-6 of Table 2, the regression coefficients of explanatory variables are positive and the P values are all less than 0.01, that is, significant at the level of 1%. Therefore, it can be concluded that the pilot carbon emission trading policy has a significant positive impact on enterprises' green investment, and hypothesis 1 is confirmed.

Table 2 Baseline regression

	(1) EPI	(2) EPI	(3) EPI	(4) EPI	(5) EPI	(6) EPI
DID	1.763*** (0.441)	1.764*** (0.441)	1.794*** (0.441)	1.809*** (0.441)	1.813*** (0.441)	1.815*** (0.442)
Size		0.306*** (0.091)	0.207** (0.095)	0.237** (0.097)	0.258*** (0.097)	0.272*** (0.101)
Lev			1.320*** (0.370)	1.051*** (0.396)	1.228*** (0.400)	1.205*** (0.403)
ROA				-1.478* (0.774)	-0.663 (0.811)	-0.711 (0.817)
Growth					-0.348*** (0.106)	-0.349*** (0.106)
TobinQ						0.021 (0.044)
Constant	0.581*** (0.181)	-5.932*** (1.948)	-4.300** (2.001)	-4.735** (2.014)	-5.190** (2.019)	-5.516*** (2.128)
N	43575	43575	43575	43574	43550	43550
r2	0.002	0.002	0.002	0.002	0.003	0.003
YEAR	YES	YES	YES	YES	YES	YES
Fe	YES	YES	YES	YES	YES	YES

Note: ***, ** and * indicate that the regression results are significant at the level of 1%, 5% and 10%, respectively.

4.4. Heterogeneity analysis

Table 3 presents the heterogeneity analysis of this paper, which evaluates the varying impacts of carbon emission trading policies on green investment by enterprises under different conditions, based on their property rights attributes and the regions they are located in. The first column of Table 3 lists state-owned enterprises, the second column lists non-state-owned enterprises, the third column indicates that the enterprises are located in the central and western regions, and the fourth column indicates that the enterprises are located in the eastern region.

The results of the heterogeneity analysis in the first and second columns show that the DID regression coefficients for listed state-owned enterprises are higher than those for non-state-owned enterprises, indicating that the introduction and implementation of carbon emission trading policies have a greater impact on green investment by listed state-owned enterprises. The primary reason for this difference is the distinct differences in resource acquisition and social responsibility between state-owned and non-state-owned enterprises.

Firstly, in terms of resource acquisition, state-owned enterprises (SOEs) have a significant advantage over non-state-owned enterprises (NPOs) in acquiring policy resources, particularly due to the heterogeneity of these resources. According to the criteria of value, scarcity, non-imitability, and non-substitutability in resource-based theory, government subsidies and low-interest loans provide SOEs with unique competitive advantages. Secondly, in terms of social responsibility, SOEs' social responsibility orientation enhances their motivation for green investment. As a key pillar of the national economy, SOEs actively respond to policy requirements and fulfill their social responsibilities, not only aligning with the country's low-carbon policies but also enhancing their long-term competitive advantage by improving their corporate reputation. In contrast, NPOs tend to focus more on short-term economic benefits, and their green investment decisions are more influenced by market risks and financial constraints.

As can be seen from the regression results of the third and fourth columns, the regression results of listed companies belonging to the eastern region are significant at the level of 1%, while those

belonging to the central and western regions are not significant. The main reasons for this difference are the differences in market mechanism efficiency and regional resource endowment.

In terms of the effectiveness of market mechanisms, the eastern region, which hosts the main areas of the national carbon market pilot (such as Beijing, Shanghai, and Guangdong), has seen its enterprises adapt to carbon quota trading rules earlier due to the policy's leading effect. This has led to a more mature capacity for low-carbon resource allocation, allowing more resources to be allocated for green investments. In terms of regional resource endowments, the eastern region's economic development and innovation resources provide a solid foundation for green investments. In contrast, the central and western regions face technological and financial bottlenecks, which have led to relatively lagging progress in the transformation of green technologies and investment in green projects by enterprises in these regions, thereby limiting the effectiveness of policy implementation to some extent.

Table 3 Heterogeneity analysis

	(1) EPI	(2) EPI	(3) EPI	(4) EPI
DID	2.105*** (0.602)	1.265* (0.649)	0.843 (1.098)	2.058*** (0.479)
Controls	YES	YES	YES	YES
Constant	-13.769*** (3.721)	-2.095 (2.616)	-11.330*** (4.091)	-3.356 (2.493)
N	15094	28456	12108	31417
r2	0.006	0.003	0.006	0.002
YEAR	YES	YES	YES	YES
Fe	YES	YES	YES	YES

4.5. Robustness test

Table 4 presents the robustness test results of this paper, which were verified by adding control variables (cash flow ratio and the shareholding ratio of the largest shareholder), conducting a one-period lag regression, adjusting the policy timing to 2011, incorporating industry fixed effects, and changing the dependent variable to investment efficiency. The company's cash flow ratio (Cashflow) is defined as the ratio of net cash flow from operating activities to total assets, and the company's investment efficiency is measured by the absolute value of the Richardson model's residual.

The robustness test results in Table 4 support the baseline conclusions, indicating that the policy effects are stable. The results in columns 1 and 3 further confirm that the carbon emission trading policy has a significant positive impact on corporate green investment. Column 2 shows that even after accounting for the potential lag in policy effectiveness, the policy's impact remains evident. The regression results in column 4 are significant at the 5% level, indicating that the carbon emission trading policy also significantly affects investment efficiency in corporate investment behavior, confirming that the policy indeed influences corporate investment behavior.

Table 4 Robustness test

	(1) EPI	(2) EPI	(3) EPI	(4) Inveff
DID	1.795*** (0.442)	1.443*** (0.405)	1.613*** (0.463)	-0.008** (0.004)
Controls	YES	YES	YES	YES
Constant	-6.105*** (2.147)	-2.397 (2.127)	-4.484 (3.269)	-0.053*** (0.019)
N	43519	38789	43550	44561
r2	0.003	0.002	0.009	0.047
YEAR	YES	YES	YES	YES
Fe	YES	YES	YES	YES
Industry			YES	

4.6. Intermediary mechanism test

Table 5 is the test of the mediation mechanism in this paper, and columns 1-3 correspond to the regression results of models 2-4 respectively. Column 1 conducts the benchmark regression with enterprise green innovation as the mediating variable, while column 2 and column 3 conduct the benchmark regression with enterprise total factor productivity measured by LP and OP as the mediating variable respectively.

According to the test results in Table 5, the regression coefficients of explanatory variables are all positive and the P values are all less than 0.01, that is, significant at the level of 1%. Therefore, hypothesis 2 and 3 are both valid, that is, carbon emission trading policy can affect the green investment of enterprises by influencing the level of green innovation and total factor productivity of enterprises.

The regression results in the first column indicate that carbon emission trading policies significantly enhance corporate green innovation, which aligns with the dynamic capability theory of the resource-based view. This theory suggests that carbon emission trading policies increase the cost of emissions, compelling companies to adjust their strategies and prioritize green technology research and development as a key strategy for building core competitiveness. To boost their green innovation capabilities through R&D, companies are compelled to increase investment in green projects, thereby promoting greater green investment.

The regression results from the second and third columns indicate that carbon emission trading policies can significantly enhance firms' total factor productivity, thereby improving their resource allocation capabilities. The total factor productivity measured by the LP method is more suitable for assessing the short-term effects of these policies, while the total factor productivity measured by the OP method is more suitable for assessing their long-term effects. Carbon emission trading policies force firms to optimize resource allocation through carbon quota constraints, promoting technological upgrades and production efficiency improvements. This requires firms to invest in high-value-added, low-emission technologies, thereby increasing green investments.

Table 5 Test of mediation mechanism

	(1) GreenIn	(2) TFP LP	(3) TFP OP
DID	0.101*** (0.021)	0.439*** (0.025)	0.508*** (0.026)
Controls	YES	YES	YES
Constant	-0.528*** (0.027)	4.040*** (0.034)	4.572*** (0.035)
N	53669	48044	48044
r2	0.022	0.306	0.137
Fe	YES	YES	YES

5. Conclusions and recommendations

This paper, from the perspective of the resource-based view, examines the impact of carbon emission trading policies on green investment in listed companies by using a difference-in-differences model. It focuses on the company's total factor productivity and the level of green innovation. The study concludes: First, carbon emission trading policies significantly enhance green investment in listed companies. Second, based on the results of the heterogeneity analysis, it is concluded that these policies have a stronger positive effect on green investment in state-owned enterprises compared to non-state-owned enterprises. Additionally, the policy has a stronger positive effect on green investment in companies in the eastern region compared to those in the central and western regions. Third, the analysis of the mediation mechanism shows that carbon emission trading policies enhance corporate resource allocation capabilities, thereby increasing green investment levels. Furthermore, these policies boost green innovation, which in turn increases green investment.

To further enhance the development of the carbon emission trading market, based on the conclusions drawn from this article, the following recommendations are proposed. Firstly, at a macro level, since carbon emission trading policies positively promote green investment by enterprises, it is essential to further improve the construction of the carbon emission trading market. This involves expanding the market's scope and including more industries and enterprises in the national carbon emission trading market. This will guide enterprises to increase their green investments and achieve low-carbon and green transformation and upgrading. Secondly, for enterprises with different ownership characteristics and located in different regions, targeted green investment incentive policies should be formulated to guide enterprises to increase their green investments based on their own and regional characteristics. For example, in addition to providing subsidies and financial support for green investments by state-owned enterprises, greater policy incentives should be provided for non-state-owned enterprises to encourage them to actively engage in green investments and achieve low-carbon development. Finally, enterprises should be guided to optimize resource allocation and independently develop green technologies, thereby enhancing their level of green investment and ultimately promoting the sustainable development of a green and low-carbon economy throughout society.

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